The Darwinian Revolution as a knowledge reorganization

A historical-epistemological analysis and a reception analysis based on a novel model of scientific theories

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Content

1 Introduction

"It is difficult, if possible at all, to describe the history of a field of knowledge. It consists of many coinciding and mutually influential developmental lines of different thoughts, all of which require presentation, first, as single, isolated lines and, second, in their particular relations. Third, one would have to draw a separate, idealized line to depict the average development. Thus writing a history resembles giving an accurate, written transcript of a heated discussion of several persons, all of whom talked at the same time and in whose discussion a common thought slowly crystallized."
Ludwik Fleck, 1935[1]

"When the progress of experimental physics goes counter to a theory and compels it to be modified or transformed, the purely representative part enters nearly whole in the new theory, bringing to it the inheritance of all the valuable possessions of the old theory, whereas the explanatory part falls out in order to give way to another explanation. Thus, by virtue of a continuous tradition, each theory passes on to the one that follows it a share of the natural classification it was able to construct, as in certain ancient games each runner handed on the lighted torch to the courier ahead of him and this continuous tradition assures a perpetuity of life and progress for science. This continuity of tradition is not visible to the superficial observer [sic!] due to the constant breaking-out of explanations which arise only to be quelled." *Pierre Duhem, 1906*

This dissertation is devoted to the Darwinian[2] Revolution, i.e. the transformation of biological knowledge after 1859, the year in which Charles Darwin published his seminal *Origin of Species*.[3] It pursues a three-dimensional project which is partly historical-epistemological, partly philosophical-systematic and partly sociological and seeks answers to the following questions:

> **Historical-epistemological project:** How can the Darwinian revolution be described in a manner which accounts for both theoretical discontinuity and empirical continuity?

1 Quoted from (Duhem 1962 [1906]: 32-3), (Fleck 1980 [1935]: 23). The translation of Fleck is my own; it is somewhat liberal and more oriented towards clarity than stylistic resemblance.

2 For a discussion whether it is justified to speak of the "Darwinian" revolution, see section 5.1 viii.

3 The full title reads "*The Origin of Species By Means of Natural Selection or The Preservation of Favoured Races in the Struggle for Life*".

In what aspects is the Darwinian theory different from preceding and competing theories? How much of the revolutionary change is an individual achievement of Darwin?

Philosophical project: How can scientific theories be described in a general framework which (i) highlights differences between the theories as well as common elements (static perspective) and which (ii) allows for describing historical developments of theories (dynamic perspective)?

Sociological project: How are scientific theories and revolutions of such theories perceived by different audiences and how does the depth of reception influence the acceptance or dismissal of a theory by these audiences? What is the impact of the Darwinian revolution on 19th century biology?

The arguments on these three projects can be read separately[4] but they provide complementary perspectives. The historical-epistemological analysis focuses on the innovative elements which Darwin achieved towards his predecessors and competitors. The sociological project provides the recipient's perspective in that it asks whether this innovation reached the theory's audience and which impact it ultimately had; for the community of biologists, this is achieved by the first large-scale analysis of the reception of Darwin's theory in his discipline. The philosophical project serves as the hinge between the other perspectives in that it provides the analytic framework which structures both the historical-epistemological analysis and the reception analysis of the sociological project.

By combining these different perspectives, this dissertation provides an innovative and original contribution to existing research. First, it develops novel analytic frameworks for the analysis of scientific theories and their reception. Second, it provides the first application of a sophisticated model of scientific theories in a thorough, empirically sound historical study of a scientific revolution.[5] Third, it provides novel insights into the reception of scientific knowledge among heterogeneous audiences. Fourth, in combination, these different contributions allow for a much more precise description of large transformations in knowledge systems and will contribute to a deeper understanding of scientific theories than has hitherto been possible.

1.1 Historical-epistemological project: understanding Darwin's revolution

In the first place, my dissertation aims at integrating the Darwinian revolution into a research program which is being pursued at the Max Planck Institute for the History of Science in Berlin: the

4 The historical-epistemological argument is developed in sections 1.1 and 0, applied in chapter 3, summarized in section 3.5.6 and discussed in section 5.1. The philosophical-systematic argument is developed in sections 1.2 and 2.1, applied in chapter 3 and 2.3 discussed in the annex, section 6. The sociological argument is developed in sections 1.3 and 2.2, applied in part 0, summarized in section 4.4 and discussed in sections 5.2 and 5.3.

5 Unfortunately, philosophical-systematic studies tend to model a history which never thus happened, simplifying historical events and entities to a point where they are misrepresented. (cf. Thagard 1993) There obviously exist excellent studies on the history of biology but I know of none which developed a sophisticated framework for the analysis of scientific theories.

program of Historical Epistemology.[6] Within this research program, scientific revolutions or, more neutrally, large transformations of scientific knowledge systems are not understood as a series of individual achievements by a few hero scientists. Instead, Historical Epistemology aims at embedding these individual contributions in their historical and social context. The goal of this embedding is not to deny the role of individuals but to assess how much individuals were rooted in the social context of their time and how this context nourished and shaped their contributions.

Previous studies on early modern mechanical knowledge in the early 17th century and on the relativity revolution at the beginning of the 20th century have shown that the work of scientific greats as Galileo and Einstein were not the singular achievements as which they are often regarded. Such, Matthias Schemmel (2008) has demonstrated how European contemporaries of Galileo have studied the problem of falling bodies in very similar ways as Galileo and have drawn comparable conclusions – most notably the "English Galileo", Thomas Harriot. For the relativity revolution in 20th century physics similar results were found. (Janssen et al. 2007a; Janssen et al. 2007b; Renn and Schemmel 2007a; Renn and Schemmel 2007b; Renn and Schemmel 2012)

Therefore, explanations of structural transformations of knowledge systems need to take into account the collective character and historical specificity of the knowledge to be transformed. Otherwise our understanding of knowledge transformations in science will remain incomplete and it will lead to misconceptions about such problems as scientific progress or scientific truth. In other words, without regard for the social (collective) historical character of scientific theories, we will remain in the position of Duhem's "superficial observer" and gain a distorted image of science.

The research program of Historical Epistemology is organized around a number of concepts which allow for the description and explanation of long-term transformations of large systems of knowledge. The most important are: (i) multi-layered knowledge systems, (ii) shared knowledge, (iii) challenging objects or events, (iv) shared beliefs[7] and (v) mental models. (Renn 2008)

First, scientific systems of knowledge are investigated as *multi-layered architectures* which comprise both, layers of empirical knowledge and more conceptual layers. The latter provide interpretations and explanations of the more former ones and aim at world representations beyond the empirically accessible. As these layers are interrelated, changes in one layer may affect others.

Second, large transformations of knowledge systems begin within these very systems, they rest on a fundament of *shared knowledge*, i.e. a collective resource. On such a fundament, historically specific reorganizations of knowledge may be suggested and – sometimes – achieved. In describing such

[6] There are three strands within this program which focus on histories of epistemic objects, histories epistemic concepts and dynamics of long-term scientific developments. My work is part of the third program. – An overview over all three strands is provided by (Feest and Sturm 2011). (Renn 2008), (Schemmel 2008) as well as (Damerow and Lefèvre 1998) and (Lefèvre 2000) provide outlines of this program. – Note that I did not mark quotes from these texts in this introduction in order to improve the readability. For an earlier, less detailed historical-epistemological study of the Darwinian revolution, see (Lefèvre 2009).

[7] The concept of shared beliefs as a complement and counterpart of shared knowledge is less developed in earlier works of Historical Epistemology, often the term 'knowledge' is used for both. I attempt to establish a clear distinction between both in my model of scientific theories. (see section 2.1) By shared beliefs, I denote the following elements of my model: denotation, interpretation, narration, ontological implications. I use 'belief' not necessarily in a religious sense, although beliefs in scientific theories might stem from religious sources. Rather, it is meant to connote something like the term 'conviction' connotes.

transformations, it is paramount to distinguish the collective fundament of shared knowledge from the specific reorganization suggested by one or more scientist(s).

Third, the specific reorganizations which scientists suggest to their peers are often triggered by *challenging objects or events*, i.e. historically specific material objects, or historically specific events, processes or practices which have entered the domain of a system of knowledge but do not fit with the system's conceptual layers, i.e. interpretations and explanations provided by the system.

Fourth, reorganizations of knowledge systems often imply the alterations of *shared beliefs*, i.e. interpretations and explanations of the shared knowledge as well as their philosophical-ontological implications.[8] Such alterations may produce tensions and inconsistencies in scientific theories (knowledge systems) and may lead to further alterations. Alterations of shard beliefs are the most visible part of knowledge reorganizations, particularly when they touch central elements of world representations. [JR: OK?]

Fifth, alterations of shared beliefs are often structured by *mental models*, i.e. mental representations of basal belief structures and/of shared knowledge, often practical or intuitive knowledge. In reorganizations of knowledge systems, mental models often play a crucial role in that modifications of shared beliefs employ historical (old) mental models, thus putting innovative interpretations and explanations in continuity with older epistemological traditions. [9] In such use, mental models may be modified but do not give up their basic structure; they are characterized by a remarkable longevity.[10]

When transformations of knowledge systems are described in these concepts, both the revolutionary (discontinuous) and the conservative (continuous) aspects of such transformations are revealed; in their historical and social context the scientific revolutions become collectively achieved reorganizations of knowledge. For instance, for the revolution in pre-classical mechanics, Matthias Schemmel, Jochen Büttner and Matteo Valleriani demonstrated why parallels between Galileo and his predecessors, notably Guidobaldo del Monte, as well as his competitors, notably Thomas Harriot. These parallels are not accidental but can be explained by (i) a body of shared knowledge to which they all had access – notably the works of the Greeks – as well as (ii) common challenging objects / events of mechanics, notably the balance, the pendulum and the trajectories of cannon balls. From shared knowledge, shared beliefs about this knowledge and shared challenges to both arose from shared research questions, partly structured by shared mental models. Thus, the strictly individual

8 For a specification of the concepts of interpretation and explanation, see sections 2.1.2 to 2.1.4.

9 In my conclusion, I will identify three central mental models in the Darwinian revolution, two of which are very old or have very old components. (See section 5.1 vi)

10 My use of mental models differs slightly from the typical use within Historical Epistemology. I am not considering mental models to shape shared beliefs but rather scientists to employ mental models in their formulation of shared beliefs. This, however, is a difference in narrative only. Both explanations are based on the observation that specific mental models appear, first, in the history of a discipline and, second, (in modified form) in novel scientific theories. I construct this correlation as a human action to employ a certain model, whether this action stems from conscious choice or not. Historical Epistemology would rather construct it as a mental model shaping a knowledge-reorganization. My explanation employs more of a social science narrative, the historical-epistemological one more of a natural science narrative. (see section 2.1.4 for narratives in explanation) – Due to my different focus, I am not referring to mental models in default logic. See (Johnson-Laird 1980; Garnham, Oakhill, and Johnson-Laird 1982; Johnson-Laird 1983; Levinson 2000), for its use in the history of science see (Renn and Damerow 2007).

part of the works of Galileo or Harriot is rather limited.[11] (cf. Schemmel 2008; Büttner, Damerow, and Renn 2001; Büttner et al. 2003; Valleriani 2010)

In the present dissertation, I undertake such a historical-epistemological reconstruction of the transformation of biological knowledge during the Darwinian revolution. I therefore begin my dissertation with an analysis of the shared knowledge of biology and shared beliefs about biology at the beginning of the 1840s, around twenty years before the publication of the *Origin of Species*.

This moment appears like the retarding element[12] in the drama of the Darwinian revolution. In the previous seventy years, biology had successively tapped the knowledge sources[13] on which Darwin would construct his theory: biogeography, embryology, morphology and paleontology. (See sections 2.3 iv and vi.) Moreover, it had produced the kind of challenging objects the Darwinian theory aimed to explain.[14] On the side of beliefs, the late 18th and early 19th century had seen several pronouncements of early evolutionary concepts, notably Jean-Baptiste Lamarck's 1809 *Philosophie Zoologique*, the first full-fledged explanation of evolution.[15] The idea that organisms transformed over time without direct divine intervention was thus known to both scientists and the public. Yet, it was far from a shared belief; particularly, Lamarck's explanation had been dismissed vehemently. As biologists continued to exploit their knowledge sources and piled up more and more objects which challenged the dominant beliefs, the tension between the shared knowledge of and the shared beliefs about knowledge continued to rise.

Simultaneously, the 1840s marked a geographical shift in the theoretical discourse on biology. From the 1770s to the 1830s, roughly, French scientists had dominated the theoretical debates. [16] Around the 1840s, Britain began to take center-stage, a trend which would find its culmination in the 1859 *Origin*. In the second part of my dissertation, I will analyze four different accounts and explanations of evolution which were published during this time and each enjoyed important reception[17]:

- *Vestiges of the Natural History of Creation* and its sequel *Explanations* by the journalist and amateur-scientist Robert Chambers' (1844/5)

[11] This does not imply that this individual part does not matter, on the contrary.

[12] In drama theory, the retarding element denotes a sequence in a play in which the action has taken a turn towards the eventual conclusion but it is not yet achieved. Instead, during the retarding moment, the end seems up in the air again and the audience is left in doubt about how it will turn out. In a five-act play, the turning point is usually found in the 3rd act, the retarding moment in the 4th act, and the conclusion in the 5th.

[13] In the two decades from 1840 to 1859 biology, certainly, continued to produce new knowledge, some of which would lend precious support to the theory of evolution. It did not, however, integrate a new type of knowledge source like biogeography, morphology, paleontology or embryology, all of which had been integrated ca. between 1770 and 1840.

[14] That the challenging objects and necessary shared knowledge was already present in the 1840s seems to be confirmed by the fact that Darwin's famous transmutation notebooks date back to 1837. Throughout the 1840s he would develop and specify his views but did not dare to publish, deeming his own views too speculative and not sufficiently supported by empirical evidence. (Darwin 1958a [1842]; Darwin 1958b [1844])

[15] By the term 'evolution' I denote any description of long-term changes of groups of organisms in time. Such concepts were also referred to as 'transmutational' or 'developmental' or 'derivative', among others. For simplicity, I will refer to all of them as 'evolutionary'. For an overview on the historical use of the term, see (Bowler 1975).

[16] There exited an extensive theoretical discourse in Germany but it was only loosely connected to the shared knowledge of biology. Thus, its impact on biologists was very limited. (See Section 2.3 v)

[17] The reception differed by public and country; I will specify both in section 0.

- A series of theoretical remarks throughout the works of Richard Owen between 1848 (*On the archetype and homologies of the vertebrate skeleton*) and 1868 (*On the Anatomy of Vertebrates. Volume III: Mammals*)
- Two papers by Alfred Russel Wallace, namely *On the Law which Has Regulated the Introduction of New Species* (1855) and his part of the joint paper *On the Tendency of Varieties to depart indefinitely from the Original Type* by Alfred Russel Wallace and Charles Darwin (1858)
- *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* by Charles Darwin (1859-1872)

My analysis of these texts is content-centered, not people-centered. I do not aim to analyze the motivations, values or thought-processes of the authors but the texts they published. There are two reasons for this: First, there already exist a number of excellent analyses of the genesis of these texts, particularly in Darwin's case. (Darwin 1960a; Darwin 1960b; Darwin 1960c; Darwin 1960d; Darwin 1961; Darwin 1967; Gruber 1974;Grinnell 1974; Schweber 1977; Grinnell 1985; Sheets-Pyenson 1981; Beatty 1985; Kohn 1985a; Oldroyd 1986; Richards 1987b; Mayr 1991; Kutschera 2003; Hodge 2003; Hull 2005; van Wyhe 2007; Hodge 2010; cf. Desmond and Moore 1995; Browne 1995; Browne 2002; Browne 2006) It is not my project to extend on these texts. Second, I am interested in science as a social phenomenon, not in scientists as psychological subjects. Therefore, motivations or values matter only insofar as they were accessibly to the audience of scientific communications.[18] For instance, it matters little for the reception of Darwin what role Darwin intended to attribute to God when recipients based their understanding of his theory on the text of the *Origin.* This text might allow for different readings and, thus, for interpretations which differed from Darwin's intentions.

The focal point of this analysis is, evidently, Darwin's *Origin of Species*, the book to which the Darwinian revolution is usually and rightly traced. During Darwin's lifetime, the book appeared in six editions of 1859, 1860, 1861, 1866, 1869 and 1872.[19] My analysis will center on the second edition which is differs from the first only in minor editorial changes and, therefore, best allows for analyzing the book which Darwin wrote in comparison to his predecessors and competitors; the later editions are much more marked by the reception in England. Where adequate, I will emphasize important differences between the editions. For Chambers' Vestiges and Explanations I chose the second edition as well; equally, it differs barely from the first. Wallace's papers did not appear in different editions; I am thus analyzing the original papers. With respect to Richard Owen, I am making an exception, analyzing writings which span twenty years and partly appeared long after the *Origin*. I do this because Owen's championed an important and influential account of evolution in Britain which he did not dare to express throughout the 1850s and published only after 1859.[20] In order to assess Darwin's particular role in the Darwinian revolution, I will take Owen's writings of the 1860s into account.[21]

I will carry out my comparative analysis before the background of the shared knowledge and shared beliefs of the time, the early and mid-19th century. I will ask how Darwin integrated the shared

[18] Ignoring verbal statements, the author's intentions are only accessible if they are present in text.
[19] For bibliographical details, see section 3.4.
[20] Like Darwin, Owen feared the public controversy.
[21] One might fear that this leads to portraying Owen closer to Darwin than he actually was. Yet, my analysis will show, that Owen went out of his way to draw this line himself; he clearly delineated himself from Darwin.

knowledge in comparison to other authors, which shared beliefs and mental models he incorporated in his explanation of the shared knowledge, which ones he dismissed and in what aspects these decisions differed from other authors. Thereby, I will identify different lines of thought in the debates about evolution, mainly in the works of my four focus authors – Chambers, Owen, Wallace and Darwin – but also in the continental debate, notably in France. I will highlight relations between these different lines and reveal how they contributed to the emerging evolution theory and, consequently, to what we call the Darwinian revolution. (Sections 3.1 - 3.4)

In a concluding section, I will synthesize these results. (Section 3.5) In the conclusion I undertake a historical-epistemological reconstruction: I will identify challenging objects which drove Darwin's search for a reorganization of biological knowledge and the mental models which structured his interpretation and explanation of this knowledge. (Section 5.1)

1.2 Philosophical-systematic project: A model of scientific theories

Within this historical-epistemological project, I pursue a philosophical (or systematic) one: I will suggest a novel model of scientific theories, in order to specify the concept of 'multi-layered knowledge systems' for the theories Darwin and his contemporaries suggested. My model is inspired by both philosophical and sociological considerations.

In philosophy of science, it has become common sense that scientific theories are more than mere aggregations of facts; somehow, they mingle facts, hypotheses, beliefs and values. Still, philosophy of science has hitherto been unable to explain how these different elements come together in theories, how they interact and how they impact the use and reception of scientific theories in practice. Unfortunately, this incapability has fueled the popularization of crude misrepresentations and exaggerations by Thomas S. Kuhn and Paul Feyerabend, among others.[22] Despite their misfit with the historical record and common sense, such ideas continue their firm grip on parts of the public and philosophical discourse. In other words, the shared beliefs of philosophers about the history of science do not yet fit the shared knowledge about this history. I hope that my model contributes to bridging this gap as it may be closer to the mental models of philosophers than the historical discourse.

In the 20th century two influential philosophical programs have failed at adequately describing and modeling scientific theories: the so-called[23] syntactic view of the 1930s and the so-called semantic view of the 1960s. The first program started with Rudolf Carnap's *Der Logische Aufbau der Welt* (1929) and dominated analytic philosophy far into the 1950s. Its main objective was to develop a comprehensive model of scientific theories which would construct theories as true representations

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22 For instance, Feyerabend claimed that scientific theories are mere belief systems – on par with ideologies or religions – because they involve *some* speculative part. (Feyerabend 1986 [1975]: 385-97) Kuhn popularized the idea that cumulative progress throughout scientific revolutions is impossible. (Kuhn 1970 [1962]: 160-73, 205-7) That such views are actually supported is demonstrated by (Kyburg 1990). For my discussion of these questions, see sections 5.2 and 5.3.

23 As F.A. Muller highlighted, the terms 'syntactic' and 'semantic' are somewhat misleading. More aptly, the syntactic view would be termed 'linguistic' and the semantic view 'non-linguistic' because the former describes theories as sets of statements, i.e. linguistic entities, while the latter describes theories as set-theoretical entities which are no linguistic entities and have little to do with the way in which scientists describe their models and theories. (Muller 2011: 91, 103)

of parts of the empirical world and explain how careful empirical observation allows for the construction of true theories. Scientific theories were modeled as sets of statements and formalized in predicate logic. In the 1950s, the syntactic view encountered a group of formal problems[24] and fell out of favor with philosophers. Its gravest problem, however, was its incapability to provide a satisfactory model of scientific theories; its proponents never got beyond highly distorted, a-historic accounts of scientific theories: they modeled theories which had never existed in this form.

The second program, termed 'semantic view' was fueled by two papers by the mathematician Patrick Suppes. (Suppes 1960; Suppes 1969) Suppes suggested that philosophers stop treating theories as linguistic entities and focus on the mathematical notion of a model instead. This notion describes scientific theories as set-theoretical, non-linguistic entities; roughly speaking, a model in Suppes' sense is an assignment of truth-values. Consequently, the objects studied by the semantic view are no closer to actual scientific practice than the Carnapian ones.[25] Moreover, as one of its supporters recapitulated in 2009, the semantic view never explained what a scientific theory is either. (Muller 2011:87)

In the late 1990s and the first decade of the 21st century, many philosophers have abandoned theories and turned to models as their main theoretical objects of studies. Moreover, they re-approached specific disciplines and increasingly studied models as they are employed by the scientists. This strand of research has led to innovative and fruitful insights. (Hartmann 1999; Morgan 2003a, 2005; de Langhe 2010b; Parker 2010; Frigg, Reiss 2009) While some philosophers still express support for the semantic view (Giere 1999), few continue to employ its formal structures, instead, most display a pragmatic[26] understanding[27] of models.[28]

While I want to re-enlarge the focus from models to theories, I do see my work in this pragmatic and practice-oriented strand of research. In a similar spirit, I have developed a novel framework for analyzing scientific models and theories: a model of multi-layered systems in which scientists organize knowledge. I will provide a detailed presentation of my model in section 2.1; however, let me specify some principles which clarify what the model is intended to provide:

First, it will be a model of scientific models and theories, no ontology or any kind "essential" embodiment of what constitutes a model or theory[29]; if successful, it displays basic features in the

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24 These were the distinction of analytic and synthetic statements, the reduction of theoretical expressions to observation statement (as exemplified in the Ramsey-sentence and the Craig theorem) and the problem of confirmation holism. For a discussion of these issues with respect to my model, see section 6 ii.

25 Its most accomplished proponent, Bas van Fraassen, provided the most lucid account of this assignment on a fictional example of geometrics, an unempirical discipline. To my knowledge, he never presented a detailed account of how the semantic view could be applied to an empirical discipline like physics or biology, particularly to a "living" theory. It seems like the semantic view studied mathematical-philosophical artifacts, no actual scientific theories.

26 I do refer to the philosophical program of pragmatism, here, but to the common sense use of 'pragmatic'.

27 One has to admit though, that this pragmatic understanding is also somewhat vague; I know of no satisfying (sufficiently large, sufficiently precise, empirically adequate) definition of the term 'model'.

28 For unsuccessful or incomplete attempts to model evolution theory according to the semantic view, see (Beatty 1980; Griffiths 1997; Lloyd 1988; Thompson 1989; Thompson 2007). For a pragmatic attempt, see (Wilson 1992).

29 Particularly, I do put models and theories in relation to actual descriptions of observational or experimental results, not ideal or idealized observation statements. Thus, I do not follow Rudolf Carnap's early intuition that the 'structure' of observation statements reflects the 'structure' of reality. (Carnap 1998 [1929])

form of scientific theories, not their "structure".[30] I aim to show how a scientific theory can be described and how its elements are employed, not what it "is".

Second, I do not claim that all scientific models and theories display all my model's features, quite the opposite: Exactly as the objects of biological, sociological or psychological models, the models and theories I intend to study are much too diverse to resemble each other in a large set of interesting properties. Thus, I will present a regular scientific model, i.e. a framework by which one can analyze and compare empirical objects, in my case scientific models and theories; it provides a toolbox for the analysis of different theories rather than template of the ideal theory. In other words, my model is my research design[31] and – as any interesting comparison should highlight both, common features and differences – my model will reveal interesting differences and interesting common features of the theories I compare.[32]

Third, my conception of scientific theories and models is centered on empirics. I do not analyze models or theories in the non-empirical sciences (logic, mathematics, geometry), where general statements (axioms) are assumed as true and more specific ones (theorems) are deduced from them. While some branches of empirical science display a strong tendency towards deductive arguments and sometimes employ terms like 'axiom', these should not be confounded with the axioms of mathematics[33]. The more general statements as well as shared beliefs in the empirical sciences are considered true or false / right or wrong / empirically adequate or inadequate in virtue of empirical facts and regularities as ascertained in observation and experiment (the shared knowledge) – not by virtue of assumptions.[34]

Fourth, I will analyze scientific theories as linguistic entities, for two main reasons. First, this reflects scientific practice; scientists write their findings and interpretations down or they communicate them

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Beyond the lack of an operational definition of the ominous 'structure', I do not see actual descriptions as supporting such a view.

30 In the 20th century, the problem of modeling scientific theories was often referred to as describing the "structure" of scientific theories. (Suppe 1979; Lloyd 1988; Thompson 1989; da Costa and French 2000; Thompson 1989; da Costa, French 2000) I suggest speaking of the much more neutral 'form' which does not connote that one seeks a deep, hidden secret or the miraculous workings of a theory but wishes to model it. As it is, 'structure' seems to have become the new 'essence', i.e. a term which is employed as if its meaning was clear and well-known and which is applied to virtually any complicated object or form. Instead, the only definitions of the term 'structure' seem to exist in mathematics and they are clearly not applicable to the empirical sciences.

31 Some philosophers might not consider this a "philosophical" perspective. My ambition is a *systematic scientific* study in the science studies, which may be called philosophical but need not.

32 For two empirical objects, it is always possible to identify aspects which they share and in which they differ: apples and pears are both fruits. Thus, the challenge of a good comparison is to find *interesting* common features and differences.

33 This impression is fueled by deductive formulations as in Newton's *Principia* or the three "axioms" of the Rational Choice theory in the social sciences and it is sometimes readily accepted, particularly, by former mathematicians and mathematical physicists who turn to philosophy of science. Familiarity with the scientific practice in the empirical sciences quickly reveals that such a view is untenable. Moreover, as Kenneth Schaffner emphasizes, most theories have never been formulated in such a form. (Schaffner 1996: 27) Schaffner identifies "middle range" theories in a large part of biology exactly because it does not prescribe a fixed form of formulation in universal theories.

34 This does not imply that beliefs play no role in the acceptance or rejection of such statements.

via speech.[35] In both cases, they employ languages, be they formal (mathematics, logic) semi-formal (nomenclatures, technical languages), or natural. Second, the only way in which I can access the knowledge and knowledge systems which I analyze is via text.[36] The objects of my study and the sources of my research are books and articles, composed of text and a few images. Thus, there is no other way to access these theories or models than as linguistic entities.[37]

Fifth, in my linguistic analysis, I will distinguish two kinds of meaning in scientific theories. Based on works by Gottlob Frege, John Stuart Mill and Ludwig Wittgenstein and, more importantly, modern psychological and linguistic research, I will argue that scientific language conveys two very different kinds of meaning, roughly, the meaning of truth values in logic and the meaning of metaphors in natural languages or literature. While both kinds of meaning are frequently being addressed – the former mostly by philosophers, the latter mostly by historians – I see few systematic and thorough attempts to cater to both in comparative analyses of scientific theories. I will demonstrate that this distinction provides not only philosophical insights, but a clear plus-value for both the historical-epistemological and the sociological project of my dissertation as it caters to both the logical-empirical component of theories and their social-cultural component.

Sixth, my model of scientific theories will distinguish several levels of abstraction, or, multiple layers within the knowledge systems we call 'theories'.[38] As the model overall, these levels are analytic tools; they do not reflect any ontological, historical or epistemological principles. Particularly, their order does not reflect in which order scientific theories are being developed or modified.[39] Also, I do not claim that all scientific theories display all these models.[40]

Seventh, I will present my model as a qualitative one, without equations or numeric values. This is due to the context in which I will apply my model – models in 19th century biology were not quantitative[41] – but no principal feature of it. While my analysis focusses on relations between concepts (Begriffe), these could easily been supplemented by a quantitative framework of measured values and equations.

Eight, my model relates to a number of philosophical problems, namely (i) the distinction of analytic and synthetic statements, (ii) the explanation of confirmation holism (the Duhem-Quine hypothesis)

35 This does not immediately include physical objects or diagrams serving as models. Such objects, however, can only serve as models if it is specified linguistically how they relate to the logical elements of the model. (see Zacharias and Lenel forthcoming)

36 Living scientists may be addressed in direct communication. Also, it is *per se* possible to access scientific knowledge via a reproduction of experiments and observations. For instance, at the Max Planck Institute for the History of Science, one of Galileo's experiments on the law of fall has been reproduced with interesting results. However, few historians and philosophers of science do this and the sources of science studies are mostly texts – plus some images and artifacts.

37 Hence, I consider myself closer to the linguistic approach of Carnap than to Suppes' non-linguistic approach, however, only in the very qualified sense I do outline by my principle and in the explication of my research design in section 2.1.

38 The idea of abstraction level seems like a rather intuitive thought. Thus, the fact that Rudolf Carnap but also someone like R.I.G. Hughes with respect to models share this idea implies no direct influence nor many common points. (cf. Carnap 1998 [1929]; Hughes 2009)

39 Already from my limited experience I see that there are many different ways in which this can happen. I will describe some of them in my historical-epistemological analysis.

40 For a short normative discussion of what should be called a scientific theory, see section 6 vi.

41 In the description of observations, however, numbers were frequently found, for instance in the description of bone lengths or geographical coordinates in which observations were made.

and underdetermination, (iii) a model of scientific explanations, (iv) the theory-ladenness and of observations and the supposedly resulting incommensurability, (v) the debate between scientific realism and empiricism.[42] To me, these problems are predominantly theoretical problems, i.e. terminology problems. Hence, they can be solved or softened by a better (more precise) formulation of the field in which they appear, usually by the introduction of novel distinctions. In this dissertation, I do not have the space to discuss these problems in depth. However, the annex contains a number of argument sketches which suggest that problems (i) and (ii) are solved in my model. I will, furthermore, suggest concepts for (iii) and (iv). Finally, I will clarify (v) and (vi) in a way which, in my opinion, renders them much less of a problem. (See annex, section 6)

1.3 Sociological project: Darwin's reception in Victorian Britain

The aim of my third project is an analysis of the impact of Darwin's *Origin* among his contemporary recipients in Britain. This reception analysis complements the comparative analysis of the theory contents in chapter 3. It investigates (i) which elements of the Darwinian theory were received by its recipients, (ii) by which criteria the Darwinian theory was assessed and (iii) which elements of the theory were ultimately accepted by its recipients. The underlying assumption in the reception analysis is that a scientific theory may change when transmitted from sender to recipient and may become quite independent from the text in which it was expressed; it becomes a social entity. Therefore, in order to understand the Darwinian revolution and to assess its impact on 19th century biology, one has to take into account what happened to the Darwinian theory once it left the pages of the *Origin of Species* and became an object of public and scientific discourse.

For my case study, this sender-recipient gap is further widened by the fact that the Darwinian was the first scientific revolution to be received by a large laymen audience.[43] 19th century Britain had seen the introduction of steam printing machines in 1814, and their widespread use since the 1830s had led to a massive increase in printing[44] and a decrease in printing cost. This fostered the publication of cheap popular books and magazines[45] (Secord 2000: 31-2) but also an unprecedented popularization of science:

> "Science continued to captivate the Victorians right up to the end of the century … through witnessing the spread of dazzling new technologies, through encountering exotic animals and plants, [but also] through experiencing heated controversies about the validity of novel theories[, such as Darwin's]. […]These controversies

[42] I do address these philosophical problems not for the sake of it but because discussion of my model did often give rise to them. The discussion in the annex demonstrates how I took them into account in the development of my model.

[43] This effect was even stronger for the Relativity Revolution in early 20th century physics. Milena Wazeck (2009) provides an excellent study on the public reactions to Einstein.

[44] Secord reports that the number of titles published per year in London, Oxford, Cambridge, Edinburgh and Dublin multiplied by four from 1800 to 1870. (Secord 2000: 31)

[45] Secord highlights that "During the 1830S and 1840s, quarterly periodicals such as the Edinburgh, Quarterly, and Westminster reviews – dominant in setting the literary agenda from the early 1800s through the 1820s – were supplanted as the most significant sites of debate by the monthlies and weeklies. 'Magazine day', the first Monday of each month, became a major event on the publishing, bookselling, and Post Office calendar." (Secord 2000: 35)

> involved scientists like Huxley, John Tyndall, and Thomson [Lord Kelvin], who were larger than life public figures." (Lightman 2007: 3)

From the start of the century to the 1840s and 1850s, the number of science titles rose fourfold – a remarkable rally. (Lightman 2007: 32, 18) Oftentimes, the publishers, not the authors, were the "driving force behind the production of scientific works for a popular audience." (Lightman 2007: 16) Fittingly, it was a professional publisher who landed one of the first remarkable successes in popularized science: Robert Chamber's *Vestiges* of the *Natural History of Creation* was a remarkable popular success. (Lightman 2007: 34, 38)

Due to this public attention and the trend towards popularization, mid-nineteenth century scientists like Charles Darwin, geologist Charles Lyell, or physicists John Tyndall and James Clerk Maxwell were accessible "to readers without a scientific training. Their texts could be read very much as literary texts": Scientists shared a literary, non-mathematical language with this laymen audience. (Beer 2009: 4, cf. 47) This shared language, however, forced someone like Darwin to "work with (and against) the shared metaphors and preferences of the broader community within which [he lived, worked, played and thought]." (Beer 2009: xxv) In other words, while it rendered Darwin's theory accessible to a much wider audience, this lack of separation between scientific and literal language held one imminent danger: Darwin could not control the exact meaning of his texts:

> "One of the major questions raised by *The Origin* is how far metaphors may overturn the bounds of meaning assigned to them, sometimes even reversing the overt implications of the argument. Seemingly stable terms may come gradually to operate as generative metaphors, revealing inherent heterogeneity of meaning and of ideology. Darwin's use of the concept of 'struggle' is one well-known example…" (Beer 2009: 50)

> "It is the element of obscurity, of metaphors whose peripheries remain undescribed, which made *The Origin of Species* so incendiary – and which allowed it to be appropriated by thinkers of so many diverse political persuasions. It encouraged onward thought: it offered itself for metaphorical application and its multiple discourses encouraged further acts of interpretation. The presence of latent meaning made *The Origin* suggestive, even unstoppable in its action upon minds." (Beer 2009: 92-3)

In sum, once the *Origin* reached public discourse it began to lead its own life, quite independent from what Darwin said were his intentions[46] or what the actual text might say, sometimes contrary to them: in some respect, publishing the *Origin* must have felt like opening Pandora's Box.

A theory which receives such wide-spread reception necessarily has a heterogeneous audience; in Darwin's case it comprised biologists, scientists from other disciplines, notably physics and geology, but also laymen, educated and uneducated. It does seem intuitive that the reception among such a heterogeneous audience is not symmetric; different recipients with different backgrounds received different information on the theory and the theory meant different things to them. Moreover, these

[46] As I will demonstrate, this independence from the author's intentions was remarkably strong in Darwin's case. His theory is certainly among the most powerful in the history of science and does not cease to inspire scientific, political and popular thought far beyond its original domain, i.e. the explanation of variation in animals, plants or their fossil remains. (Beer 2009: xxi-xxiii)

different backgrounds – previous knowledge, training, values, world-views – should matter for the acceptance and/or dismissal of Darwin's theory (or elements of his theory).

This point has first been systematically developed by Ludwik Fleck in his *Entstehung und Entwicklung einer wissenschaftlichen Tatsache* (1935) where Fleck discussed how a scientific fact – in his example a diphtheria diagnosis – might be communicated to different recipients: a bacteriological specialist, a practical doctor without particular knowledge on bacteriology and the mother of an infected child. (Fleck 1980 [1935]: 150-152; cf. Fleck 2011) Depending on their background, these recipients understand the diagnosis to different depths and are able to react to it to different extents.

Fleck's discussion reveals that the same diagnosis is communicated very differently to different recipients; it changes in form and level of abstraction within a thought collective (Denkkollektiv)[47]. Fleck, therefore, distinguishes between specialists, who share similar knowledge and a common language, and more distant recipients (laymen) whose understanding of the topic decreases with distance to the specialist group. He terms the communication within the specialist group 'esoteric' and communication towards laymen 'exoteric'.

In my reception analysis, I suggest a distinction along the lines of Fleck's model but with a different terminology. I will distinguish three recipient groups with three different backgrounds: (i) laymen without scientific training: the *public*, (ii) scientists from other disciplines: the *broader scientific community*[48], (iii) biologists[49]: Darwin's *immediate scientific community*.[50] I will study to which depth

[47] The members of a thought collective are defined by their taking part in the communication within the thought collective. Fleck describes it as a community of people who exchange ideas and stand in intellectual interaction. (Fleck 1980 [1935]: 54) (This is similar to Niklas Luhmann's definition of systems via communicative acts.) Thought collectives exist only with respect to specific fields of knowledge / discourses. For instance, a bacteriologist is a member of the thought collectives of bacteriologists, but may be a layman with respect to teleology or football.

[48] I refer to the first two groups as scientific communities. This does not imply that they resembled the modern scientific community. In fact, mid-Victorian science was still far from today's professionalism and institutionalization. It comprised a considerable number of amateur-scientists; Darwin himself is a case in point. Moreover, today's relatively clear boundary between science and non-science was far vaguer. (Lynch 2000b: xiii,: xviii) This is highlighted by the theologians and gentleman-naturalists who engaged in the debate on Darwin and were frequently accepted as valid participants. (This merging of, speaking in today's terms, scientific and religious discourse was certainly fostered by the emphasis on religion in academic training.)

[49] Note that the term 'biology' gained wide-spread acceptance only during the 19th century, particularly after Darwin provided a framework in which the different strands of biology could be integrated. Thus, Victorian researchers in zoology or botany might or might not have referred to themselves as 'biologists'. (See 2.3) For me, the term summarizes paleontologists, zoologists, botanists etc.

[50] These distinctions are the most precise for which the data and the topic allow. Particularly, I did not attempt to identify a subgroup within biology which could have formed a close thought collective in Fleck's sense. While Darwin did have a close group of scientists with whom he shared and debated results, this group comprised researchers from different sub-disciplines and from neighboring disciplines. (For instance, John Dalton Hooker was a botanist, Huxley a zoologist, Charles Lyell a geologist.) This is not by accident, obviously; Darwin's theory was a unifying theory and did thus apply to all biological sub-disciplines (or was supposed to). Therefore, it was discussed by biologists from different fields and research traditions. Moreover, Darwin specifically addressed young scientists from different strands in order to test his theory against their experience and convictions.

these three groups received the Darwinan theory[51], by which criteria they judged it and which elements of the theory they accepted or rejected.

The recipient groups are distinguished by the type of publications they typically read: (i) scientific papers in biological journals represent the debate in the *immediate scientific community*, (ii) scientific papers from other disciplines or papers with a strong scientific focus from more encompassing publications stand in for the debate in the *broader scientific community*, (iii) general newspapers and magazines represent the *public* debate. The analysis of reception depth will be oriented on the abstraction levels which I will develop in my model of scientific theories in section 2.1.[52] The criteria by which the theory was assessed as well as the acceptance and rejection of specific elements will be deduced from the lines of criticism which were directed at Darwin. For the immediate scientific community, this qualitative approach will be supplemented by a large-scale quantitative analysis of British biological journals.

My hypothesis is, first, that the reception depths in these publications form concentric circles with respect to the body of knowledge of 19th century biology: Only biologists had a deep understanding of the biological discourse and its empirical implications. Scientists and amateur naturalists from other disciplines had but an abstract understanding of biological topics and seldom debated it; however, through their training or practical experience they had a fundamental understanding of theorizing and empirical work in science and might have checked biological theories against theories in their own field.[53] The public hardly ever addressed biological topics and had only superficial knowledge of scientific practice; still, they could check biological theories against common sense and existing world views, notably religious[54] convictions.[55] (See Figure 1)

These graded reception depths will show in my analysis. A number of topics in the debate on Darwin were received only by the immediate scientific community or only by two scientific audiences. Other topics were shared between two or three of the audiences, for instance the descent of Man, the role of God in biological explanations and the missing links in Darwin's classification. However, when topics were addressed by different audiences, they were usually discussed in different depths and complexities. This becomes particularly visible when one compares articles from authors who wrote for different audiences, like Thomas Henry Huxley.

51 I will study but the reception of the *Origin*, I ignore the few reviews of the joint Darwin-Wallace-paper which were written before the publication of the origin, notably (Boyd 1859). For an analysis of such reviews, see (England 1997). For the reception of Chambers *Vestiges* see (Secord 2000; MacPherson 2001; Ruse 1979: 98-131; Voss 2007: 73-94; Lynch 2000b; Lynch 2000a; Schwartz 1990; Padian 2007: lxxv-lxxvi; Cosans 2009: 37; Brooke 1977). For the reception of Richard Owen, see (Rupke 1995; Rupke 1994; Padian 2007; Cosans 2009; Richards 1987a; Amundson 2007)

52 Hence, my reception analysis will demonstrate that the abstraction levels in my model do not merely apply to theories as linguistic entities but also to theories in their reception, i.e. as social entities.

53 With respect to biology, I am part of this group, too. I do not understand empirical work in biology but know how to analyze theories.

54 As Lightman remarked, in Victorian Britain, "Scientific knowledge seemed to offer the magical password – the 'open sesame' – that unlocked the doors to exhilarating new worlds ... But the fascination with science operated at an even deeper level. For some, it provided the basis for making sense of themselves and their place in the universe, either in conjunction with revised Christian notions or completely on its own terms." (Lightman 2007: 3-4)

55 In a small number of cases, practitioners could check biological theories against their practical knowledge, e.g. breeders and gardeners. I will address this issue in the reception analysis.

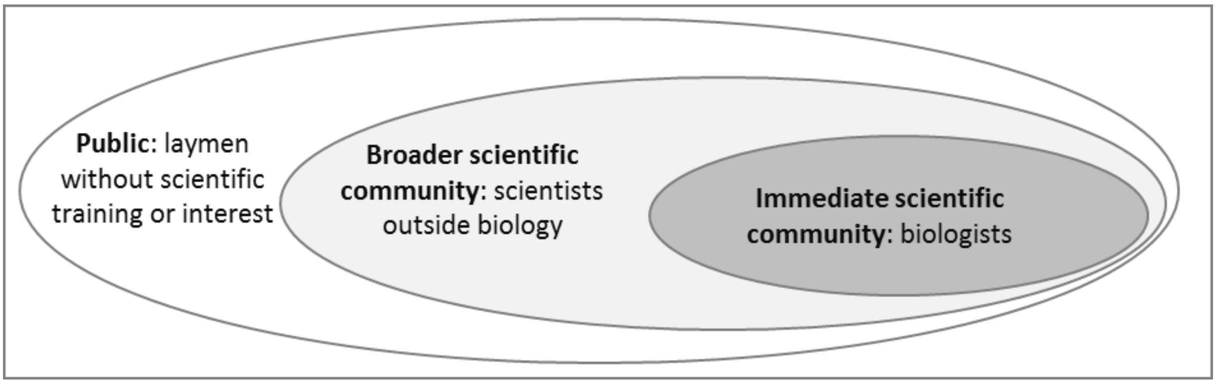

Figure 1: Reception depths with three audiences of Darwin's theory

Second, I suppose that these different levels of reception depth influenced the criteria by which the theory was judged as well as the question which elements of the theory were accepted and which rejected: Biologist assessed the Darwinian theory by different standards and accepted different elements than physicists or laymen. Thus, my analysis will not only provide a classification of reception depths but it will demonstrate that these depths explain the criteria by which the Darwinian theory was assessed by its recipients and, partly, what elements of the theory were accepted.

As my discussion at the beginning of this section suggests, it is not my goal to classify the reception as right (valid) or wrong (invalid). I do not aim to assess whether Darwin's theory was correctly understood and represented by its recipients nor whether the criteria by which recipients judged the theory were legitimate nor whether recipients were consistent in their arguments and their acceptance or rejection of specific elements of the theory. Rather, I aim to represent the Darwinian reception as a social phenomenon, i.e. as a phenomenon which was shaped both by Darwin's book and by the historical context in which it was received.[56]

My study covers the period from 1859 to ca. 1875 in Britain[57], i.e. the sixteen years following the publication of the *Origin of Species*. The consensus among historians and Darwin's contemporaries is that the Darwinian revolution was achieved by ca. 1868, i.e. in the middle of the covered period. In 1868, the majority of biologists and the public had accepted[58] evolution as a general concept[59].

56 For readers interested in contextualization, I will provide some comments from a modern perspective, clarifying how biological knowledge has evolved and how issues are seen today. For readers interested in the gap between the reception and the text of the Origin, my analysis in 3.4 provides a thorough basis.

57 For an overview over the European reception, see (Engels and Glick 2008) and (Engels 1995b; Engels 1995a; di Gregorio 1995; Glick 1988). For a focus on Germany see (Junker 1995; Engels 2000; Montgomery 1988; Seidlitz 1875; Haeckel 1873; Haeckel 1882; Sandmann 1995; von Kölliker 1864; von Baer 1973 [1873]), for France see (Farley 1974; Harvey 1995; Flourens 1864; Pictet 1973 [1860]). For the United States of America, see Glick 1988; Horenstein 2009; Gray 1860a; Gray 1888a [1860]; Gray 1860b; Gray 1888b [1860]; Gray 1888c [1874]; Gray 1888d; Gray 1888e; Agassiz 1860; Agassiz 1973 [1874]).

58 This is reported in unison by (Ruse 1979: 228-9; Himmelfarb 1959: 252; Bowler 1990: 183) as well as by Ellegård who cites the contemporary *Spectator*, *Nature* and *Athenaeum*, *Inquirer* and the *Quarterly Review* as reporting between 1868 and 1871 that evolution had become the majority opinion among biologists. (Ellegård 1958: 58-9) In the same mold, the editor of the *Ibis* in 1869 (Newton 1869: 216) spoke of "[t]he Darwinian school (to which belongs, we believe, the majority of our readers)". Finally, Darwin himself acknowledged his accomplishment when he altered the second sentence of the historical sketch from the 4th to the 5th edition of the Origin from "The great majority of naturalists believe that species are immutable productions, and have been separately created." to "Until recently the great majority of

Moreover, the debate began to fade; most of the controversy had passed by late 1860s. My analysis will consist of qualitative and quantitative components and it will be based both on primary and the relevant secondary sources. (For the exact research design, see section 2.2.)

naturalists believed that species were immutable productions, and had been separately created." (Darwin 1866: xiii; Darwin 1869: xv)

[59] My analysis will reveal that this general concept was not necessarily Darwin's concept of evolution, but a evolution in the sense in which one can say that Lamarck, Geoffroy, Chambers, Owen or Wallace all forwarded theories or explanations of evolution; they described a gradual development of species without constant divine interventions. (cf. section 2.3; part 3)

2 Research designs & historical background

2.1 Research Design for the comparative analysis of multi-layered knowledge systems: A four-level model of scientific theories

In order to compare biological theories on evolution, I have developed a scientific model of scientific theories. As I consider scientific theories to include scientific models, my model is both a scientific model of scientific theories and of scientific models.[60] For terminological clarity, I will refer to my model as 'my model' or the 'four-level model of scientific theories' and to the models which I analyze as Darwin's model, Owen's model etc.

My model distinguishes four different degrees of abstraction on which scientific information can be expressed and received. These degrees of abstraction may be referred to as 'levels' or 'layers'. (I will mostly speak of 'levels'.) I do distinguish four levels of abstraction which roughly follow three steps of abstraction[61]: from a detailed description to concepts, from concepts to general statements and from general statements to their implications for views of the world. I name the four levels as follows: Level 1: *Description*, Level 2: *Classification* (includes aggregation & static modeling, denotation & interpretation), Level 3: *Explanation* (includes dynamic modeling, narration), Level 4: *Ontological Implications*. Figure 2 provides a first overview of my model. [62]

	Denotative Meaning	Connotative Meaning
Ontological Implications		**Implications:** What does the narrative imply for human understanding of the world, man's place in it?
Explanation	**Dynamic modeling**: Formulation of aggregate statements over the aggregating concepts of level 2	**Narration**: The connotations of level 2, structured by the aggregate statements of dynamic models convey stories
Classification	**Aggregation** of descriptions under sets. **Static modeling**, i.e. ordering of such sets in hierarchical structures.	**Denotation** of concepts by concept names. Systematic **interpretation** of static models via interpretative principles.
Description	**Description** of events or object featu-res and empirical regularities of such events or features	

Figure 2: Four levels of a scientific theory

[60] This meta-perspective is shared by all science studies and produces no logical problems as long as my model complies with itself, i.e. if my model can be described by my model. The following presentation should reveal that it does.

[61] These abstraction steps reflect what I find in analyzing scientific theories but also the abstraction levels on which scientific theories are received, as they are visible in my reception analysis. (section 0)

[62] Remember that theories need not display all elements of my model. For a normative discussion of what a *good* scientific theory should display, see (section 6 vi)

Level two consists of two pairs of components, level three of two components. The division of these components separates two kinds of meaning, roughly: logical and literary meaning, i.e. the meaning of truth values and logical arguments and the meaning of metaphors and story-telling. Throughout this book, I will refer to the logical meaning as 'denotative' and to the literary meaning as 'connotative'.

I will argue that scientific theories display both of these kinds of meaning and that the distinction of denotative and connotative meaning allows for a much better description of scientific theories as has hitherto been possible. Particularly, it allows for describing how scientific theories aggregate knowledge and, at the same time, make sense of this knowledge through interpretation and explanation it. In other words, my model allows for separating scientific knowledge from the beliefs[63] about this knowledge.

Below, I will present each level in its components by sketching its theoretical background[64], by specifying the analytic concepts by which I will analyze these levels (operationalization) and by illustrating the application these concepts on two idealized[65] explanations from physics and the social sciences, namely the explanation Millikan employed in his experiments on the elementary charge (Millikan 1911, Millikan 1913)[66] and a Rational Choice explanation. On these examples, I will demonstrate how I am using the model and I will sketch manners in which the model could be extended and modified to apply to theories outside of the realm of my study, i.e. outside of 19th century biology. I will devote most space to the second and third level of my model as they contain the most innovative concepts and because they are crucial to my historical-epistemological argument.

2.1.1 Level 1: Description[67]

In terms of volume, the description of experimental or observational results continues to represent by far the largest part of the scientific literature; the sheer number of pages devoted to meticulous description of facts far exceeds the space devoted to their interpretation or explanation.[68] Therefore, in my analysis of these descriptions, I cannot and will not reproduce the complete knowledge which

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63 'belief' need not have a religious connotation here; it is meant to imply all kinds of convictions or assumptions about scientific knowledge, be they founded on religion or not.

64 Rather than a theoretical justification, I provide illustrations of my model. The only justification for a model should be its power to describe, classify, and explain evidence in an interesting way.

65 The actual applicability is demonstrated in sections 3.1 to 3.5.

66 Both of Millikan's papers describe similar experiments and discuss them similarly. As for the description of the experiment, the second paper is a specification of the first. Therefore, I will quote from both papers.

67 In order to avoid misunderstandings, let me point out that this level is called 'description' not 'observation'. It does not represent observations (or experiments) as acts of scientific practice but their results. I do therefore leave epistemological issues aside and focus on how scientists describe what they have observed. – Evidently, I do not know whether scientists actually made the observations they report in their descriptions; what is important to my analysis is merely whether these descriptions were considered the results of observations by other scientists. This seems to be the case. – As for the question of theory-ladenness, I do not assume descriptions of observations to be theory-free but theory-neutral. (See sections 6 iii, iv)

68 Still, this part of the scientific literature is mostly neglected by meta-disciplines like the History and Philosophy of Science.

the scientific theories of Chambers, Owen, Wallace, and Darwin aim to explain. Instead, I will focus on major empirical regularities reported by the biologists.

Why regularities?[69] Because they are the more sophisticated results of empirical study and because their description seems to mark the beginning of systematic scientific study in most disciplines.[70] Science knows both regularities between objects and events.[71] Regularities between events were rare in 19th century biology but they existed. For instance, in a famous experiment, chicken broth was boiled and then left standing. After a couple of days, life (little organisms) could be observed on the broth, a regularity which bewildered scientists for several decades. (See section 0. v)

However, the biology of the time was predominantly occupied with regularities among objects. I wish to distinguish two types of such regularities. On one hand, biologists identified taxonomic (or analytic) regularities, i.e. regularities among features of the same object. For instance, Georges Cuvier's discovered if an organism bears hooves it is a herbivore, not a carnivore. These regularities could be studied on isolated object classes, virtually independent of space and time, and they were produced by the anatomists or morphologists.

On the other hand, biologists discovered that certain fossils were linked to certain geological layers (strata), that certain living organisms correlated to certain geographical regions or that the developmental states of embryos of different species closely resembled each other. These regularities are regularities in space and time and, thus, synthetic.[72] They do not describe regularities between features of a single organism, but how such features were correlated to the organism's position in space or time.

Many more aspects of descriptions could be distinguished but this is not necessary for the level of detail of my study. However, for my analysis on level 2 and 3, I need to dissect empirical regularities one step further: When describing empirical regularities, scientists usually specify under which boundary conditions observations are made. For instance, biological field researchers could report in which geographical area at what date they found which specimens. Moreover, when events are described, scientists normally specify on what kind of objects the events were made. For instance, in

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69 Three remarks: (i) I do not speak of correlations, i.e. quantitative regularities, but only of qualitative regularities because these were the most frequent in 19th century biology. However, my model could easily be modified to accommodate for correlations as well. (ii) I do not speak of 'causalities', although some regularities are referred to as causalities by scientists and philosophers alike; I simply do not see how the difference between a causal and a non-causal correlation can be empirically determined (operationalized). In scientific practice, the term 'causal' is typically applied to very stable, long-known regularities which fall under some broadly-accepted model or theory. If it means nothing more than this, some of my regularities might be considered to be causal. If the term 'causal' implies any non-observable features, I am not associating with it. – For causality as a psychological category, see for instance (Bruner 1991: 18-9). (iii) Avoiding the terminology of causality does not imply that I assume that regularities are observable as such. Rather, when presenting two sets of empirical data as linked in an empirical regularity, scientists have already chosen one out of (several?) possible patterns in data, namely one which they believe to hold, to be more than random. Moreover, by presenting an empirical pattern in an empirical regularity, it is often given a direction, for instance from an earlier event to a later one. The choices prior to presenting empirical regularities might be (and appear as often) motivated by theoretical considerations.

70 Primitive empirical study may focus on single objects or events, e.g. describing that lightning is bright or that iron feels cold.

71 The distinction between object features and events is not sharp as a change in the features of an object can be interpreted as an event and vice versa. Also, there might be cases in which object features are correlated to events (or the opposite) and not events to events and object features to events.

72 For the distinction of analytic and synthetic regularities (statements), see my discussion in section 6.

ethology, one might specify exactly which species or sub-species or variety displayed a certain type of behavior. Therefore, I will distinguish four components of descriptions of observations. The ensemble of these components, I will call an 'observation conditional'. Figure 3 provides an overview.

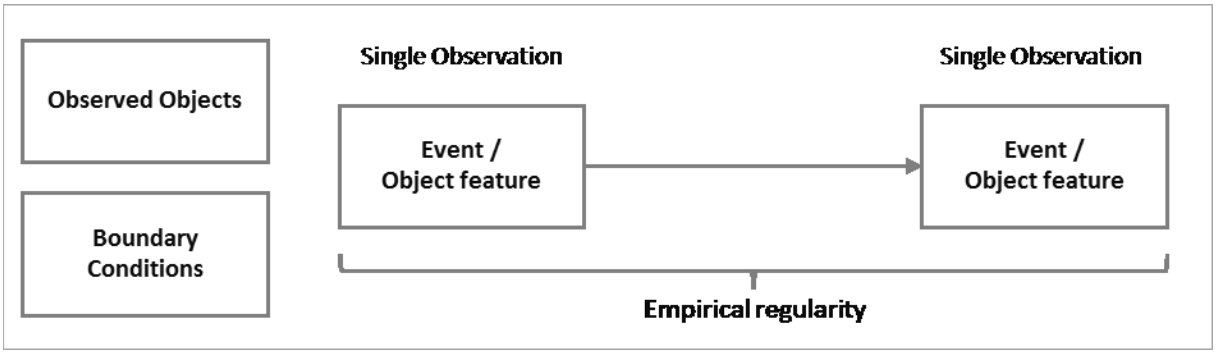

Figure 3: Four elements of an observation conditional

When comparing the empirical basis of scientific theories – the shared knowledge they aim to interpret and explain – I will do so in terms of observation conditionals and with respect to the established shared knowledge. Thus, on the first level of my model I will ask:

- **Are empirical regularities being specified in the investigated text?**
- **If so, do they extend the established body of knowledge (the shared knowledge) to novel kinds of regularities or do they complement or affirm it?**[73]

Let me provide two non-biological examples for illustrations. First, in a social science experiment, scientists may have observed that a subject (Observed Object) regularly chooses product A over product B, say ice cream over chocolate, although both are offered at a similar price. (Boundary Conditions) The experimenters approach the subject and offer them free ice cream and free chocolate and ask him to take one for free. (Event 1) The subject takes the ice cream. (Event 2) The results of the experiment can thus be described: If a subject regularly chooses ice cream over chocolate, then, when offered both, they will take the ice cream. (Empirical regularity) The observed object is the human subject; it could be described, for instance, in his age, gender, income etc. Furthermore, the exact experimental setting, i.e. price and brand of products, exact formulation of the question asked etc., could be specified. (Boundary Conditions)

In physics, Millikan's observation of oil droplets (Observed Objects) can be framed the same way. In a first run, he let the drops fall between the plates of an inactivated condenser, then when the condenser was activated. (Boundary Conditions) In the first run, Millikan observed single events, namely falls of the oil droplets. (Event 1 in 1st run) In the second run, the droplets first fell (Event 1 in 1st run) but began to rise between the condenser plates (Event 2 in 2nd run). (Millikan 1913: 123-

[73] I consider an empirical correlation to "extend" the established body of knowledge if it introduces a new knowledge source; for instance both biogeography or paleontology were integrated into biology at the turn of the 19th century. I consider an empirical correlation to "complement" the shared knowledge if it produces novel knowledge from an established knowledge source; an example would be new biogeographical information produced after the establishment of biogeography. To 'affirm' an empirical correlation is to express a correlation which has already been established and is part of the shared knowledge.

124)[74] This empirical regularity is supplemented by Millikan's very exact descriptions of his observed objects, the oil droplets (Millikan 1913: 111) as well as the physical conditions of the experiments (pressure, temperature) as well as his experimental equipment, thus specifying the boundary conditions of his experiment. (Millikan 1913: 115-123)

2.1.2 Level 2: Classification: Aggregation & Denotation, Static modeling & Interpretation

The second level of my model comprises the aggregation and denotation of empirical regularities in named sets, namely concepts with natural language concept names. I will therefore, in a first step, discuss the distinction of a concept ("Begriff") and its name, the concept name ("Begriffsname") as well as their respective meaning. [75] In a second step, I will demonstrate how complex arrangements of concepts result in hierarchical classifications – which I will term 'static models'. I will show how static modeling usually goes along with high-level interpretations and how such interpretations relate to single concept names.

i. *What does a scientific term mean beyond its reference? Concept vs. concept name, denotation vs. connotation*

By distinguishing the concept name from the concept, one can distinguish two kinds of meaning, namely the meaning of the concept and the meaning of its concept name. This difference has been pointed out by John Stuart Mill[76], by Gottlob Frege[77], and by Ludwig Wittgenstein[78], among others[79] and scientifically studied by psycholinguists[80] and neurolinguists[81].

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74 Millikan provided very exact measurements of the speeds and sizes of the droplets and, from these, calculated the elementary electrical charge. I do focus on the qualitative aspect and leave the focus of Millikan's experiment – the numbers – aside.

75 Neither candidate, 'predicate', 'term' or 'concept', connotes quite the same as 'Begriff' in German but 'concept' seems to fit it best. I will therefore mostly speak of concepts and concept names but sometimes give the German original terms as well for clarification.

76 In *A System of Logic*, Mill distinguished the 'denotation' and the 'connotation' of general and singular names. (Mill 1996 [1843]: 24-45, 133-54)

77 Frege, in *Über Sinn und Bedeutung* and in his posthumous writings, spoke of the meaning of a Begriff (concept) as 'Bedeutung' (reference) but referred to the meaning of a Begriffsname (concept name) as 'Sinn' (sense). ((Frege 1980a [1892b]; Frege 1983: 128-137; cf. Frege 1980b [1892a]) Frege actually speaks of both 'Begriffswort' and 'Begriffsname' but it seems more intuitive to oppose 'Eigenname' and 'Begriffsname', one denoting an object (Gegenstand), the other a concept (Begriff).

78 Wittgenstein spoke of 'Bedeutung' or 'meaning' in both the *Tractatus* and the *Philosophical Investigations*, but it is clear that these are two very different concepts of meaning: the earlier use resembles Mill's *denotation* and Frege's *Bedeutung* while the later resembles *connotation* and *Sinn*. (Wittgenstein 1955 [1917]: 3.203, 3.262, 3.325, 3.326; Wittgenstein 1953: numbers 139, 197-8)

79 Another important reference is Rudolf Carnap, who apparently coined the pair *intension* – *extension*. (Carnap 1958a: 118-121; Carnap 1958b) However, in technical terms, Carnap did not advance Frege's distinction of Bedeutung and Sinn, as a non-logical property. Instead, Carnap attempted to address Sinn in a modified logic which, to me, seems a fruitless endeavor. (see footnote 85) Bertrand Russell in *On Denoting* (Russell 1905) and Willard Van Orman Quine in *On what there is* (Quine 1964 [1948]) both remain much behind Frege's clarity and technical accuracy, particularly with respect to Begriffe.
I do not imply that these three distinctions by Frege, Wittgenstein and Mill are identical. Indeed, the connotations conveyed by the respective distinctions and their explications are quite different. Yet, all three describe (denote) the same phenomenon, i.e. the difference a concept name (Begriffsname) or a proper name (Eigenname) makes for human understanding of concepts. Thus, all three accounts can be

In a mixed Frege-Mill terminology[82], the relation between a concept and its concept name is this: A Begriff (concept) is best imagined as a set[83] which aggregates (summarizes) one or more objects[84]. To refer to a concept and its objects, humans employ concept names. These concept names are arbitrary signs to logic, they do not mean anything.[85] In human communication, however, these

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read as early accounts of the psycho- and neurolinguistic phenomena of associative networks and conversational implicatures. (see following footnotes)

80 In psycholinguistics, Stephen C. Levinson demonstrated the role of connotations for natural language communication in his overview work on generalized conversational implicatures. (Levinson 2000: 4-6; cf. Grice 1989) On his account, human speech is a bottleneck in communication; human brain can process information much faster than humans are able to utter them. Therefore, Levinson interprets utterances as sketches of what a speaker intends to say and identifies hints by which these sketches are decoded, namely “the form, the structure, and the pattern of choices within the utterance”. (Levinson 2000: 6) In his concept of General Conversational Implicatures, Levinson summarizes three main heuristics in this decoding process: rules by which humans interpret connoted meaning. The three heuristics are: (i) Q-Implicature: What isn’t said, isn’t: „If the utterance is constructed using simple, brief, unmarked forms, this signals business as usual, that the described situation has all the expected, stereotypical properties“. (ii) M-Implicature: What’s said in an abnormal way, isn’t normal: If „the utterance is constructed using marked, prolix, or unusual forms, this signals that the described situation is itself unusual or unexpected or has special properties“. (iii) I-Implicature: What is simply described is stereotypically exemplified: Any properties which are not described in an abnormal way (the remaining properties) are as usual. They can be filled with stereotypical values. – Accordingly, communication which is to be decoded through such heuristics follows three rules: (i) Evoke the relevant ideas, set the stage. (ii) Specify the extraordinary elements (iii) Fill the voids with default values. (Levinson 2000: 31-35)

81 In neurolinguistics, connotations are studied in the debate on associative and semantic priming. (Lucas 2000; McRae and Boisvert 1998; Hutchison 2003; Ferrand and New 2003) In this strand of research, a specific word (expression) is considered to be embedded in a so-called associative network: a network of words which are frequently used with, in place or instead of the original word. Hence, uttering a word activates an entire region of an associative network in a human brain. Therefore, when applied to a novel referent (object) or in a novel context, a word carries with it the contexts of its previous uses and these contexts will mark its new use with recipients. Two remarks: (i) From my limited reading, it seems that the distinction between associative and semantic is not clean. I subscribe merely to the phenomenon of priming as such. – On a side note, the priming networks described by neurolinguists seem closely related to the associations evoked by mental models. (ii) For illustration, an experiment on priming might look this: A subject is seated in front of a screen on which sequences of words are displayed. First, a trigger is shown for several seconds, the trigger is followed by a second word. The subject has to decide whether the second word is a correct word in his native language. He expresses this decision by pressing a button. The time between the display of the second word and the pressing of the button is measured. (reaction time) The reaction is significantly lowered if in the language concerned if the trigger is regularly used with second word in sentences, for instance in the pairs: dog – bite, cat – milk, needle – thread or if the trigger is regularly used in place of the trigger (synonyms/antonyms), for instance in the pairs: black – white, hot – warm, ship – boat. The effect of lowering the reaction time is called “priming”. – Beyond word pairs, there are experiments on priming with entire sentences but also with images.

82 Frege’s is the most exact formulation of the three and I adapt it, except for the definition of concepts (Begriffe). With respect to the meaning of Begriff and Begriffsname, I will, however, employ Mill’s terms ‘denotation’ and ‘connotation’ because they seem most intuitive. (From my experience, the distinction of sense (Sinn) and reference (Bedeutung) is not intuitive to people outside the narrow Frege-community. The pair of extension – intension is familiar to mathematicians, logicians and scientists who carry out formal work. Beyond, however, mix-ups of ‘intention’ and ‘intension’ are frequent and misleading.

83 As opposed to Frege’s definition as functions, I present concepts as sets. This should be logically equivalent but hopefully is more intuitive.

84 Objects in this sense may be anything, actual tangible objects, but also acts, other concepts; in scientific theories, most concepts aggregate descriptions of observations as I have described on level 1.

85 I do not wish to associate my work with intensional (modal) logic, as far as it is supposed to clarify or solve the problem of denotations and connotations; in my opinion, it does neither. Connotations are independent of truth-values; in logic, they are the only aspect in which terms can differ beyond their truth-values. Figuratively speaking, connotations are invisible to systems of truth-values. Intensional (modal)

concept names are no arbitrary signs. Rather, they serve as symbols by connoting (conveying) what the named concept might denote. Thus, it serves as a symbolic (coded) reference to the concept's objects, evoking these objects without enumerating them.[86] Figure 4 depicts this relation in its ideal form.

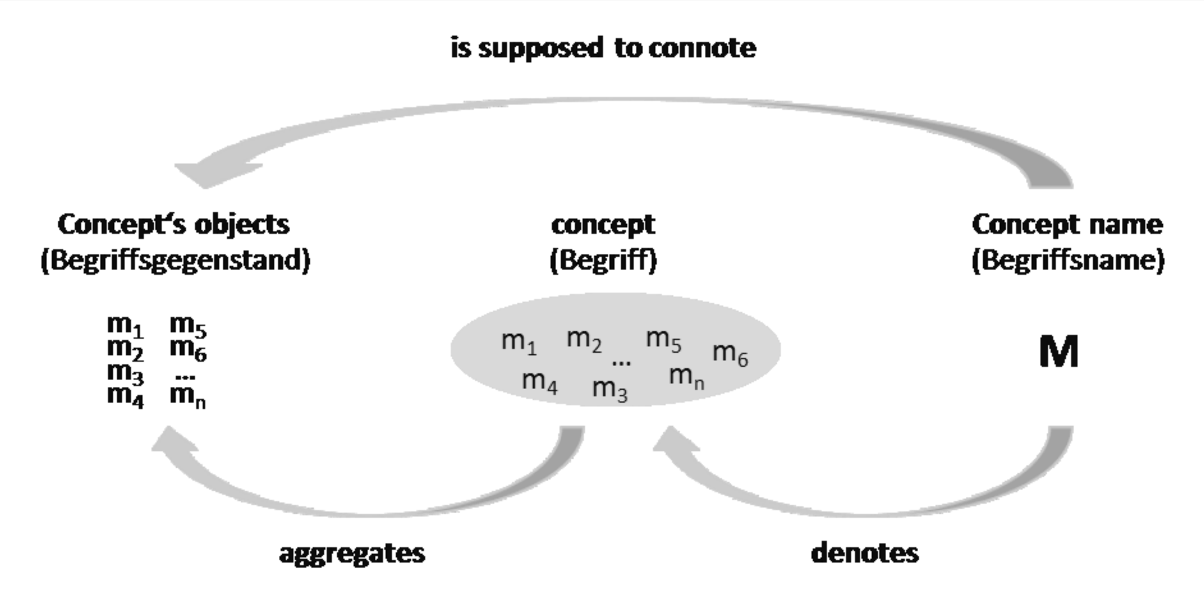

Figure 4: Concept, concept name, a concept's objects – aggregation, denotation, connotation

In scientific practice[87], however, this relation is not ideal; particularly the denotation and connotation of concept names are often not in unison. Rather, the connotation of a concept name often only partly overlaps with its denotation, hiding some of the concept's objects and connoting some objects which are not part of the concept.[88] I suppose that this has been experienced first-hand by most scientists: When introducing a novel concept or interpreting novel evidence, one often struggles to find the appropriate concept name; a term which already conveys an impression of what it denotes, works for most of an audience. Conversely, key-word searches seem to always produce numerous

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logic, however, remains a system of truth-values; it merely has fancier names for its operators. – Ironically, intensional (modal) logic succeeds in *reproducing* the problem of denotation vs. connotation, namely by introducing operators which have the same truth-value configurations as operators in regular logic but different names. These operators denote the same objects as other operators but their name connotes something beyond, namely that they differ from operators in regular logic.)

86 Some philosophers and logician distinguish two ways of defining a set, by enumerating its elements or by enumerating the properties which the elements of the sets satisfy. (see for example Carnap 1958b: 118-121) I do not see that this distinction holds. If a set is defined by a set of properties instead of the elements, one can always ask for a definition of the properties. The definition might then be given either by another set of properties or by enumerating all elements which satisfy the property. Thus, if one proceeds to ask for the definition of properties the set must eventually be defined by enumeration of its elements. (Unless the properties are not defined in which case the set is not defined.) This shows that both ways of definition are logically equivalent. Still, this equivalence might be counterintuitive as properties seem to express some "essential" or "constitutive" features of a set and are sometimes (often?) treated thus by scientists. This, however, is a psychological phenomenon, not a logical one. Rather, the distinction of definitions via properties from definition via enumeration reproduces once again the problem of denotation vs. connotations: Properties convey more than mere enumerations. (see footnote 80)

87 There may be some areas of mathematics and formal works in the empirical sciences, where concept names seem to be arbitrary.

88 John Gerring provides an excellent discussion of such problems in the social sciences and develops criteria for good concepts which should be applicable beyond these disciplines. (Gerring 1999: 367)

hits for which denote something outside the desired scope but fail to reveal much of what would be interesting.[89]

Hitherto, philosophers of science considered mainly the logical (denotative) meaning while historians of science focused rather on connotative meaning. I believe that, when analyzing the meaning of scientific theories, one has to take both denotative and connotative meaning into consideration; both influence how scientific theories are understood and, hence, what they mean to recipients. A scientific term means neither exclusively its empirical reference (object, Gegenstand) nor merely its use in previous historical contexts, it means both. Denotative and connotative meaning, denotations and connotations, are two sides of the same coin.[90]

ii. Static modeling and interpretative principles: organizing and interpreting scientific concepts

When scientific concepts aggregate large sets of empirical evidence the divide between denotation and connotation becomes more marked. This is visible in complex classificatory systems as biological taxonomies where single sets are ordered and hierarchized.

I will refer to such complex classificatory systems as 'static models' and distinguish them from dynamic models. (see section 2.1.3) The term 'static' accounts for the fact that these models do not model empirical regularities in time and/or space (synthetic regularities), i.e. dynamics, but regularities on objects within one concept (analytic regularities); they display snap-shots. Classic cases of static models are globes or maps but also an atom model in physics or a population tree in sociology. Globes and maps aggregate geographical data in a single, coherent framework and display relations between features of different places, notably distances. A model of the atom may aggregate patterns of electric impulses and display them as electron configurations on atomic orbits. A population pyramid visualizes relations between features of age cohorts, namely their absolute numbers and their share of the overall population. (For the use of static models *within* dynamic ones, see below.)

Static modeling may apply to all elements of the description of observations: objects and object features, boundary conditions, events but also entire observation conditionals. Biological taxonomies classify the objects of biological observations, animals and plants, according to object features.[91] Mechanics may distinguish different kinds of motions, events, for instance simple harmonic motions from reciprocating or linear motions. Millikan's fall is a case of the latter. Rational Choice Theory, when applied in game theory, may distinguish different kinds of boundary conditions by distinguishing games, for instance, cooperative and non-cooperative, symmetric and asymmetric,

89 Such effects are particularly marked in the social sciences and humanities, where many concept names have immediate implications for human world-views and are often subject to debate and struggle. Therefore there exist distinctions like the one between *Macht* (power) in the sense of Max Weber and *Macht* in the sense of Hannah Arendt. (Precisely speaking, it is the denotation of these terms which differs, not their connotation (sense).)

90 By this, I do not imply that scientists consciously did or do distinguish between both kinds of meaning. My distinction is a modeling choice, an analytic category.

91 Very abstract concepts in such classifications, for instance the terms 'mammals' or 'mollusks', denote large sets of observed organisms. More specific concepts as 'dogs' denote subsets of such larger sets. Thus, the definition of such subsets allows for the formulation of analytic statements like "All dogs are mammals.". (See section 6. ii)

simultaneous and zero-sum games.[92] When complex, such classifications can be arranged in tree schemes, as displayed by Figure 5.

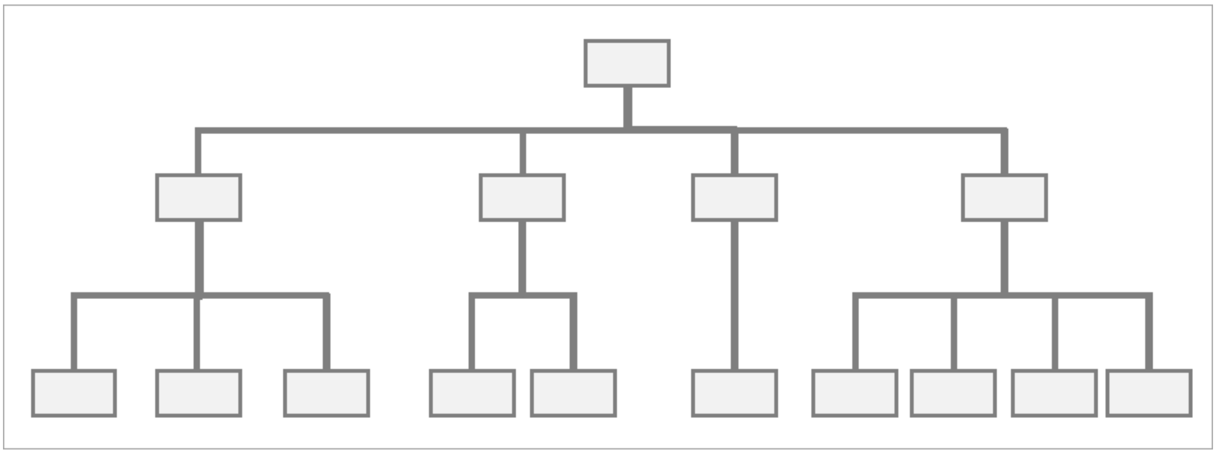

Figure 5: A static model (schematic representation)

The denotation of the single sets within a complex static model is usually no arbitrary venture but a quite systematic enterprise. Often it follows some general principles which provide a consistent overall interpretation[93] of the different sets which are hierarchized in the static model. I will refer to such principles as 'interpretative principles'.[94]

In some static models such interpretative principles seem quite metaphysical, in others, they are little developed or very pragmatic. Thus, a population pyramid aggregates demographic data in standardized columns, separating sexes and summarizing 5-year-cohorts. A map or globe aggregates topographic data, presents it in standardized format (colors, hachures) and relate it to a unifying map grid. In Rational Choice, one might wonder whether the fact that games are divided into pairs and names them by mutually exclusive terms implies some interpretative principles but, overall, in Rational Choice Theory or Millikan's physics, interpretative rules seem less intuitive. Contrarily, in biology, interpretative principles are important and there exist frequent debates on them. Thus, in the 18th and 19th century, taxonomic classifications[95] have been interpreted before the background of

92 A classification of entire observation conditionals is usually a classification of Connectors (see below). A case in point would be hierarchies of forces in physics.

93 I do speak of both, 'static modeling' and 'interpretation' in order to cater to two debates. First, the distinction between static and dynamic models caters to the model community, where it was apparently introduced by Hartmann, but not clearly specified. (Hartmann 1996) Second, 'interpretation' as opposed to 'explanation' (which I discuss in the following section), reflects the distinction between Verstehen (understanding) and Erklären (explaining/explanation). This distinction was introduced in the 19th century in Germany and is still sometimes upheld as a dividing feature of the natural sciences and the humanities. My distinction denotes the same differences but favors a different connotation with respect to Verstehen. Aside from the humanoid undertones, Verstehen is part of the context of discovery, it is a process by which knowledge is accessed and gathered. Both, interpretation and explanation are rather part of the context of justification. Hence, I find it more intuitive to oppose them. This does not imply that these two concepts are more mutually exclusive than the original ones: a scientist may do all three: understand, interpret, and explain. (cf. Scholz 2008: 116-121)

94 As with the denotative and connotative component of a concept name, the distinction between the static model and the interpretative principles is an analytic choice within my model. Also, one might find that the term static model already implies interpretation and that another term would be suitable to denote the hierarchical organization of scientific concepts.

95 Taxonomic classifications are not the only possible classifications in biology, although they were the most important ones in 19th century biology and will be the kind of classification which I address most.

the scala naturae, the archetype or common descent, each concept implying different sets of interpretative principles.[96]

In sum, in order to identify differences in aggregation and denotation as well as static modeling and interpretation, I will ask the following questions:

- **How are observations being aggregated and hierarchized? Do static models deviate from generally accepted ones?**
- **How are sets of observations being denoted; are denotations systematic? Are general interpretative principles being introduced to justify denotations?**

2.1.3 Level 3: Explanation – Dynamic Modeling[97]

The third level of my model, explanation, is divided into two parts: modeling and narrative. While narratives account for what we find intuitive and plausible in explanations (see below), dynamic models account for its logical part, namely arguments.[98] In logical terms[99], I would describe dynamic modeling as the formulation of aggregate[100] statements over large sets of synthetic[101] empirical regularities.

This is also the point in which dynamic models differ from static models. Static models aggregate regularities between features of one set of objects (or events) – analytic regularities, for instance the fact that animals which bear hooves are herbivores. Dynamic models aggregate regularities between different (mutually exclusive) sets of objects (or events) – synthetic regularities, for instance that a fossil with properties X is only found in a geological strata with the properties Y (or that an event of the class X is regularly followed by an event of the class Y), with X and Y being mutually exclusive. In other words, static models model regularities within single sets of data points while dynamic models model regularities between different sets of data points. Synthetic relations are usually told as time-bound processes, i.e. dynamic processes, therefore the term 'dynamic model'. (For static models within dynamic models, see below.)

Dynamic models may be specified to the same degree as empirical regularities, i.e. in the form of an observation conditional which comprises an event sequence or a regularity of object features on two

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Biogeographical and paleontological classifications classify organisms and fossils by the geographical area or the geological strata in which they were found.

96 Modern genetics provided another source of interpretative principles from the 20th century on. An example of interpretative principles provides the Linnean binomial system, a nomenclature in which concept shares parts of its name with the names of each of its sub-concepts.

97 For a discussion of how my model relates to the debates on explanation, see section 6 v.

98 This is a modeling choice again. As social-historical entities, models are not mere logical entities; they always convey narrative elements. (see below) I choose to separate models from narratives because it allows for novel insights and better explanation.

99 This does not immediately include physical objects or diagrams serving as models. Such objects, however, can only serve as models if it is specified linguistically how they relate to the logical elements of the model. (see Zacharias and Lenel forthcoming)

100 Past discussions have found it difficult to determine a line between theoretical and empirical statements. This seems mainly due to the unclear connotations of the term 'theory'. I avoid it and speak of aggregate or statements. The distinction between single and aggregate statements should be an empirical one, i.e. its operationalization is not trivial but feasible.

101 For a formal discussion of the distinction, see section 6 ii.

different objects, the objects on which those events or features were observed and the boundary conditions under which the observations took place. In order to cater for this complexity, I am framing dynamic models in a scheme of five features, four of which correspond to elements of a full-fledged observation conditional. Figure 6 illustrates this relation.

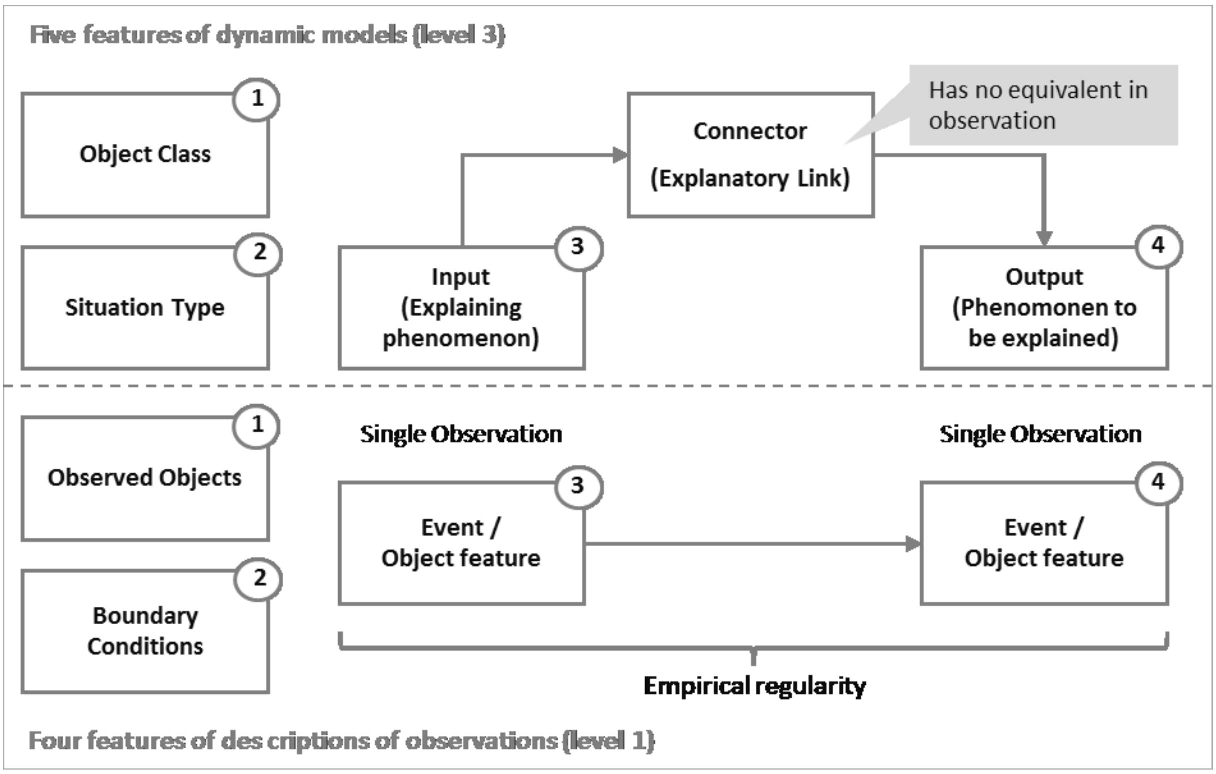

Figure 6: Five features of dynamic models, corresponding elements in the description of observations[102]

Input and Output are probably the most intuitive and the indispensable elements here. They reflect the two elements of an observation conditional, i.e. the two events of an event sequence or two correlated features of different objects. A dynamic model puts these synthetic[103] regularities in a timely relation, presenting the Output as the consequence of the Input or, in other words, linking two phenomena[104] in an effect.[105] This need not be suggested by the observed regularity. In the experiment on spontaneous generation, chicken broth was first heated and then bacteria were observed on it. This is a clear event sequence. In paleontology, however, fossils are correlated to certain geological strata and it is a choice whether to interpret successive geological strata as

102 Note that dynamic models overlap with static models (see below), therefore, the upper half of the figure overlaps with level 2 of my model.

103 Notice the difference between the analytic statements which can be formulated about elements of a static model (taxonomy) and the synthetic statements in dynamic models. The former relate features of the same objects – dogs are mammals – while the latter relate independent events or features of different objects, for instance of features of fossils with features of geological strata. For the discussion on the distinction see (6 ii).

104 I consider a phenomenon a “unique event” and an effect the sequence of two events, each of which may be a phenomenon. This seems to reflect the typical use of the term as I perceive it. I am unsure whether this sequence need be induced by human intervention as Ian Hacking suggests. (Hacking 1983: 224) But this is a question of linguistic practice and requires empirical investigation.

105 It seems to me that the terms ‘phenomenon‘ and ‘effect’ are employed for empirical facts and regularities only when these have been named (denoted). Thus, the appearance of an abnormal feature in a group of organisms becomes a phenomenon when it is called a ‘variation’.

testimony of successive historical periods. By doing so, the modeler brings his model in line with geology – a clear advantage – but this remains a choice.

It is the relating of Input and Output which allows modelers to describe, predict and produce empirical effects.[106] Therefore, it seems to be the core of modeling, a scientist's decision which empirical facts to relate in her or his account of nature. This relating is somewhat intuitive in experimental sciences where one can test empirically whether two events are related, i.e. if one can induce the second event by inducing the first. In these sciences, the intellectual accomplishment lies more in conceiving the experiments than in their interpretations. In sciences which have no access to experiments[107] and analyze data ex post – most of the social sciences and humanities, but also natural sciences like seismology – modeling consists in finding robust correlations (quantitative regularities) in the data. The efforts of 19th century evolutionists display how difficult and creative a task this can be.

Let me illustrate this on my two examples again. Millikan, in his explanation (model), linked the descent and ascent of oil drops because he observed the two events in this order. The sociologists who observe a person regularly choosing ice cream over chocolate, might refer to such events as "revealing a 'preference' " for ice cream over chocolate. Second, they might call the taking of the offered ice cream an 'action'.

The Connector may be a non-intuitive feature but it is an important element of many dynamic models. Logically, it is the name of an assignment (a function); it assigns subsets of the Output (or the entire Output) to subsets of the Input (or the entire Output). [108] Therefore, the Connector has no direct counterpart in observation[109] beyond the empirical regularities which are observed and summarized by Input and Output; graphically speaking, it means the operators which link these empirical regularities, i.e. the "if…then…" in "if event 1, then event 2." or "If object feature 1, then

[106] I distinguish the capacity to describe, to predict and to produce. The first one is ex post knowledge, the latter two constitute ex ante knowledge. Description comprises the description of single events (e.g. lightning), or event sequences (a seaquake leading to a tsunami), object features (length of the bone of a fossil) and regularities of such object features (only herbivores bear hooves). Prediction and production refer only to event sequences or object features; in prediction we cannot control the outcome, in production we can. The three concepts are overlapping: what we can produce, we can predict and what we can produce or predict, we can describe.

[107] Many disciplines run material simulations, which could be considered experiments on material models. However they do produce empirical knowledge about the model, not about the modeled object (target object). For a discussion of this see (Zacharias and Lenel forthcoming).

[108] As always there are exceptions, particularly inconsistent or unempirical models. As an analytic tool, however, the concept of the Connector is quite useful and may provide some insight into how models are built.

[109] This does not imply that we may not study the space between two observations by introducing a third observation. Yet, if we do this, between the first and the third observation remains a space and the same is true for the third and second observations. Thus, we may minimize the space between data points (observations) but we cannot completely overcome it. On the level of models, intermediate observations (the third observation) may lead to the dismissal of a Connector but they can never fully satisfy a Connector; it keeps a speculative (interpretative component.) This, however, depends on the concept name employed for the Connector and the role this name plays in the narrative which is conveyed by the model

object feature 2.".[110] [Rhetorically, i.e. in terms of connotative meaning, the *name* of the Connector also determines to a large degree what stories a model may convey.[111] (See below)]

Thus, in the Rational Choice model, the assignment of an action to a preference is a rational decision, which, in this explanation, denotes exactly the sequence of revealing a preference for ice cream and taking the ice cream. Millikan describes the fall of the droplets as "an descent under gravity" and their rise as "an ascent under the influence of the [electric] field F", introducing two different Connectors[112] for the different outcomes of dropping oil droplet in an activated condenser and in inactive one.[113] (Millikan 1913: 123)

The Object Class is supposed to sum up the different types of objects on which regularities have been observed and to which the model is supposed to apply. The Situation Type is supposed to summarize different sets of boundary conditions under which the regularities were observed. Neither of these elements of my model is specified in all dynamic models. Rather, it seems from my limited experience that they are only specified if the model covers several types of objects or boundary conditions on which different empirical regularities have been observed. In other words, Situation Type and Object Class are specified in order to distinguish whether a specific Input-Output relation applies or not.

This does not imply, however, that either is observed independently from Input and Output. For instance, Millikan states the ascent of oil-drops only under the influence of an electric field (Situation Type), otherwise the drops do not begin to ascend; they require "a vertical electrical and gravitational field combined", respectively. (Millikan 1911: 349-50) Likewise, Millikan distinguishes oil drops which become ionized ("ions") and begin their ascent from those which escape ionization[114] continue in descent. (Object Class) However, Millikan provides no independent empirical data for either distinction. The ionization is operationalized by the same Input-Output-relation which is supposed to occur on ions:

110 The Connector of a model M is logically equivalent with this conditional statement: "For all object features and events summarized by the Input or Output of M: If one object feature or event satisfies the Input of M, then at least one other object feature or event satisfies the Output of M.". In its basic logic form, my model is not far from the deductive-nomological scheme (D-N-scheme, covering-law model) which Carl Hempel developed in the 1950s and 60s. (Hempel and Oppenheim 1948; Hempel 1962) The basic form of the D-N-scheme is a syllogism of the form 'If A and (if A then B.) then B.' wherein A corresponds to the Input of my model, B to my Output and the conditional If A, then B. to my Connector. I extend on this basic form by introducing the Situation Type and the Object Class as well as a single name for the conditional: the Connector. While this single name denotes the same as the conditional If A, then B. it may connote something more, as revealed in my analysis of the link between models and narratives.

111 The clear distinction which I have suggested between a model as a logical entity and the narrative as a psychological-linguistic entity thus hangs on the name of the Connector here. As a metaphor, it feeds the narrative. As a term (an arbitrary name) it organizes the model.

112 To clarify, the gravitational field is active in both the first and second case of Millikan's experiment, only in the second case it is superimposed by the electrical field. (see below)

113 Visibly, the principal statement of a model: 'If the Input occurs and the Connector applies then the Output occurs.' is a tautological statement. This seems to be the case with many models; Darwin's is merely one famous example.

114 Ionization was achieved through Röntgen rays: „The air about the drop p was ionized when desired by means of Röntgen rays from X which readily passed through a glass window g [in the brass vessel].". (Millikan 1913: 122-3)

> „The fact that an ion has been caught, and the exact instant at which the event happened is signaled to the observer by the change in the speed of the droplet under the influence of the field.“ (Millikan 1911: 353)

The same is true for the field; we know that the ion is under the influence of the field if and when it begins its ascent (or, at least, slows its descent); there is no other empirical means of determining it.

In Rational Choice explanations, the Situation Type might distinguish a perfect market from an imperfect one and the Object Class a *homo oeconomicus* from a less "rational" agent. Equally, these classifications are not empirically accessible beyond the observable Input-Output-relation. Thus, when the observed subject behaved according to the model he or she is a *homo oeconomicus* in a perfect market[115] - otherwise not. Conversely, the absence of the Input-Output-relation can be explained by the absence of either a perfect market or a *homo oeconomicus*.[116]

Finally, how do dynamic models relate to static models? If dynamic models model regularities between different sets of data points and static models regularities within a single set of data points, then this single set of data points may be of the sets modeled by the dynamic model. Therefore, dynamic models might describe changes within static models. Thus, depending on what is modeled in a static model – events, objects, boundary conditions – the static model may overlap with the dynamic model in the Input and/or Output, the Object Class or the Situation Type.

Thus, a globe, aggregating topographic data, might be employed in a dynamic model which describes the sun's position towards the earth. Such a model could describe at what time a certain point on earth receives sunshine or undergoes a certain season (winter, spring, summer, autumn). A static model of the atom which differentiates different electron configurations can be employed in a dynamic model of chemical reactions. A population pyramids might be employed in dynamic models which describe demographic developments due to wars or the fast decline in birth rates after the introduction of the anti-baby pill. [117] In Rational Choice Theory, a political decision might be explained by the type of games political actors are playing, for instance zero-sum games, by them playing in a specific Situation like a prisoner's dilemma. In biology, dynamic models of evolution model the difference (delta) between different elements of a taxonomic classification (organisms) which, themselves, are members of the Object Class.

As on the other levels, I will ask a number of questions in order to identify dynamic models. My aim is to understand how aggregate concepts and statements in a dynamic model relate to the empirical regularities which were described on level 1. Therefore, I am asking:

- **Is an Object Class defined to which the Input-Output sequences apply?**
- **Is a Situation Type specified in which the Input-Output sequences apply?**

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115 The market is very simple in my model, obviously.

116 In sum, it seems to me that Situation Type and Object Class of a model serve, first and foremost, for theoretical classification, they allow for distinguishing and organizing sets of empirical regularities. Second, they play an important role in immunizing models or theories against contradictory evidence, a phenomenon called "confirmation holism" or "Duhem-Quine thesis". (for a discussion see section 6 iii) Third, their concept names are important elements of the possible narratives a model may convey. (see section 2.1.4)

117 My analysis will reveal this distinction as particularly fruitful for the Darwinian revolution. (5.1 iv)

- **Are two independent sets of observations aggregated and is one set (Output) assigned to the other (Input)? Does this assignment mirror synthetic empirical regularities?**
- **Are such assignments of Input and Output named by particular terms (Connectors)?**

2.1.4 Level 3: Explanation – Narration

Beyond dynamic modeling, however, there is a second dimension to explanations which transcends logical arguments. In discussions on scientific explanations, I noticed how much it matters *how* one presents a model in explanation and which terms exactly one employs: explanation is equally a logical and[118] a rhetorical task.

This point exceeds connotations and terminology as I have addressed it above. The terms employed do indeed matter but, moreover, it matters how one puts them in relation, what points of an explanation are stressed and specified what other points are merely sketched or neglected. I suppose that most good explainers, like good speakers, acquire this skill through experience, i.e. trial and error. They tell an explanation over and over, learn from the feedback and modify small parts until it sticks with audiences, until listeners (or readers) find it plausible, intuitive, obvious – in one word: explanatory. Thus, explanation reveals a very (inter-)subjective element, one that transcends the realm of logic and projects us into a realm of rhetoric, specifically: stories.

i. Stories in science?

This personal experience reflects in some strands of the history and philosophy of science. First, in an important article on scientific explanations, Philip Kitcher dismissed the logic-wise most precise account of scientific explanations – the deductive-nomological model (D-N-model)[119] – because it allowed for “intuitively non-explanatory” explanations:

> “The covering law model [D-N-model] satisfies neither of these desiderata. Its difficulties stem from the fact that, when it is viewed as providing a set of necessary and *sufficient* conditions for explanation, it is far too liberal. Many derivations which are intuitively [sic!] non-explanatory meet the conditions of the model. Unable to make relatively gross distinctions, the model is quite powerless to adjudicate the more subtle considerations about explanatory adequacy which are the focus of scientific debate.” (Kitcher 1981: 508)

While it does not seem that Kitcher draws the same consequence from this observation as I do[120], it is notable what criterion he introduces in the discourse on explanations: intuition. He disqualifies

[118] Let me clarify this from the beginning: I do not argue that scientific explanation is merely a rhetorical task. It has both a logical and a rhetorical component.

[119] Kitcher speaks of the “Covering Law Model” but refers to the model which Carl Gustav Hempel championed in the 1960s and which Hempel himself referred to as the D-N- model. (Hempel and Oppenheim 1948; Hempel 1962) In its most basic form, it presented scientific explanations as syllogisms of the following form: If A and (If A, then B.), then B. (For a more detailed discussion see section 6 v.)

[120] In the course of the article, Kitcher does not attempt to grasp this intuitive component by other means than logic.

certain logically sound and empirically adequate explanations because, intuitively, they are not explanatory.[121]

Second, and apart from the purely analytic strand of philosophy of science, there exists a tradition of historical-philosophical work which link models and explanations to non-logical linguistic entities, namely metaphors and stories. Colin Murray Turbayne, Arthur C. Danto, Mary Hesse, and Max Black have championed such views in the 1960s, Alan Gibbard and Hal R. Varian in the 1970s. (Turbayne 1962; Danto 1965; Hesse 1966b; Hesse 1966a; Black 1968; Gibbard and Varian 1978) Unfortunately, none of these accounts is very precise in specifying how models relate to stories.[122]

Recently, the debate has been revived by the historian Norton Wise and, foremost, philosopher of economics Mary Morgan. (Morgan 2001; Morgan 2002; Morgan 2007a; Morgan 2007b; Wise 2008). Wise, inspired by Morgan, identified narrative patterns in theoretical physics, an area where one would not necessarily expect it:

> "…explanation in significant areas of physics has changed in character, from deductive narrative[123] to historical narrative... I do not argue, with respect to the deductive structure of the PDE's [partial differential equations], that they themselves have a narrative form, only that they give a deductive structure to stories associated with them and, following [Mary] Morgan, that the resulting narratives are essential in relating the mathematical structure to the world. Simulations, however, seem to have an inherently [historical] narrative character, in that they generate natural histories of events [event sequences] and objects that are grown by – and known by – the simulations. The process of growth of these events and objects becomes their explanation. Through this change in character, explanation in physics begins to look much more like evolutionary biology and even history." (Wise 2008: 48-49)

> "I stress the narrative aspect because we do not normally think of mathematical deductions as narratives. Indeed, Courant and Hilbert do their best to strip their mathematical methods of all narrative elements. And yet, the toolbox [of mathematical equations] cannot be constructively employed in the world without putting the narrative back in." (Wise 2008: 42)

[121] One (once?) famous example of such an "intuitively non-explanatory" explanation involves a flagpole and its shade. Among the majority of philosophers, there seems to be a consensus that it is valid to explain the length of the shade of a flagpole by the length of a flagpole (and the angle of incidence of the sun's light etc.) but not the inverse. I know of no logical or empirical criterion which justifies this distinction and, as Bas van Fraassen, I have never found it intuitive. (In the *Scientific Image*, van Fraassen went out of his way to invent (?) a story which explains the length of a tower by the length of the shade it was supposed to throw. (van Fraassen 1980: 132-4)) Anyway, this problem reaffirms that, when justifying or rejecting scientific explanations, humans often cite non-logical criteria.

[122] The historian of economics Donald McCloskey goes a step further and, as I find, a step to far. He claims that economic models are nothing more than stories, denying their logical component: „Pure theory in economics is similar to the literary genre of fantasy. […] Good empirical work in economics, on the other hand, is like realistic fiction. Unlike fantasy, it claims to follow all the rules of the world. (Well … all the important ones.) But of course it too is fictional." (McCloskey 1990: 17; cf. McCloskey 1983) In my opinion, this clearly is an exaggeration; McCloskey falls to the fallacy that because models convey stories or are also stories, they are nothing but stories.

[123] I do not concur with Wise's use of the term 'narrative' with respect to deductions.

The most sophisticated account of the relation of models and stories in explanations seems to be provided by Mary Morgan. First, she emphasizes that economic explanations are both[124] arguments and stories, which do interact. Second, she differentiates between a narrative and a story, pointing out that the narrative represents a basic literary form which might be applied to different specific situations in specific stories.[125] Thus, Morgan speaks of scientists telling specific stories by applying certain narratives to specific situation:

> "Modelling involves a style of scientific thinking in which the argument is structured by the model, but in which the application is achieved via a narrative [sic!] prompted by an external fact, an imagined event or question to be answered. Economists use their economic models to explain or to understand the facts of the world by telling stories [sic!] about how those facts might have arisen. The stories are neither 'merely heuristic' nor 'just rhetoric' but an essential part of the way models are labelled and used." (Morgan 2001: 361)

> „…we only fully understand our model when we have identified all the specific stories that it can encompass or tell about the world." (Morgan 2001: 380)

Therefore, to Morgan,

> „The two explanations, scientific [deductive] and narrative, are clearly complementary. The same seems to hold in using economic models. To the extent that we make use of general theoretical claims we have embodied in the structure of the model, then we make use of theoretical (scientific) explanation, but when we use the model to discuss specific cases, we also rely on the complementary explanatory power of narrative. […] It is because of the dual nature of a model's relationship with the world that in using models we can call on the explanatory power of more than one mode of argument: the theoretical and narrative forms."(Morgan 2001: 378-9)

Third, in the literary science, Gillian Beer has made this case for Darwin specifically, arguing that, in the Origin, Darwin provides both a logical argument for and a story of evolution for

> "…how Darwin said things was a crucial part of his struggle to think things, not a layer that can be skimmed off without loss. It shows how his non-technical language … allowed a wide public to read his work and appropriate his terms to a variety of meanings (Nature, race, man, struggle, fit, and family would be examples of story-generating words). My argument demonstrates the degree to which narrative and argument share methods; indeed, it enquires what differences can be maintained between narrative and argument." (Beer 2009: xxv)

[124] Hence, Morgan emphasizes that the explanation is not exhausted by the story nor the model (structure): "…models [are not] just stories. In practical terms, models and stories go hand in hand. I agree with Gibbard and Varian when they say that a model is 'a story with a specified structure', but the story is not wholly given by the structure. The structure constrains and shapes the stories that can be told with a model, but the structure itself, like the metaphor in McCloskey's account, cannot do the work expected of a model on its own. Using a model necessarily involves both." (Morgan 2001: 366)

[125] Thus, the coming-of-age narrative is exemplified by quite different stories in Goethe's *Werther* and Salinger's *Catcher in the rye*.

In sum, there are historians, philosophers and literary scholars who suggest analyzing scientific models as both arguments and stories, who argue that explanation involves both a logical and literary component. Still, does this make sense? Why would scientists – consciously or not[126] – employ narrative structures in explanations?

ii. Stories in communication, knowledge procession and decision-making

I believe that the answer to these questions is a very general one: Humans make sense of their experiences by telling stories and they organize their knowledge in the form of narratives. (Bruner 2002: 7, 28; Bruner 1991: 4)

This claim is supported by several psychological and psycholinguistic observations. In a groundbreaking psychological experiment of the 1940s, Fritz Heider and Marianne Simmel, presented arrangements of geometrical shapes to test subjects and successively altered features of these shapes or their positions to one another. (Heider and Simmel 1944) When asked to describe their observations, most subjects told little stories about what they had just seen, which included causal or teleological explanations of the observed actions; it was explained why (causal) or what for (teleological) certain changes in the setting had occurred. Figure 7 displays one state in which the geometrical shapes were displayed.[127]

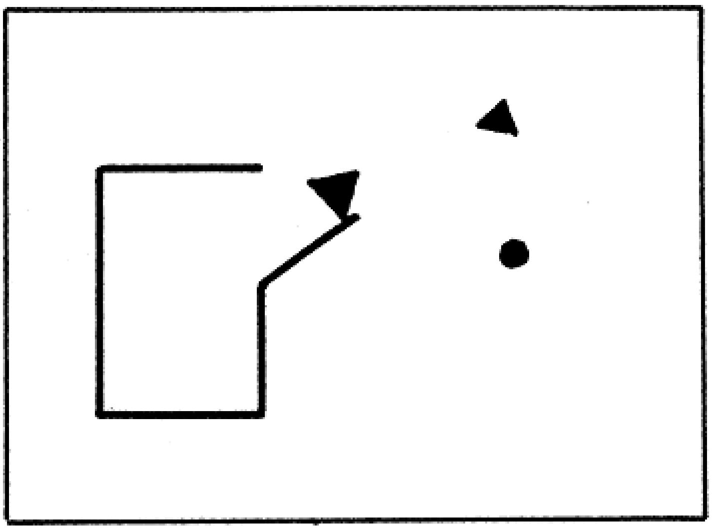

FIG. 1. EXPOSURE-OBJECTS DISPLAYED IN VARIOUS POSITIONS AND CONFIGURATIONS FROM THE MOVING FILM.
Large triangle, small triangle, disc and house.

Figure 7: Geometrical shapes in a configuration shown by Heider and Simmel (1944: 244)

Jerome Bruner, Jacqueline Goodnow and George Austin, in a fascinating experiment on card games, revealed the same tendency in the 1950s. (Bruner, Goodnow, and Austin 1990 [1956]) First, they

126 I do not believe that many scientists do so consciously. Like good speakers they notice that certain metaphors, stylistic devices, forms of presentation "work". Actually, one might wonder how much of such work can be done consciously for as Bruner still resumed, "we know precious little in any formal sense about how to make good stories." (Bruner 1991: 14; cf. Bruner 2002: 3-4) Such, a story may also be "too good to be true", i.e. too rhetorically sophisticated. (Bruner 2002: 5)

127 The shapes were a larger triangle, a smaller triangle, a disc, and a large rectangle, of which one corner could be "opened".

gave to their subjects a set of cards which displayed geometrical figures which could differ in certain properties thus allowing for a fixed numbers of possible combinations and a fixed numbers of possible cards. The experiment leader chose one of those configurations and let the subject show him cards. For each card he declared whether the card exemplified the chosen configuration. The game was over when the subject could correctly describe the chosen configuration. The psychologists observed the number of guesses it took a subject to arrive at the correct conclusion and the tactics they chose to get to the conclusion.

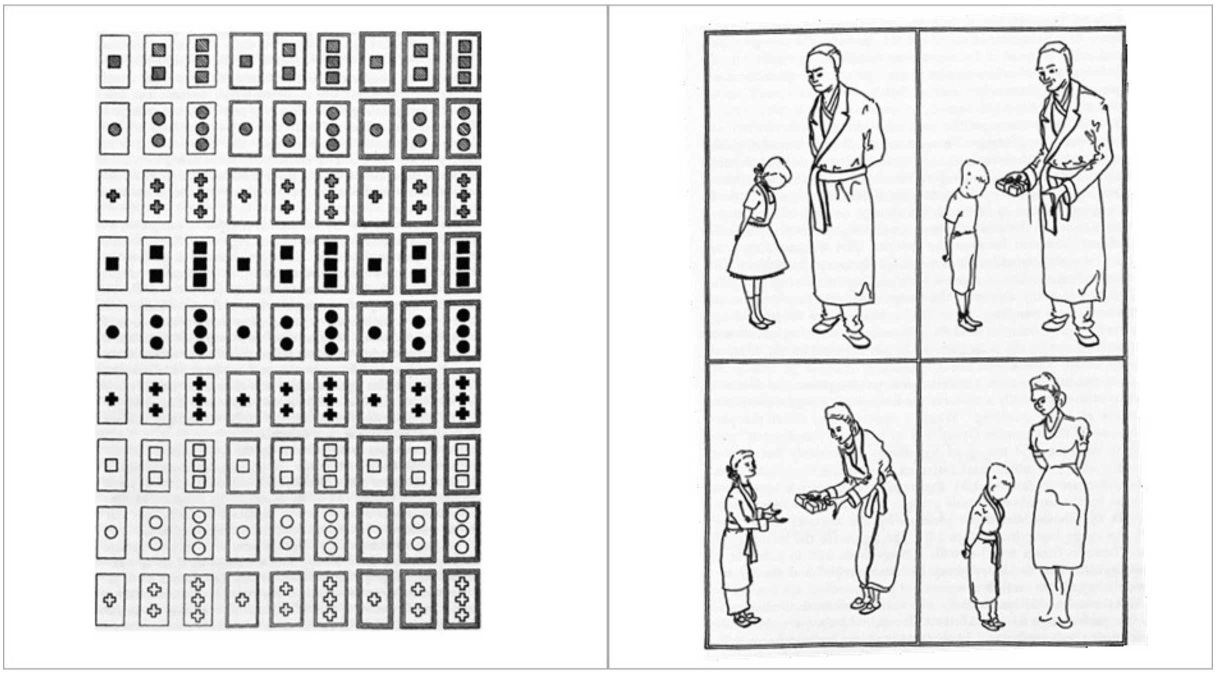

Figure 8: Geometrical and thematic configurations shown by Bruner et.al. (1990[1956]: 42, 107)

Second, the same game was played with set of cards which displayed people with different features (facial expression, clothing, sex), "thematic" cards. (see figure x for the two types of cards) The thematic cards displayed the same number of possible configurations, yet the behavior of the test subjects changed considerably: First, subjects were inclined to interpret the images of the cards as evocative of "little stories or themes". Second, many subjects pursued less-efficient strategies and took considerably longer to determine the correct configuration. Particularly, they were very hesitant to change certain features of the thematic cards, notably of the adult on the right side of the card.[128] (see Figure 8)[129]

Yet, stories do not merely shape how we tell and store our knowledge of the world but what decisions and actions we take; they serve as powerful heuristics in dealing with a complex environment. How much so is reported in a famous paper from 1981 by the economists Amos Tversky and Daniel Kahneman, in which they demonstrate how much decision making depends on the formulation, the "framing", of the decision. (Tversky and Kahneman 1981)[130] Nicolas Taleb's

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128 Least often, the sex of the figures was altered.

129 In more recent works, Kieser, Livingstone, Meldrum report that students find classes more satisfying when the content is presented in the form of stories (Kieser, Livingstone, and Meldrum 2008). (Black & Bower 1980) go a step further and analyze which elements of a story are best remembered by recipients: Agent, then Act.

130 The experiment was not intended to analyze the impact of narrative patterns, Tversky and Kahneman referred to their effect as "framing". Yet, it can easily be interpreted thus; in a neutral description the

devoted a chapter of his best-selling *The Black Swan* to what he calls the "narrative fallacy": the fact that if something sounds plausible, if it is a good story, we tend believe it independently of whether we have the empirical information to assess it. (Taleb 2008) Usually we do not even notice that we are being told stories.[131] As Bruner put it "Only when we suspect we have the wrong story do we begin by asking how a narrative may structure (or distort) our view of how things really are." (Bruner 2002: 9)[132]

In sum, stories are far more than children's entertainment or mere ornaments of language. Humans employ them to communicate their experiences, to process and store experiences and they employ them as heuristics in their decision-making.

iii. How to identify narratives? – Kenneth Burke's literary (narrative) pentad

In order to analyze narratives, I employ a classic framework from the literary studies, Kenneth Burke's literary (narrative) pentad. In his classic Grammar of Motives, introduces narratives in terms of human motives.

> "We shall use five terms as generating principle of our investigation. They are: Act, Scene, Agent, Agency, Purpose. In a rounded statement about motives, you must have some word that names the *act* (names what took place, in thought or deed), and another that names the scene (the background of the act, the situation in which it occurred); also, you must indicate what person or kind of person (*agent*) performed the act, what means or instruments he used (*agency*), and the *purpose*. Men may violently disagree about the purposes behind a given act, or about the character of the person who did it, or how he did it, or in what kind of situation he acted; or they may even insist upon totally different words to name the act itself. But be that as it may, any complete statement about motives will offer *some kind of* answers to these five questions: what was done (act), when or where it was done (scene), who did it (agent), how he did it (agency), and why (purpose)." (Burke 1969 [1945]: xv)

The five expressions – Act, Scene, Agent, Agency, Purpose – denote five elements of any story, or – better – five questions to which any story should answer:

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observed phenomena much resemble those observed by Bruner, Goodnow, and Austin. Moreover, the boundary conditions of the experiment and the observed choices can easily be interpreted in terms of Burke's literary (narrative) pentad. (see below)

131 Salmon speaks of narratives as "bewitching the modern mind", which puts it very well. We may believe that our post-enlightened, post-modern society does not fall for cheap tricks of the mind; yet, we consider one fictional story to be "truer" than another, one piece of art to depict reality better than another, one scientific theory to represent the actual ("causal") reality while another one is but an approximation. (Salmon 2010)

132 In consequence, it is hard to escape the trap of narratives. Today, marketing departments, motivational coaches and even football managers have discovered the power of stories. If you believed what your financial advisor told you about investment opportunities in the US house market before 2008, you are also inclined to believe a story about why this was wrong, tales about a corrupt banking system, greedy financial advisors or a housing bubble. If macroeconomics was unable to predict such a bubble, why should we trust their story in how this bubble evolved now? (Granted, among the ten-thousands of professional economists, a few who predicted the crisis, but such accidental outliers are to be expected; the discipline as a whole got it wrong.) In the end, however, you better also mistrust stories about the dangers of story-telling.

> "Act, Scene, Agent, Agency, Purpose. Although, over the centuries, men have shown great enterprise and inventiveness in pondering matters of human motivation, one can simplify the subject by this pentad of key terms, which are understandable almost at a glance. They need never be abandoned, since all statements that assign motives can be shown to arise out of them and to terminate in them. By examining them quizzically, we can range far; yet the terms are always there for us to reclaim, in their everyday simplicity, their almost miraculous easiness, thus enabling us constantly to begin afresh." (Burke 1969 [1945]: xv-xvi)[133]

In telling stories, the elements of the pentad can be arranged in many different constellations; Burke discusses such constellations at length. (Burke 1969 [1945]). Thus, stories do not follow a specific outer form[134], one story may be told from the Scene another from the Agent. Consequently, the pentad's elements are not supposed to be mutually exclusive, cleanly separated concepts as one would expect them in models. Rather, one aspect of a story may specify several elements of the pentad and each element may overlap with others in some respect. To Burke, however, this is an explicit strength of his framework:

> "…instead of considering it our task to "dispose of" any ambiguity by merely disclosing the fact that it is an ambiguity, we rather consider it our task to study and clarify the *resources* of ambiguity. … it is in the areas of ambiguity that transformations take place; in fact, without such areas, transformation would be impossible. Distinctions, we might say, arise out of a great central molteness, where all is merged. […]
> And so with our five terms: certain formal interrelationships prevail among these terms, by reason of their role as attributes of a common ground for substance. Their participation in a common ground makes for transformability. At every point where the field covered by any one of these terms overlaps upon the field covered by any other, there is an alchemic opportunity, whereby we can put one philosophy or doctrine of motivation into the alembic, make the appropriate passes, and take out another. Form the central molteness, where all elements are fused into one togetherness, there are thrown forth, in separate crusts, such distinctions as those between freedom and necessity, activity and passiveness, cooperation and competition, cause and effect, mechanism and teleology." (Burke 1969 [1945]: xix)

Moreover, Bruner, developing on Burke, highlights that the molteness of the central concepts is crucial in creating the tension required for good story telling:

> "What drives a story is a misfit between the elements of the Pentad: Trouble. It can be a misfit between Agent and Action, Goal and Setting [Scene], any of the five elements of the Pentad. How could Agamemnon and Clytemnestra share a bed after he had sacrificed their daughter Iphigenia, the beloved fruit of her womb?" (Bruner 2002: 34)

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[133] On a side note, the schemata employed in narrative research seem linked to both mental models and associative networks. It seems as all three concepts analyze a common complex problem from different perspectives.

[134] Such ideas were pursued by a research program called ‚story grammar'. (cf. Andersen and Slator 1990)

Before illustrating the pentad on two examples, let me specify three points in which I extend Burke's framework. This is necessary because, in my application to scientific theories, I will consider stories which do not center on human actions and human motives. First, I will interpret the Act, very generally, as an event, namely the event which the story aims to explain. It need not be the result of human action. Second, the Agent need not be a human, just some entity which is considered to be able of acting. Third, the Purpose may also be a Cause, thus we may not only ask teleological questions (what for?) but also causal ones (why?).[135]

Now let me exemplify how the elements of the pentad relate to the questions about stories and how stories may answer these questions. Table 1 demonstrates the workings of the pentad on two stories, a stereotypical hero tale and the biblical Genesis.

Five elements of narratives	**Question**	**Example 1: The male hero**	**Example 2: Genesis**
Scene	When or where was it done?[136]	In a dark dungeon…	First God made heaven and earth. The earth was without form and void, and darkness was upon the face of the deep; and the Spirit of God was moving over the face of the waters.
Agent	Who/what did it?	…the hero…	God
Agency	How was it done?	…with a concealed knife…	God said, "Let there be light".
Act	What was done?	…breaks his chains…	…and there was light.
Purpose / Cause	What was it done for? Why was it done?	… to escape and save his beloved one.	And God saw that the light was good…

Table 1: Illustration of Burke's pentad on a generic story and on the biblical Genesis

The comparison of these two small stories reveals an interesting aspect which also mattered in the Darwinian revolution: telling stories about God requires much less effort for plausibility and graphic imagery than stories about non-divine agents. In the Genesis, neither God's Purpose nor the means by which he act (his Agency) become very clear and the Scene is rather abstract and hard to grasp. Still, this story is among the most famous ever told and quite a number of people find it more convincing than anything scientists have ever told about the origin of our planet and the life on it. This effect seems attached to the powerful metaphor 'god'; apparently, almighty beings make up for some shortcomings in story-telling.

In sum, Burke's pentad allows for suggesting a general definition of a narrative and thus to provide clear criteria for what I will mean when I speak of narratives and stories[137] in my analysis:

[135] I am aware that the possible answers to both questions overlap, particularly when purposes are presented ex post as the reasons for an act. Non-overlapping concepts are hard to find in natural sciences.

[136] Generally speaking, one may understood the Scene as specifying what one needs to know to process the story, connect the dots given by Act, Agent, Agency and Purpose.

> *Definition*: A narrative is a presentation of a sequence of events (or sequence of state changes), in which these events are put in a spatial and timely context (Scene) in such a way that the later event (Act) can be understood as a consequence of the former (Agency). This consequence might either be presented as a teleological or a causal link, i.e. it might stem from the purposeful acting (Purpose) of an entity (Agent) or the existence of an entity might be presented as the consequence's cause (Cause). [138]

This definition clarifies how observable event sequences, as observed by scientists or interpreted into their evidence, may relate to narratives[139]: They must be set in a Scene and they must be linked to the existence or the Purpose of an Agent. As I said above, this Agent need not be a human or even tangible entity; it might be wholly abstract or imaginative, as long as it has the power to achieve the Act. Let me specify by linking narratives to dynamic models as described above.

iv. Mapping the elements of dynamic models onto narratives

First, however, allow me to repeat a point I made about my model (research design) in general. I do not expect all models to convey complete and explicit narratives – although some do. Rather, in most models, the connotations of the terms used in dynamic modeling convey meaning which satisfies only some of the five elements of Burke's pentad. In other cases, some narrative elements might be implied or suggested[140] by the context.[141] In sum, my claim is not that every model conveys a story. Instead, I suggest analyzing those parts of an explanation which exceed logical arguments as metaphors and elements of a story.

From what point could such story-telling start? Given a specified dynamic model, at least three elements of the Narrative can be covered. The predicate(s) of the Situation Type describe the Scene. The Output will specify the Act. Third, both the Input or an eventual Connector may connote some kind of Agency, each own its own or in combination. These three elements being covered, the decisive question in my comparative analysis will be whether the respective theories do specify an Agent and a Purpose to explain their models. These two elements are crucial; without them, there is no narrative.

It would appear that the Object Class of the model might connote the Agent and, indeed, in the social sciences, humans provide for the Object Class in the model and the Agents in the narrative. Yet, this type of story-telling is rare in the natural sciences and it was rare during 19th century

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[137] I know of no exact distinction of stories and narratives, therefore, I will use the terms somewhat synonymously. Roughly speaking, a narrative can be considered a story-container or story generator.

[138] For a similar definition with a different connotation, see (Wolf 2002: 51). For a discussion of events and eventfulness see (Hühn 2009).

[139] Because this question occurred in some discussions of earlier versions of my framework: event sequences on the level 'description' do not constitute stories or narratives because they lack the specification of an Agent or Purpose as required by my definition of a narrative. Event sequences claim that a sequence of events occurred but do not put them in a meaningful context as do narratives.

[140] This relates to Levinson's implicatures, namely the third one. (see footnote 80) A model might be presented in the context of a discipline which typically employs a certain type of narratives. When the modeler does not specify his deviation from these typical narratives, readers may assume that he accepts them and project them onto the model.

[141] Such an array of possibilities is not surprising, considering that few scientists consciously set out to tell a story; as with respect to finding the good concept names explanation is a question of experience, of trial and error. And as it happens, experience seems to lead towards story-telling.

biology.[142] In all other cases, where an Agent is specified, it has to be a new, external entity, i.e. one which is not already specified in the model. Combinations of several complementary Agents are also possible.

In theories without a dynamic model, the case is more complicated. Changes within a static model may account for an Act. All other elements, however, require substantial specification. My analysis will show that all theories without dynamic models drew on the biblical narrative and God for this specification. In order to identify narratives in both, theories with dynamic models and theories without, I will ask the following questions:

- **If there is a dynamic model, does it specify an Output which can be understood as the Act of a narrative? If there is a static model, can changes within its framework be understood as an Act?**
- **Does the text specify an Agent (or several ones) involved in producing the Act?**
- **Is a Purpose of this Agent specified or a Reason for which he acts?**
- **Is an Agency specified by which the Agent achieves the Act? Does it correspond to the Input or Connector of the dynamic model?**
- **Is a Scene specified in which the Act takes place? If not, can it be reconstructed from the other four elements of the narrative?**

Let me illustrate this on my two idealized examples again. A Rational Choice explanation follows a classic anthropocentric narrative; its Agent is the observed object: a human. He undertakes an action (Act) within a possibility space (Scene) by making a rational decision (Agency) in order to maximize his profit (Purpose/Cause). In retrospect, one may also explain his action causally by stating that the Agent undertook an action because he had a preference (Cause) for its outcome.

In this case, the five narrative elements can be satisfied by the elements of the dynamic model. The Scene is filled by the concept name for the Situation Type, the Agent by the name for the Object Class, the Act by the Output, the Agency by the Connector and the Cause / Purpose by the Input.[143] Table 2 summarizes these relations.[144]

In Millikan's explanation of falling and rising oil droplets, the case is more complicated. The rise and fall, the Output of the model, is the Act of the narrative, too. The Scene is specified by the Situation Types in which the experiment takes place, namely a gravitational in the first run and a gravitational plus an electromagnetic field in the second run. For the other three elements, however, things are different. First, the observed objects are not considered to be Agents, it is not their acting which produces their rise. Rather, when we ask what made them rise, Millikan would answer that it was the electromagnetic force which superimposed the gravitational force and made the droplets rise. (Agents) Second, there is no Purpose by which Millikan would explain the droplets' rising; he does not ascribe a Purpose to either force. Rather, the presence of the force and its acting on the ions is

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[142] The only model which might be understood to convey such a narrative is Lamarck's. (see section 2.3 vii)

[143] Additionally, one might mention the Connector, as part of the Cause / Purpose, if one says that the Agent acted because he made a rational decision. It seems to me, however, that my version is more frequent.

[144] This assignment is not the only possible one; it could be specified more or shifted semantically. For instance, the Scene and Situation Type might be specified by the type of game that is played or characterized as a "perfect market". The human could be described in his preferences, thus creating an overlap Object Class and Purpose/Cause. The Purpose might be described as a cause in that the human undertakes the Action because his preferences suggested the Action as the most useful option and because he makes rational decisions.

presented as Cause; it explains why (Cause) and how (Agency) the droplets rose (Act): "the speed of the drop is proportional to the force acting upon it". (Millikan 1911: 354) The Scene is specified by the two fields, the electromagnetic one and the gravitational one.

In this case, there is no one-on-one mapping of the elements of the model. While the Scene is satisfied by Situation Type (the fields) and the Act by the Output (the motions), the observed objects are not Agents but subject to forces. Consequently, the Input of the bodies, their initial fall between the condenser plates, cannot satisfy the Agency or the Purpose / Cause of the narrative. Rather the latter is explained by the sheer presence of the forces, the former by their acting upon the observed objects. Table 3 specifies the narrative elements in his explanation and how they relate to the elements of the model.

Elements of narratives	Rational Choice explanation	Assigned elements of model
Scene Where, when?	Possibility Space	Situation Type
Agent Who? What?	A human	Object Class
Agency How?	Rational decision	Connector
Act What?	Action	Output
Purpose / Cause What for? / Why?	Maximization of Profit / Preference	- / Input

Table 2: Narrative elements in a Rational Choice explanation

Elements of narratives	Millikan's explanation	Assigned elements of model
Scene Where, when?	Gravitational field, Electro-magnetic field	Situation Type
Agent Who? What?	Gravitation, Electromagnetism (Forces)	-
Agency How?	Acting of the force	Connector
Act What?	Motion (descent, ascent)	Output
Purpose / Cause What for? / Why?	- / Presence of Forces	- / -

Table 3: Narrative elements in Millikan's explanation of falling and rising oil droplets

2.1.5 Level 4: Ontological Implications (Implications for the world-views)

Explanatory narratives constitute the link to what I consider the highest level of a scientific theory. This level contains a complement to the theory's narrative which, just as the narrative, conveys connotative meaning. It covers what a theory's narrative implies about the world or, in other words, what the world would look like if the narrative were true.

I refer to this fourth level as containing 'philosophical implications' because it expresses an ontology, i.e. postulations of entities and relations between these entities. This ontology describes a reality behind the observed reality and does thus make sense of thus make sense of the scientific knowledge by embedding them in a world-view. Three basic questions allow for identifying possible ontological implications:

- What Agents would exist in the world?
- What rules would govern the world in which these Agents act?
- What would be Man's position and his relation to the Agents?

As these questions suggest, ontological implications are strongly culture-bound. For instance, in 19th century British biology, there existed one undisputed Agent in the world, to which all narratives had to relate: God.[145] As my analysis will demonstrate, to Darwin and his contemporaries, the question was not whether to present God as the principal Agent in Nature, but whether they could introduce other Agents besides God. Moreover, with respect to the governing rules, many of Darwin's contemporaries drew parallels between the rules which governed Nature and those which governed society. Therefore, these were considered to have social and political implications about the inner workings of society. From these two considerations, the generic ontological questions above can be specified and, in my analysis of the theories Darwinian revolution, I will ask them in the following form:

- **What would be God's role in the world? What Agents exist besides God?**
- **What would the world and society be like if the model's narrative applied to it?**
- **What would be Man's position and his relation to the Agents, particularly God?**

In other disciplines and cultural contexts, this specification could be much different. For instance, in 20th and 21st century science, God is no compulsory Agent any more. In the social sciences, the dominant (and mostly only) Agent is Man; as far as I see it, his relation to God is no topic. Instead, the ontological questions in the social sciences focus on the rules which allegedly govern human behavior. Thus, the hottest public social science topic of the last decade was the *homo oeconomicus*, the image of a human who maximizes profit independent of values or morals as it appears implied by Rational Choice explanations. This question is discussed in great length in journals and magazines and often is the focal point of the critique of macroeconomics.[146] Thus, the public debate does not focus

[145] This does not imply, however, that the concept of God would be much developed in biological writings. Biological texts which mention God contain neither teleological discussions nor criteria for the use of terms like 'divine' 'Creator' etc. 'God' serves as a metaphor instead.

[146] There are some strands of Rational Choice modeling which actually include values and morals as part of the preferences. Yet, apparently, these differences in modeling do not reach the public as long as actions are still explained as the result of "rational" decisions.

on modeling but on narration and its implications – as formulated by the axioms[147] of Rational Choice Theory.[148]

In modern physics, God is no part of the explanations anymore. Yet, some physicists do refer to God when interpreting their models, for instance in interpretations of the Big Bang or in the hunt of the so-called “God-particle”, the Higgs bosom. The narrative of Millikan’s explanation remained within the established ontology of natural forces which act upon inanimate matter.[149] While the axioms which claim the existence of such forces and their mutual relations do indeed postulate indeed an ontology – a non-religious one – they implies no novel implications.[150]

However, Einstein when popularizing General Relativity made use of little stories (Gedankenexperimente) which exemplified what his theory meant for the man on the streets. Thus, his story about the twin brothers, one of which travels at the speed of light and remains young and one of which lives on earth and ages, brought the relativity principle within the realm of everyday culture. The same is true about the two people watching their watches while one leaves a station on a train while the other remains on the platform.

Some words of reserve. First, as ontological implications are implied by narratives, not all models evoke such implications; some may not display enough narrative elements to evoke such implications. Notably, a model might not postulate a Purpose/Reason or not specify an Agent. Second, a narrative may be only loosely connected to the relevant world-views or, as in Millikan’s case, largely comply with it. In these cases, ontological implications are difficult to identify or, simply, uncontroversial and therefore, historically less interesting. (In my analysis, I will indeed focus on points where narratives convey controversial implications.) Third, ontological implications might be exemplified by a theory’s author, as is the case for Darwin, Owen and Chambers, but they need not. For some models, the ontological implications might come into being only in the reception of a model. In such cases, they even might have been not intended by the author but arise when his model is translated[151] into the language of public discourse.[152] Therefore, may be difficult to draw a line between implications as addressed by the author and implications as interpreted by a theory’s recipients.[153]

This should not, however, prevent us from identifying such implications with a theory. The public interest in scientific theories is triggered primarily by these implications, be they intended by or not.

147 These axioms postulate humans as decision makers. The describe how a person makes decisions and how options in such decisions may relate to the person’s preferences

148 I discuss the dangers of these asymmetries in sections 5.2 and 5.3.

149 It also acts upon animate beings but not in the aspects which constitute their being animate.

150 To give a historic example, the Newtonian axioms in mechanics postulated bodies and forces acting on these bodies as functions of a property of the bodies, namely their masses. Then they described these masses and forces as triggering motions. Moreover, they specified the model by which to describe (ex post) or predict (ex ante) the resulting motions.

151 I do sketch some dangers of this translation in section 1.3.

152 Such, it were Galileo Galilei and Giordano Bruno who exemplified those possible ontological implications of Copernicus’ astronomical model which led to what we call the Copernican revolution. – One might wonder to what point ontological interpretations are legitimate and at what point they become misinterpretations. Such a classification however, is of limited value: It provides an interpretation of social-historical events but no explanation.

153 In my examples, the line is quite clear. Thus, I will address the implications as addressed by the authors in the comparative analysis (chapter 3) and those implications which arise in reception in my reception analysis (chapter 4).

When theologians rebuke scientists for contradicting religious truths, when journalists criticize scientific theories for their view of Man, when scientists of different disciplines fight for supremacy[154], we are in the sphere of ontological implications.

Thus, ontological implications explain how scientific theorizing impacts culture beyond the narrow domain of observed empirical phenomena or reproducible effects; they are a cultural product, the result of scientific narratives relating to extra-scientific conceptions of the world. I would even go so far that we consider an explanation to express a theory if its narrative evokes such ontological implications. Explanations which remain in the realm of logical arguments are usually not referred to as ‘theories’. Thus, it seems to me, that level four of my model, ontological implications, answers to the question what a theory is beyond a model or an explanation?

2.1.6 Summary, overview

In sum, my model is a static model of scientific theories. It distinguishes different possible components of scientific theories, namely 4 levels, sublevels on two of these levels and different concepts which may or may not be satisfied on these levels. Figure 9 provides an overview of the different levels and the analytic concepts I have introduced on each level.

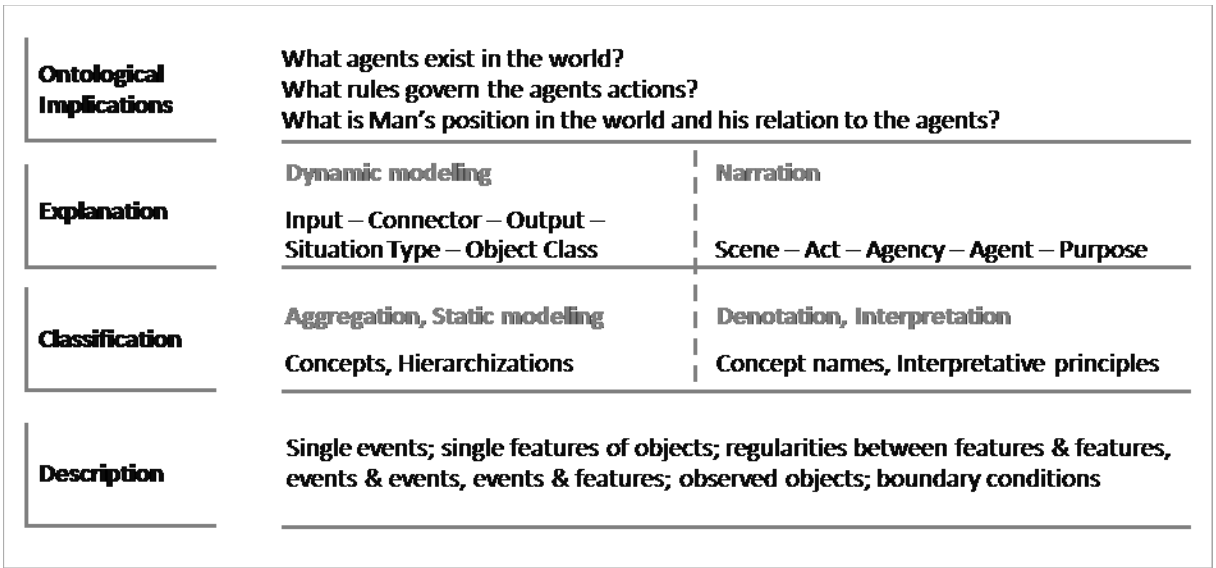

Figure 9: Analytic concepts in my four-level model of scientific theories

As my explanation of the model has shown and as my comparative analysis will show, the four levels overlap in certain areas. This is rather obvious with respect to Description, Aggregations and Dynamic models, i.e. the denotative part of the model. Events and object features are aggregated and classified on level 2 and modeled as Inputs and Outputs on level 3. Equally, the Object Class and the Situation Type of level 3 denote sets of boundary conditions and observed objects of level 1. In connotative terms, there exists overlap (or close relation) between the concept names used for interpretation on level 2 and the Act and Agency on level 3. Equally, the Agent, its Agency and Purpose strongly determine the possible ontological implications on level 4.

[154] For an example of such a struggle, see the earth-of-the-age debate in (section v).

In my analysis, I will apply my static model within a dynamic one, namely the model of Historical Epistemology. (see section 5.1) Thus, I aim to transcend interpretation, employing my model as a tool for historical explanations. In this enterprise, I employ the distinction between connotative and denotative meaning as well as between models on one side and narratives and their ontological implications as marking the limit between knowledge and beliefs in a scientific theory. I consider the shared body of described observation and correlated observations to represent the shared scientific knowledge of a domain. As mere logical entities, static and dynamic models do organize this shared knowledge. Conversely, the interpretation of aggregated observations and the narrative explanation of observed regularities represent beliefs[155] about the shared knowledge which then connect to general beliefs about the world (world-views) via ontological implications of narratives. These beliefs may be said to make sense of the knowledge.

[155] These beliefs may or may not be shared.

2.2 Research Design for the reception analysis: concentric circles of recipients

In the reception analysis, I am pursuing three guiding questions. First, I wish to investigate the depth and extent to which the Darwinian theory was received by the three recipient groups (audiences). Second, I wish to understand by what criteria the different audiences assessed the theory. Third, I will assess which elements of the theory were ultimately accepted and which were dismissed by its recipients.

2.2.1. Empirical basis

My reception analysis covers the contemporary British reception, i.e. publications which appeared in Britain after 1859 and before ca. 1875, i.e. within sixteen years following the publication of Darwin's *Origin of Species*. These publications were classified by three groups of recipients to which they were addressed and which had access to them: (i) the *public: laymen*, (ii) the *broader scientific community*: professional and amateur scientists from outside biology, (iii) the *immediate scientific community*: biologists.

Publications were considered as "public" when they addressed a general readership[156] without scientific training or particular interest in science and when it covered mostly non-scientific topics, for instance literature or politics. As such I count newspapers like *Times* or *Guardian*, general or literary magazines like *The Spectator, MacMillan's Magazine* or Charles Dicken's *All the Year Round*, *Chambers' Magazine*[157] but also the *Cornhill Magazine* or the *Examiner*. In these magazines, Darwin's theory was usually presented by laymen – although there exist notable exceptions like anatomist and Darwin-friend Thomas Henry Huxley's review for the *Times* and the review in the *Spectator* which came from the Cambridge geologist Adam Sedgwick. An important and very successful monograph addressing the public was *The Reign of Law* which was authored by the Duke of Argyll, a politician.

I have classified a publication as addressing the broader scientific community if its debates addressed a scientific audience outside biology, be they general publications with a focus on science, general science publications or publications from other disciplines. High-quality reviews like *Westminster Review*, *Edinburgh Review*, *Quarterly Review*, the *North British Review* had a strong science section and published long articles on science, usually written by scientists. Examples of general scientific journals are the *Natural History Review*, *Recreative Science*, *Nature*[158], *The Zoologist* or the printed reports of the *British Association for the Advancement of Science*[159]. Journals from other disciplines

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156 Note that this does not apply to the authors in these publications. For instance, Thomas Henry Huxley, a member of the immediate scientific community, wrote reviews for both the *Times* and M*acMillan's Magazine*.

157 Chamber's journal was edited by Robert Chambers, the (anonymous) author of *Vestiges*.

158 As it is today, 19th century *Nature* was a popular science magazine. While most of its authors were renowned scientists, its texts were very short and left out much of what is considered scientific about a scientific text, i.e. description of methods and exact observation results, justification of classifications etc.

159 The British Association for the Advancement of Science which "… was not a purely scientific forum. As its audience consisted not only of scientists, but also of scientifically interested laymen, and as, moreover, it was recognized that the meetings also served a propagandistic function; papers had to be selected not only on the strength of their scientific quality, but also for their appeal to the general public. Above all, the discussions arising out of the papers often had another character than the one to be expected in purely scientific contexts. This was probably especially true of the Darwinian discussions…" (Ellegård 1958: 92)

were, for instance, the *British and Foreign Medical-Chirurgical Review* or *The Geologist*. Authors in these publications were mostly scientists. The group comprised biologists like John Dalton Hooker, Thomas Henry Huxley or Alfred Russel Wallace, geologists like John Philipps, Frederick Wollaston Hutton or Charles Lyell – Darwin's old mentor – and physicists like G.G. Stokes, Peter Guthrie Tait and William Thomson (the later Lord Kelvin). Important monographs on the topic were provided by the biologists Thomas Henry Huxley and St. George Mivart. Moreover, the three great Victorian philosophers of science weighed in on Darwin: William Whewell, John Herschel and John Stuart Mills.

As biological publications, i.e. publications of the immediate scientific community, I have identified six journals: the three journals of the Linnean Society, the transactions of the Zoological Society and of the Royal Entomological Society as well as the ornithological journal *Ibis*. These journals were clearly biological publications and addressed biologists.[160]

In compliance with my reading of Fleck, I consider the recipient groups to approximately form overlapping concentric circles where member of the inner circles tend to be members of the outer circles, too, and may communicate with these different groups. For instance, A.R. Wallace, a member of Darwin's immediate scientific community read a biological journal like *Transactions of the Linnean Society*, but also had access to the debates of the broader scientific community in the *Quarterly Journal of Science* and, finally, the debates of the public in the *Westminster Review* or the *Times*.

2.2.2 Reception depth

The investigation of reception depths is guided by the categories which I have developed in the previous section and by which I did denote the four levels of my model of scientific theories: description, classification, explanation, ontological implications. (see section 2.1) My question is, thus, on which of these four levels of abstraction the different recipient groups received information on the Darwinian theory. The criteria for determining whether a text covered these abstraction levels where the following:

- *Ontological implications*: Did the text raise philosophical, religious, or political issues? Where Man's position towards God and other beings being addressed?
- *Explanation*: Was the Darwinian narrative presented as a whole or in its main metaphors, notably the Struggle for Existence and Natural Selection? Was the explanation discussed as a dynamic model, notably were logical relations between concepts and sub-concepts addressed?
- *Classification*: Was Darwin's static model discussed in its logical and/or interpretative part? Were classifications of specific specimen (fossils, living organisms) being discussed?
- *Description*: Did the text provide detailed and/or extensive descriptions of observations? Compared to empirical papers in biological journals, were these descriptions much idealized, simplified or biased?

In the early 1860s, the British Association attracted attendances of more than two thousand spectators. (Hodge 1988: 8) Particular interest was raised by the debates with obvious implications for the Victorian conception of Man. (Hodge 1988: 9-10)

160 Popular journals with a scientific focus were not considered here, notably *Nature: a weekly illustrated journal of science* and *The Zoologist*. During the period here considered, these journals had a popular character and published only very short articles, either scientific results in simplified form or brief notes on single observations, regularly by laymen, and very few discussions or systematic works.

2.2.3 Criticism and criteria for the assessment of the theory

Once the reception depths of the three recipient groups are established, I will study the criteria by which these groups have assessed the Darwinian theory, i.e. the criteria which guided their accepting or rejecting elements of the theory. These criteria will be deduced from the lines of criticism against the Darwinian theory as they are visible in reviews and other publications on the topic: I will ask by what standards the theory was assessed and I will classify these standards.

There exists excellent works on the reception among the public and the broader scientific community, on which my analysis of reception depths and the criteria for theory assessment in these groups can be founded. First, Alvar Ellegård's seminal *Darwin and the General Reader* provides an excellent analysis of the reception of Darwin in the British Press from 1859 to 1872. (Ellegård 1958) His work continues to stand as the most complete and most systematic study on the topic and it is specific enough to distinguish between my abstraction levels. Second, for the broader scientific community, a number[161] of compilations and studies exist. (Himmelfarb 1959; de Beer 1963; Vorzimmer 1972; Hull 1973; Ruse 1979; Bowler 1990; Desmond and Moore 1995; Mayr 1991; Mayr 1984; Ellegård 1958; cf. Kohn 1985b).[162] I will complement these existing secondary sources by a qualitative analysis of by the 36 British reviews on the Origin.[163]

2.2.4 Acceptance of elements of the theory

For the public and the broader scientific community, the criteria for the theory assessment, acceptance will again be deduced from the reviews of the *Origin* as well as from secondary sources. I will identify which elements were not criticized or implicitly accepted as well as explicit statements which support elements of the theory. My judgment here will rely, again, on primary and secondary sources, both by historians and contemporaries.

For the biologists themselves, I was able to recur to a more specific resource: digitalized versions of the six important biological journals of the time. In order to assess the acceptance of Darwin's theory within his immediate scientific community, I have checked these journals for references or the use of Darwinian concepts. For comparison, I have decided to include the *Philosophical Transactions of the Royal Society of London* and the *Proceedings of the Royal Society of Edinburgh*, both of which published high-quality articles on biology and clearly addressed a scientific audience but were not, strictly speaking, biological journals.

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161 Indeed, most philosophical and historical works on Darwin and his reception concentrate on what I call the broader scientific community.

162 The reception among the immediate community is sparsely covered, with the notable exception of Frederik Burkhardt's short analysis of the Proceedings of the British Learned Societies. (Burkhardt 1988)

163 While reviews are not representative for the reception as a whole they certainly provided the deepest source of information on the Origin short of reading the book. – All reviews can be accessed via the *Darwin Online Project*: http://darwin-online.org.uk/reviews.html. I considered all articles there which appeared in a British publication and review the Origin. The restriction to British reviews and reviews of earlier publications (like Darwin's *Beagle* journals) excludes 48 of the 96 reviews listed. 12 articles review later publications, namely *Variation of animals and plants under domestication* (Darwin 1868), *Descent of Man* (Darwin 1871) and *The expression of the emotions in man and animals* (Darwin 1872b).

Overall, 85 volumes of eight journals were analyzed, encompassing 1.916 articles on 34.209 pages. These volumes appeared between 1859, the year in which the Origin was published, and ca. 1875; they do cover a period of sixteen years and encompass the heated debates of the 1860s and the point at which evolution theory had become the majority opinion among biologist, ca. 1868. In sum, these volumes should cover the large majority if not all of biological articles published within the immediate scientific community in Britain in the period of interest. (see Table 4)

Journal	First volume	Last volume	# of volumes	# of articles	# of pages
Transactions of the Zoological Society of London	Vol. IV (1862)	Vol. VIII (1874)	5	84	2.469
Transactions of the Linnean Society	Vol. XXI (1855)	Vol. XXIX (1875)	9	173	4.218
The Journal of the Proceedings of the Linnean Society – Botany	Vol. I (1857)	Vol. XIII (1873)	13	219	3.625
The Journal of the Proceedings of the Linnean Society – Zoology	Vol. I (1857)	Vol. XII (1876)	12	191	3.450
Transactions of the Royal Entomological Society	Vol. III (New Series) 1856	Transactions 1875	16	316	7.839
The Ibis – A quarterly journal of ornithology	Vol. 15 (1857)	Vol. 10 2nd series (1875)	17	703	7.842
Philosophical Transactions of the Royal Society of London	Vol. 146 (1857)	Vol. 164 (1875)	17	100	4.288
Proceedings of the Royal Society of Edinburgh	Vol. III (1857)	Vol. VIII (1875)	6	130	478

Table 4: Journals of the immediate scientific community for quantitative analysis

Not all journals appeared in all years or always in the correct timely order and the Transactions of the Royal Entomological Society appeared twice in both 1868 and 1869. Thus, the number of volumes per year is not constant. Articles were not analyzed individually but as elements of the volume in which they appeared.[164] Consequently, articles were counted in the year in which they appeared in print, not in the year in which they were read (which may have been one or two years earlier). Finally, not all journals published a volume in 1875 such that the analyzed period ends between 1873 and 1876, depending on the journal.[165] Were possible[166], one or two volumes before 1859 were included in the analysis in order to provide a pre-Darwinian baseline.

All volumes were tested for the use of three concepts: (i) evolution, (ii) natural selection and, for comparison, (iii) Richard Owen's archetype concept including his classificatory concept of

[164] This was due to my original research design which aimed at assessing how many articles employed the Darwinian concepts, not when exactly they were published or who authored them. A further study could provide more precise information here.

[165] I chose the volume which seemed to most adequately cover the aimed period. The botany section of the Linnean Society published no volume between 1873 and 1878.

[166] The *Transactions of the Zoological Society of London* did publish no volumes between 1849 and 1862.

homologies. The focus is on the two Darwinian concepts, one representing his static model and its interpretation, the other his dynamic model and its narration. The two were tested separately because the historians agree that the support for evolution and natural selection differed considerably.[167] Owen's concepts archetype and homology were chosen for comparison; they stemmed from the same period and country and Owen employed both in his discussion of evolution.

Concept	String	Possible keywords
Evolution	Evol*	Evolve, evolved, evolution
	Transmut*	Transmutes, transmuted, transmutation
	Inherit*	Inherit, inherited, inheritance
	Origin*	Origin, originates, original, originated
	Fit*	Fitter, survival of the fittest
	Ancest*	Ancestor(s), ancestry
	Progen*	Progenitor(s), progeny
	Descen*	Descendants, descend, descends, descended
Natural Selection	Select*	Selected, selection, select(s)
	Preserv*	Preserve(s), preservation, preserved[168]
	Struggle	Struggle for life, struggle for existence
Archetype	Archetyp*	Archetype, archetypal
	Homolog*	Homologue, homologous, homology
Darwin	Darwin*	Darwinian(s), Darwin's theory, Darwin's explanation

Table 5: Keystrings and possible keywords for the concepts evolution, natural selection, archetype

The use of the concepts was tested through full-text searches for groups of keywords associated with the concepts, or, more exactly, for letter strings within these keywords. Uses of the term 'Darwin' were also tracked. For the concept evolution the list is longest because many synonyms were in use at the time[169]. Table 5 specifies the concept and letter strings for each of the concepts.

As could be expected, the simple keyword search produced many token hits for the two Darwinian concepts, i.e. uses of the keywords which were unrelated to the concepts in question. (This occurred particularly often for the strings 'select', 'descen' and 'orgin'.) Therefore, hits had to be filtered

167 There seems to be a consensus that only a minority of biologists supported both of Darwin's concepts, notably Joseph Dalton Hooker, Alfred Russel Wallace and Henry Walter Bates, all of whom had similar research interests as Darwin. Thomas Henry Huxley, one of Darwin's confidants, did never fully support natural selection. (Ellegård 1958: 47-8; Ruse 1979: 230; Young 1985: 109; Desmond and Moore 1995: 663) According to Ernst Mayr, hardly any experimental biologist fully supported Natural Selection until the 1920th and the synthesis of Evolution and Genetics but this is probably too strong a statement. (Mayr 1991: 45)

168 The term ‚elimination' was not included in the analysis because a pre-test revealed that it was not employed in any significant frequency.

169 Even Darwin did use the term only once in the 1st edition of the Origin. Due to these synonyms, I expected that the concept evolution produces hits before the publication of the *Origin* – unlike natural selection.

semantically in order to identify relevant uses. Table 6 illustrates this problem by listing examples of relevant and irrelevant uses for each of the key-strings.

String	**Relevant Hits: counted**	**Irrelevant hits: not counted**
Evol*	Clear references to Darwin's theory: how has a species evolved from what progenitor/ancestor	Metaphorical use. Use referring to the development within the lifespan (ontogeny)
Transmut*	References to theories of trans-mutation e.g. by Chambers, Lamarck	[not applicable]
Inherit*	References to Darwin's theory	Inheritances mentioned in obituaries
Origin*	References to the origin of specific species, their ancestors / progenitors.	References to specific specimen, not species/varieties: “The original specimen was found by the naturalist XY."
Fit*	References to the origin of specific species, their ancestors / progenitors.	General description of an organism’s featu-res as fitted to its habitat, without reference to evolution or natural selection.
Ancest*	References to genealogical relations among species	References to ancestors without discussion of genealogical relations: “The ancestors of the Maori preserved extinct species.”
Progen*	References to genealogical relations over several generations	Descriptions of how organisms care for their very own progeny, e.g. birds for their young
Descen*	References to the concept of common descent, e.g. in claims that a certain species has descended from another	Descriptions of morphological structures – "descending lobes of the pancreas" – or terrains - " a slope descends to the sea"
Select*	Clear references to natural or sexual selection, in general or in specific cases	Explanations of how and why specific specimens were selected for preservation.
Preserv*	Clear references to natural or sexual selection, in general or in specific cases	References to specific specimen, by whom and where they were/are preserved: by naturalist XY, in museum Z, in spirit
Struggle	Clear references to Darwin's theory: “Evolution occurs in a struggle for life / struggle for existence.”	Descriptions how captured animals struggled against their chains
Archetyp*	References to Richard Owen's concept of archetype	Citations of a paper on archetypes or of Owen’s *On the Archetype* (Owen 1848a)
Homolog*	Uses of the concept in anatomical or morphological descriptions.	Metaphorical use, e.g. the characterization of two lines of thoughts as homological.
Darwin*	Clear references to Darwin's theory, i.e. evolution, natural selection	References to other empirical papers by Darwin or to species named after Darwin or discovered by Darwin.

Table 6: Relevant and irrelevant hits for the different key-strings

In a third step, the filtered hits were classified with respect to the position the article[170] (its author) took on the concept question. A neutral, a positive and a negative case were distinguished. A mere mention of a concept was counted as a neutral use. Explicit approval of a concept or its application to specific cases was counted as a positive use. Explicit criticism or disapproval of a concept was counted as a negative case. Thus, within the set of semantically relevant hits it could be distinguished whether an author merely acknowledged the existence of a Darwinian concept, whether he approved of it and/or employed it or whether he rejected it. Finally, the counted hits will be classified for each of the concepts, years and journals. Results will be presented and discussed in section 4.4. I suppose that they provide for a good indicator of the impact of the Darwinian revolution on 19th century biology in Britain.[171]

2.2.2. Summary

The reception analysis which I have described in this section complements my comparative analysis of theory contents in that it studies the Darwinian theory as a social object, not as a logical-linguistic one. It does not investigate what theory Darwin described in the Origin and how this theory differed from other theories of evolution. Instead, it asks (i) which parts of the theory were received, (ii) by which criteria these parts were assessed and (iii) which of the elements were ultimately accepted and which rejected. These three questions are pursued in a combined qualitative-quantitative study for three different audiences: biologists (Darwin's immediate scientific community), other scientists (a broader scientific community), and laymen (the public). The questions will be answered in sections 4.1 to 4.3. The results will be synthesized and discussed in section 4.4.

[170] Note that this classification was done per article, not per hit, i.e. it was assessed what position the article displayed in general.

[171] Other, more powerful indicators may exist. I have additionally checked for substantial increases in papers on classification or massive modifications of taxonomies after 1859 but I could not observe any such trend. In any case, I am convinced that the use of the Darwinian concepts as here measured is a necessary condition for Darwin having had any impact on the scientific practice in his discipline.

2.3 Historical Background: The shared biological knowledge and the shared beliefs about biology up to the 1840s[172]

i. Antiquity & Middle Ages: basal mental models about life

The first biological[173] thoughts may be traced back to the Greek philosophers Anaxagoras (ca. 500-428 BC), Empedocles (495-435 BC), Democritus (ca. 450-404 BC) and to the school of Hippocrates (ca. 460-370 BC). They expressed some of the first and most basal ideas about the animal world: there exist different animals with different features and skills which occupy different places in nature. They saw that animals differed with their environment and held some basal ideas about adaption. Plato (ca. 424-348 BC) added the idea that such adaption would express a fundamental harmony in nature.

The first systematic studies of animals can be attributed to Aristotle (ca. 384-322 BC). In his *Natural History of Animals*, he compared animals and discussed criteria for their distinction, mostly based on outward features. In hindsight, some of these criteria read as if Aristotle had anticipated classificatory criteria which were only established in the 19th century.[174] (Perrier 2009 [1884]: 8-13) Aristotle, however, never employed them to advance any definite grouping of animals; he suggested no hierarchical classification or explicit definitions of the species he distinguished. Besides, Aristotle seems to be the first to describe the idea of a struggle in Nature:

> "Animals often fight with each other, particularly those which inhabit the same places and eat the same food; for when food becomes scarce, congeners fight together. They say that seals which occupy the same locality will fight, the males with the males and the females with the females, until one party is either killed or ejected by the other, and their cubs also will fight in the same way. All animals also will fight with carnivorous creatures, and these will fight with other animals, for they feed upon living creatures; for which reason augurs observe the disputes and agreements of animals, considering that their disputes betoken war, and their agreements peace with each other."[175]

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172 In this historical introduction, I present mostly established knowledge on the history of biology. My main sources are Edmond Perrier's contemporary *The Philosophy of Zoology before Darwin* (Perrier 2009 [1884]), Ernst Mayr's modern *Einführung in die biologische Gedankenwelt* (Mayr 1984), and the more recent *Die Entdeckung der Evolution* (Hoßfeld and Junker 2001). For better readability, from these books, I have marked quotes only for key statements, general assessments or less-known facts. Primary sources and supplementary secondary sources are quoted as usual.

173 For convenience and clarity, I will speak of 'biology' with respect to all fields of research which are today included in the discipline biology. As for the term 'biology' itself, it seems that it was first used in the second half of the 18th century. Lamarck's and Treviranus' independent uses of the term in 1802 are the most popular, but Peter McLaughlin has demonstrated that the first uses may be traced back at least to the 1770s. (McLaughlin 2002) The term then gained wide acceptance during the 19th century, particularly after Darwin provided a framework in which the different strands of biology could be integrated (at least partly). Huxley's article on "Evolution in Biology" in the *Encyclopedia Britannica* of 1878 seems to speak for its wide-spread use. (Huxley 1893a [1878]; cf. Huxley 1893b)

174 As with Democritus' atomic hypothesis, it is difficult to assess to what degree his statements correspond to modern thought and to what degree, conversely, such association is supported only by the fact that later theorists reused ancient terminology.

175 This quote is from the 9th book, Chapter II, No. 1; quoted from (Aristotle 1887: 231).

His most influential idea probably was the concept of a *scala natura*, a great step ladder which linked the lower organisms to the higher ones in a continuous chain. This *scala natura* was no evolutionary[176] concept, however, but a static one; the most Aristotle could imagine was a flowing equilibrium. – As will become clear below, ll of these early and basal ideas about and mental models of biological objects and processes can be traced throughout biological thinking at least up to Darwin.

First, it was mainly the concept of the Aristotelian scala which had a great impact. During the Middle Ages, Aristotle was interpreted and commented in scholarly exercises, particularly the scala was the subject of much debate. This implied little empirical work however. Some rare independent minds as the German[177] bishop Albertus Magnus (1193/1206-1280)[178] carried out empirical studies and complemented Aristotle's descriptions but none left the theoretical framework of the Greeks: there was unity in the diversity of life, organisms were adapted to conditions and species were constant. Overall, biological thinking remained within the framework set by the biblical Genesis: After creating heaven, earth, day and night, the firmament, the earth and the sea, God had made, in this order, plants each "according to its kind", the animals of the sea, birds and the land animals and finally Man, again, each "according to its kind".

ii. The 16th and 17th century: renewed interest and technical innovations

The Scientific Revolution of the early modern period hit biology a bit later than physics or chemistry. A renewed interest in the nature led to larger descriptive and comparative works in the 16th century. In zoology, new classifications were suggested but they still mingled mythological beasts among the animals actually observed. In botany, a number of Kräuterbücher (herbal books) in southern Germany provided systematic illustrated accounts of native plants. (Mayr 1984: 78, 125, 253) From the 16th to the 17th century, the number of known plants mulitiplied. (Hoßfeld and Junker 2001: 33)

Such botanical works were facilitated by an important technical innovation: the herbarium. Luca Ghini (1490-1556), an Italian physician and botanist seems to be the first to have dried plants and plant parts, a practice which facilitated comparative and systematic botanical research immensely.[179] Ghini also founded the supposedly first botanical garden in Europe, the *Orto botanico* in Pisa, which dates back to 1544.

At the same time, the first wave of European explorers brought descriptions and exemplars of foreign organisms from overseas. The age of royal and private collections dawned, rare specimen were collected and presented in European salons and cabinets; books on natural history became popular. Overall, the number of known plants and animals grew immensely in these decades and marked first biogeographical thoughts as particular animals where linked to particular environments.

176 By the term 'evolution' I denote any description of long-term changes of groups of organisms in time. Such concepts were also referred to as 'transmutational' or 'developmental' or 'derivative', among others. For simplicity, I will refer to all of them as 'evolutionary'.

177 For convenience and clarity, I am using modern geographical attributes in my description. I am aware that the political entities of 21th century Europe did not exist through most of the early modern and modern period.

178 Albertus' exact birth date is unknown.

179 The equivalent for zoology, formalin conservation, was introduced only at the end of the 19th century, i.e. after the Darwinian Revolution.

The immense growth of empirical knowledge had a flip-side, however: it threatened the status of ancient sources such as Aristotle and the biblical account of the genesis and the Flood. The more organisms were discovered, the harder it became to imagine how Noah had fitted them onto his Arch. Besides, many of the new organisms were to be found neither in the biblical nor in antique accounts; they stemmed from totally different floras and faunas.

The invention of the microscope around 1600 opened new horizons for biology. The Italian astronomer Giovanni Battista Hodierna (1597-1660) published a first detailed microscopic study on the fly's eye in 1644, but it was not until the 1660s and 1670s that microscopy became a wide-spread technique in biology. In 1676, the Dutch Antoni van Leeuwenhoek (1632-1723) discovered red blood cells and spermatozoa.

Besides, microscopy was very important for a debate on a belief that had been held throughout the middle ages and would still shape parts of the Darwinian debate. The belief was referred to as "spontaneous generation" and it consisted of the idea that God created life spontaneously and continuously out of non-living matter. As evidence for such a "vital force" several observations were provided, for instance, that maggots grew on meat when left in the open. Microscopy gave rise to a series of experiments in which this idea was tested. In 1688, the Italian physician Francesco Redi (1626-1697) did this for the maggots and dismissed spontaneous generation in this particular case but similar arguments continued to be made in other cases were microorganisms seemingly appeared out of nowhere.[180]

iii. The enlightenment: from theism to deism

One prominent place for this argument was Telliamed (1748), a posthumously published book titled by its author's name in reverse. Benoît De Maillet (1656-1738) had developed an interest in natural history while traveling overseas as a French diplomat. In Telliamed, he imagined the origin of life as a spontaneous generation from an infinite number of germs which were disseminated all over the earth's crust. He believed that God continuously created new organisms from these germs and that these germs in term would develop into higher organisms. He hypothesized that primitive sea animals had grown more complex and had then moved on land where they continued to develop.

There were at least three very innovative aspects about de Maillet's theory. First, de Maillet seems to be the first who applied hereditary thinking to questions of natural history. While inheritance was a well-known phenomenon and breeders held important knowledge on it, it had hitherto not been integrated in the thinking about the origins of life. Second, de Maillet cited fossils to support his theory, being one of the first to interpret fossils as remainders of historic animals and clues to the development of life – and not as natural artifacts. (see below) Third, while the sequence by which animals appeared according to de Maillet complied with the bible and God clearly played a major role in de Maillet's account, he did not describe any divine interventions in the development of one living form to another. This was a perfectly natural process and God did not interfere with it.

[180] It was not until French chemist Louis Pasteur (1822-1895) demonstrated the emergent growth of bacteria that accounts of spontaneous generation would fade. Incidentally, his experiments with swan-neck flasks were carried out in 1859, the same year the Origin was published. (cf. Owen 1868: 814) For a lucid and simple overview on the debate see http://www.microbiologytext.com/index.php?module=Book&func=displayarticle&art_id=27

Thus, de Maillet broke with an important theological tradition: the idea of divine providence or theism. Hitherto, God had been conceived of as a personal, intervening agency to which a faithful human stood in close contact. In de Maillet's account, however, he did not intervene directly anymore, he did not transform organisms by specific acts but acted through intermediate means. In the English debate these means would be referred to as 'secondary causes' or, simply, 'laws'. This view of God is usually referred to as 'deism'.[181]

It was no accident that such liberal thinking was first expressed by a Frenchman. While the Age of Enlightenment seized all of western and central Europe[182], its center certainly was France. Authors like Voltaire[183] (1694-1778), Montesquieu[184] (1689-1755), Jean-Jacques Rousseau (1712 –1778) or Denis Diderot (1713-1784) inspired Europe with their ideas of liberty and free thought. But they did not confine themselves to the sphere of politics and society; their common project, the *Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des métiers* (1751-1772) carried liberal ideas in the realm of science. This impact showed particularly in the role God played in scientific theories; French scientists of the later 18th and early 19th century referred much less to divine power in their writings than the English, whose natural history was still firmly embedded in natural theology. [185]

iv. Linnaeus & Buffon: classification and biogeography

The two most important biologists of the 18th century would deliver their most important works in this very period, before the outbreak of the French revolution in 1789 and the ensuing period of political restauration. (Mayr 1984: 259) Coincidentally, both had been born in 1707, in very different corners of Europe. One was the Swedish university professor Carl Nilsson Linnaeus (1707-1778), the other the French director of the *Jardin des Plantes* in Paris, Georges-Louis Leclerc (1707-1788), who later became the Comte de Buffon. These two very different characters began their careers on opposed missions and while they approached each other's work over time, their different ways of doing biology would shape the discipline.

Linnaeus, on one hand, laid the ground for modern taxonomy. He devoted his life to large systematic classificatory works and, in a strive for precise language, developed the binomial nomenclature, a method which allowed for classifying plants in a hierarchical structure of disjunctive sets. The basic logic of Linnaeus' system was to specify an empirical criterion and distinguish those organisms which fulfilled it and those which did not. By summarizing groups of such criteria under larger ones, aggregate sets could be formed, distinguishing groups of organisms which shared more such criteria with members of their group than with non-members. To Linneaus, such classifications were, first of all, pragmatic tools which provided simple and transparent rules for the identification of specimen with their taxonomic groups, i.e. for placing them in the smallest group to which they belonged. Linnaeus distinguished four kinds of such groups in classification: species, genera, orders and classes.

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181 The term 'deism' came in use in the 17th century and denoted views of the world in which God acted a supreme architect or machinist who built the universe but lets it run on its own according to natural laws. He does not (or very rarely) intervene directly in it its course. Therefore, deists refused supernatural events like miracles which would constitute direct divine intervention.

182 One of the important trailblazers of the French enlightenment was the German polymath Gottfried Wilhem Leibniz (1646-1716).

183 'Voltaire' is the pen-name of François-Marie Arouet.

184 Montesquieu's full name was Charles-Louis de Secondat, baron de La Brède et de Montesquieu.

185 Such, less and less prominent references to god can be found in the works of Geoffroy or Lamarck than in those of Lyell, Sedgwick, and Paley.

Around 1800, these groups were complemented by the family, a group between the order and the genus. (Perrier 2009 [1884]: 32) Linnaeus' classifications would be developed by new generations but remain remarkably stable until today.

Despite his methodological achievements, Linnaeus' project was not confined to pragmatics. Instead, his classifications were supposed to approach Aristotle's scala natura; Linnaeus envisaged it to reveal the harmony of nature. Such, the classifications in his 1776 *Systema naturae* aimed at such a natural system. The French zoologist Perrier describes Linnaeus' ambition as follows:

> "Each species in the long series of living forms should fit neatly between two others. Scientists should strive to place species in this kind of order, for only then can they be confident that their system of classification is definitive. Such a system would not necessarily be unique, and it should be referred to as a *natural method*. Linnaeus thought that this could be achieved by setting up a series of procedures of this kind and then perfecting them by successive refinements, so that they would gradually merge into a more and more definitive system. Thus, each of these tentative systems resembles a theory that initially offers only approximate explanations for the phenomena it is meant to relate to one another, but with time, progressive improvements made it possible to give the relationships firmer cohesion." (Perrier 2009 [1884]: 30)

Linnaeus' thinking was still deeply rooted in theological convictions – despite the enlightenment movement. How much so, was displayed by his concept of species. To Linnaeus, a species was formed by all those animals which have come in pairs from the hands of the creator. Thus, they were per se invariable and while Linnaeus, as many others, mentioned some kind of struggle in nature, he believed in a fundamental equilibrium and harmony. (Perrier 2009 [1884]: 30; Mayr 1984: 207-9)

Many of these beliefs and assumptions were fundamentally questioned by Buffon in his epic *Histoire Naturelle* which appeared in 35 volumes between 1749 to Buffon's death in 1788[186], covered animals and minerals and was read all over Europe. Especially in the early volumes, Buffon dismissed systematic concepts and dismissed the systematists' efforts: He favored holistic descriptions over the meticulous study of single aspects and their role for classification. He concentrated on individuals instead of groups. He emphasized the continuity in nature and neglected those aspects that suggested distinction.[187]

Buffon softened his rejection of classifications in his later works, accepting their usefulness in description. At the same time, he continued his fundamentally holistic research program and it bore fruitful results. First, Buffon became the founder of biogeography, publishing the first systematic accounts of how organism types correlated to regions. In a regularity called 'Buffon's law', he pointed out that many regions display different animals and plants despite similar physical conditions.

Second, Buffon was the first to take a dynamic viewpoint on the question of life. He pondered the idea of spontaneous generation and speculated that organisms might have emerged by a spontaneous clumping of organic molecules. From certain centers of such spontaneous generation,

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186 Several additional volumes were published by Buffon's collaborators after this time.

187 Buffon expressed this idea by claiming that everything which could exist does indeed exist, an assertion which Mayr traces back to Gottfried Wilhelm Leibniz (1646-1716), the German mathematician and philosopher.

they might, then, have migrated to other parts of the world and transformed into other forms, either by "degeneration" or "improvement". In the fourth volume of his Natural History (1753) and an essay on the degeneration of animals (1766) he discussed the implications of such a view and clearly saw that if Nature was able to transform one animal in another, then, given enough time, it might be able to produce *all* organisms in this manner. But then, in a turn which continues to bewilder historians, Buffon dismissed the idea altogether, stating that it was incompatible with Revelation. (Mayr 1984: 265; Hoßfeld and Junker 2001: 40-1)

This dismissal does not seem to have been a precautionary measure, i.e. a concession to religious authorities supposed to hide secret evolutionary position. [188] Actually, there was not nearly enough empirical support for such a bold break with established explanations. In any case, Buffon introduced the question of evolution on the table, establishing it as a possibility and a point of reference for future biological thought.

v. France, Germany and England at the turn of the 19th century

Buffon's lasting impact was felt most in France and Germany, less so in England. One immediate example is the Latin American expedition (1799-1804) of Aimé Bonpland (1773-1858) and Alexander von Humboldt (1769-1859) which followed Buffon's footsteps and became a milestone of systematic biogeography. Another, more durable effect of Buffon's achievements was the position natural history had achieved in France. After the French Revolution, the royal *Ménagerie* and Buffon's *Jardin des Plantes* became integrated in a single institution, the *Muséum National d'Histoire Naturelle*. Founded in 1793, it was the first natural history museum of its size and kind and would inspire the construction of the Natural History department of the British Museum in London in 1881[189] and the construction of the *Museum für Naturkunde* in Berlin in 1889.

Overall, French biology entered a period of professionalization and it saw three researchers take the stage who all would be employed at the Muséum National and, together, would dominate the theoretical discourse in Europe until the 1830s. These three naturalists were Jean Baptiste de Lamarck[190] (1744-1829), Étienne Geoffroy Saint-Hilaire (1772 –1844), and Georges Cuvier[191] (1769-1832). The former two had close ties to Buffon; Cuvier, however, was much closer to Linnaeus. (see below)

In Germany, Buffon's ideas were disseminated by the theologian Johann Gottfried Herder (1744-1803). In his *Ideen zur Philosophie der Geschichte der Menschheit* (1784-1791), he interpreted the Aristotelian scala natura as a time line and expressed ideas about a struggle for life. Herder, in turn, would have a major influence on the German of natural philosophy (Naturphilosophie) and its major

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188 On at least two other occasions, Buffon had to write retractions to satisfy religious critics. This, however, did not hinder him from continuously expressing a-religious positions. Thus, it seems like he could have pursued a similar compromise on the question of evolution. As he did not and as he provided further arguments against evolution, it seems reasonable to assume that this reflected his actual position. (Hoßfeld and Junker 2001: 41) However, while Buffon's addressed several topics many times and changed positions over time; therefore, it is hard to attribute a definite position to Buffon.

189 Richard Owen was much involved in this project and would become the museum's first director. (See section 3.2)

190 His full (or actual) name was Jean-Baptiste Pierre Antoine de Monet, Chevalier de la Marck.

191 Sources on his full name differ. It might either be Georges Chrétien Léopold Dagobert Cuvier or Jean Léopold Nicolas Frédéric Cuvier.

proponents Carl Gustav Carus (1789-1869), Friedrich Wilhelm Joseph Schelling (1775-1854) and Lorenz Oken (1779-1851).

Similar to France, in Germany, natural theology already had given way to less theistic world views. Polymath Gottfried Wilhelm Leibniz (1646-1716) was an early proponent of such views. About a century later Immanuel Kant (1724-1804), like Buffon, had speculated on the age of the earth and the possibility of evolution and had published a *General Natural History and Theory of the Celestial Bodies* in 1775. Hence, at the turn of the 19th century, scientific explanations in Germany required no more direct interventions of God and biological processes were constructed as natural ones.

These constructions were not without metaphysical overtones, however; they stood under the influence of the cultural movement of *Romantik*. Instead of creation and the divine plan, the natural philosophers spoke of Entwicklung (development) and speculated about how organisms might develop in naturalistic processes. In the wake of these idealistic natural philosophers, Germany developed a lively tradition of naturalistic evolutionary thought.[192] In hindsight, it is impressive to what extent and in what detail evolutionary ideas were discussed in the late 18th and early 19th century in Germany. As Ernst Mayr points out, it makes one wonder why it was no German who came up with a solution to the evolution puzzle. (Mayr 1984: 310)

One explanation seems to be the gap and lack of communication between the evolutionary theorizing of natural philosophers and the empirical work of scientists. The German zoologists, anatomists and botanists dismissed most of the contemporary philosophy as unempirical and naïve speculation. Such, the Baltic-German embryologist Karl Ernst von Baer (1792-1862), in the 1820s, rejected the speculative theory of transformation in Germany all the while having an open ear for the evolutionary thoughts of Buffon. (Mayr 1984: 309) Johann Wolfgang von Goethe (1749-1832) remains an exception in that he was a respected morphologist and anatomist – despite his literary and theoretical prowess.[193]

Considering Germany and France, it is remarkable how much English biology still felt the firm grip of natural theology. Naturalistic explanations were refused point-blank and only one agent was accepted in biology: a personal and intervening God. The book which most strikingly symbolized this traditional theistic attitude was probably the British best- and long-seller[194] *Natural Theology, Or, Evidences of the Existence and Attributes of the Deity, Collected from the Appearances of Nature* (1802) by the British philosopher William Paley (1743-1805).[195] Consequently, the British theoretical discourse in the natural sciences considerably lagged behind the continent.[196]

192 Mayr (1984: 309-10) mentions a number of authors who display evolutionary thinking.

193 In the 1780s, Goethe discovered two unknown intermaxillary bones in mammals and described the cranium as composed of vertebrae. He developed the latter discovery in a research program founded on the idea that organisms are composed of repeated forms of the same part, only in modified form. (Perrier 2009 [1884]: 111-3) Goethe's program showed some resemblance to the structuralist approach of Geoffroy (cf. Amundson 2007: xvi-xvii) as well as to Owen's homologies. (See sections 3.2.2 and2.3 ix)

194 Remarkably, the book is still on sale today, more than 200 years after its initial publication.

195 Despite being, at best, a popular science work like Chambers' *Vestiges*, *Natural Theology* was widely received, also among scientists. Darwin studied it in during his studies in Cambridge and was much impressed by it. Padian sums up Paley's line of argument as follows: "Paley began his argument by imagining that a person crossing a heath was to strike his foot against a stone. He would think nothing of finding the stone, a quite natural part of the environment, in that particular place, nor would he require an extraordinary explanation of how it had come to be there or how it was made. But, Paley continued, if one were to encounter a watch on the same heath, it would be obvious that it was not a natural part of the

The times were about to change however. In terms of beliefs, the Scottish Enlightment[197] and liberal English societies[198] spread liberal thought.[199] In 1785, the Scottish geologist James Hutton (1726-1797) expressed a revolutionary, and fully naturalistic, theory of geological change. Erasmus Darwin (1731-1802), in his *Zoonomia or, The Laws of Organic Life* (1794), took up biological ideas from the continent and presented them to the British public. The reverend Thomas Robert Malthus (1766-1834) published his famous *Essay on the Principle of Population* (1798), the sixth edition (1826) of which would later be read by Charles Darwin and Alfred Russel Wallace. Moreover and more importantly, the British would be at the forefront of a new development in biology which tapped into a novel, explosive source of knowledge: fossils.

While single fossils had been known since the antiquity, for a long time, they had mostly been interpreted as natural artifacts, crystallizations or random imprints of the vital force. At the end of the 18th century, however, scientists started to reinterpret them as relicts of historic animals. (cf. McGowan 2001: 1; Hutton 1860: 293) Suddenly, biologists could combine their study of organisms in space, biogeography, with a study of organisms in time. A window to natural history had opened;

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environment, nor could it have formed spontaneously. It must have been made, because a watch, like any living organism, is a machine, and must be purposefully assembled ... So, he argues, the complexity of living organisms, with their superbly adapted parts, implies a Creator of all life. To deny this is to embrace atheism." (Padian 2007: lxxxii-lxxxiii)

196 How far the English discourse had uncoupled from the continental one is exemplified by the preface to the German edition of Paley's *Natural Theology* (1837) in which the German translators gives a lengthy explanation for why Paley still employed theistic explanations, something which had long disappeared from the German debate. It is worth quoting the first paragraph in full. In modern German orthography, it reads: "In der höheren wissenschaftlichen Auffassung der Natur vermögen wir die, in anderer Beziehung, namentlich im poetischen Gefühl uns so nahe stehenden Engländer kaum als unsere Stammesgenossen zu erkennen. Deutsche Naturphilosophie ist ein ganz anderes Ding, als was der Engländer ‚natural philosophy' nennt. Der uns [den Deutschen] innewohnende, durch so manche wunderliche und erhabene Geistesschöpfungen beurkundete Triebe, die Natur in letzter Instanz poetisch zu konstruieren, fehlt dem sonst so poetischen Inselvolk fast ganz, oder er ist durch seine historische Entwicklung in ihm zurückgedrängt worden. Einerseits fasst der Engländer die Naturwissenschaften rein praktisch auf, mit Rücksicht auf die der Natur abzugewinnenden Vorteile für Künste und Gewerbe, andererseits bleibt seine Philosophie im Kreise der Theologie, auf theologisch-dogmatischem Standpunkt stehen. Durch die starren Formen der öffentlichen Erziehung, so wie durch den Umstand, dass die behagliche Muße des höheren Klerus dem Naturstudium viele Propheten zuführt, und wirklich England von jeher unter seinen bedeutenden Naturforschern sehr viele Geistliche der Hochkirche zählte, mag die Emanzipation der Philosophie von der Theologie verhindert worden sein. Dem Deutschen muss in dieser Beziehung der Standpunkt des Engländers ein beschränkter erscheinen, und unter diesen Umständen müsste ich eigentlich die deutsche Philosophie um Vergebung bitten, dass ich eine jener Abhandlungen über natürliche Theologie einführe, deren mühselige Argumente und rhetorische Theodizeen wir längst hinter uns zu haben meinen und deren vielseitig bewiesener Gott uns anthromorphistischer erscheint, als der, den wir spekulativ selbst machen. Aber ich will auch nicht die englische Philosophie empfehlen, sondern ich appelliere mit Paleys Buch einfach an das gemeine Bewusstsein des nicht philosophischen Lesers, der bei Betrachtung der organischen Schöpfung mit Freude und Genuss, und als wirksames Mittel der geistigen Bildung, seinen eigenen Verstand in den Werken der Natur findet." (Paley 1837: iii-iv)

197 The 18th century saw a stream of intellectual and scientific accomplishments to come out of Scotland, particularly from Edinburgh. Among the most famous were the works of philosophers David Hume (1711-1776) and Thomas Reid (1710-1796), economist Adam Smith (1723-1790), sociologist Adam Ferguson (1723-1816), mathematician John Playfair (1748-1819), chemist Joseph Black (1728-1799), and poet Robert Burns (1759-1796).

198 One famous society, the Lunar Society of Birmingham (1765-1813), was a meeting point for entrepreneurs and natural philosophers and counted both of Charles Darwin's grandfathers as his members: Erasmus Darwin (1731-1802) and Josiah Wedgwood (1730-1795). (Uglow 2002)

199 This is all the more remarkable as the 1780s and 1790s considering the climate of political conservatism and restoration after the French revolution of 1789 and its ensuing chaos.

what Buffon had only dared to speculate upon now moved into the realm of the empirically accessible.

vi. The ascent of geology and paelontology: what time-line for biology?

As before, this new source of knowledge threatened established religious beliefs – and those beliefs reestablished during the political restoration of the 1790s. A first problem for the church was the simple fact that the bible knew no extinctions; exemplars of all species had been saved on Noah's arch. How to explain fossils which did not match any of the living creatures? Three possible explanations were discussed: (i) the missing species were not extinct but had moved to other parts of the earth or sea which had not yet been (re-)discovered, (ii) Man had eradicated them, (iii) they had died in the Flood. With increasing knowledge, each of these explanations became more difficult to uphold. The discovery of mammoth and mastodon fossils and the fact that many of the extinct animals were sea animals complied with neither explanation. The latter would not die in a flood and the former were simply too big to go unnoticed, either in their existence or in their eradication by Man.

The second problem was the age of the earth, which the church, based on biblical accounts, estimated at about 6.000 years.[200] This estimate had already been called into question publicly, for instance by Immanuel Kant who, in 1755, speculated about the earth being "thousands, possibly millions of centuries" old (Hoßfeld and Junker 2001: 32) or by Buffon who had given an estimate of 168.000 years[201] in his 1779 *Époques de la Nature.*[202]

In 1785, the Scottish geologist James Hutton (1726-1797) held a speech at the Royal Society of Edinburgh *Concerning the System of the Earth, its Duration and Stability* in which he presented a model of geological change and suggested that the earth was much older than men could imagine, possibly millions of years old. (Repcheck 2007) Despite growing empirical evidence, Hutton's model encountered much resistance[203], particularly in Britain, but it would inspire the most important geologist of the next generation, Charles Lyell. (see below)

Now, however, this question became one of empirics not of speculation – and much harder to dismiss. Geologists began to systematically study geological formations and interpreted them as sediment layers – in geological terms: strata. Layers of 3.000 to 30.000m were discovered and it soon became doubtful that these could have formed within less than 6.000 years; presumably, the earth was much older. There was, however, no direct evidence for such estimates; scientists had to interpret the geological relicts they found.

The first systematic empirical geological studies were apparently carried out by William Smith (1769-1839), an English geometer. During the beginning industrial revolution in Britain, he was occupied in

[200] No one less than Isaac Newton had provided some of the calculations which supported this estimate. (Repcheck 2007: 24)

[201] Buffon seems to have spoken of smaller numbers in earlier publications, too.

[202] Due to pressure by religious authorities, Buffon had to publish a retraction on the topic but he did not withdraw the publication.

[203] One important competing model had been published by the Abraham Gottlob Werner (1749-1817), a professor at the *Bergakadamie* in Saxony. In a lecture from 1779, Werner had defended the estimate of 6.000 years. Werner was supported by Hutton's Edinburgh rival Robert Jameson (1774-1854), but also by the geologists William Buckland (1784-1856) in Oxford and Adam Sedgwick (1785-1873) in Cambridge, the latter of whom was Charles Darwin's geology professor.

the construction of channels and had access to mines. From 1791 to 1799, he used his time to study the geological strata in England and Wales and published a famous map in 1815.[204] In publication, he was bypassed by the German paleontologist Ernst Friedrich von Schlotheim (1764-1832) and by one of Buffon's heirs, the French zoologist and paleontologist Georges Cuvier (1769-1832), in collaboration Alexandre Brongniart (1770-1847). Schlotheim published on plant fossils in 1804 and 1813, comparing their morphology with contemporary plants and classifying them according to the Linnean system. Cuvier published on the strata of the Paris basin in 1808 and 1811 and claimed that the area had been submerged by both, sea water and fresh water, during different historical periods – a spectacular interpretation.

From these studies, two disciplines emerged: the study of sediment layers (strata) in geology: stratigraphy, and the study of prehistoric life in biology: paleontology. In an interesting twist in the history of science, these young disciplines would align forces in the next decades and grant each other mutual legitimacy and plausibility. The reason of this alliance lay in a knowledge source they shared: fossils. While the geologists were not much interested in the fossils as biological objects, they soon noticed that the sediment types in which fossils were found correlated to the type of fossil; certain fossils were found in certain strata, but not in others. This was most clearly demonstrated by Cuvier in the Paris basin, subsequently in other parts of Europe, and finally overseas. If strata and fossils corresponded, biological and geological history had to be brought in line.[205]

Before the great geological discoveries of the turn of the century, it had usually been assumed that the geological history of the earth had been one of continuous and regular progression, without any major interruptions – except for the biblical Flood. Now, stratigraphy threatened this harmonic image by uncovering several sharply distinguished sediment layers, intuitively suggesting a discontinuous history of the earth's crust. This position was indeed taken by Georges Cuvier who, in his *Discours sur les révolutions du globe* (1802), argued that the earth had seen several "révolutions", each of which had extinguished the complete fauna. Given the available evidence and his domain of expertise, Cuvier's seemed the most adequate hypothesis: In the first decade of the 19th century, no higher species was found in successive strata. It was, however, disputed by a group of opponents, which dismissed the idea of regular *révolutions*, or *catastrophes*, as they were often termed. Cuvier's opponents championed *uniform geological changes* throughout the history of the earth.[206] The best-known representative of this second group was the English geologist Charles Lyell (1797-1875). Lyell claimed that throughout history, only those geological forces had been at work which were still observable and only at their then-observable intensity.

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204 Unfortunately, Smith was mostly overlooked and enjoyed scientific recognition for his pioneering work only late in life.

205 The most poignant expression of this mutual dependency was uttered by Thomas Henry Huxley in his reply to the physicist challenge of Darwin's model on the grounds of geological time: "Biology takes her time from Geology. The only reason we have for believing in the slow rate in the change of living forms is the fact that they persist through a series of deposits which, geology informs us, have taken a long while to make. If the geological clock is wrong, all the naturalist will have to do is to modify his notions of the rapidity of change accordingly." (Huxley 1869: 329; cf. section v)

206 In 1832, the British philosopher of science William Whewell (1794-1866) would term the opposition between both paradigms as "catastrophism" vs. "uniformitarianism".

Within both groups, several factions would differ over the details of their geological models; for instance, Lyell believed in a steady state around which the geological phenomena revolved.[207] What matters for biology, however, is first and foremost the issue of catastrophes. If biological and geological history were to be brought in line, the doctrine of catastrophes meant that a biological history could only be written between such catastrophes, i.e. over relatively short intervals of time.[208] Uniformitarianism, however, provided biology which a much more unified account of natural history and a much more challenging problem[209]: to explain the succession of fossils across geological strata. While Cuvier had some important disciples, most of the geologists and biologists would look for uniform and continuous explanations rather than successive catastrophes.

vii. Jean-Baptiste Lamarck: evolution & its first dynamic model[210]

Among them was the eldest of Buffon's heirs, Jean-Baptiste Lamarck (1744-1829). He came from an impoverished noble family, had fought in the Seven Years War (1756-1763) as a young man, and retired from the army with an injury in 1766. For the next decades, he would live of a small pension and commissioned literary work. On the side, he developed an interest in natural history and began to publish on the topic. Eventually, Buffon employed him as a private tutor for his son and Lamarck began working with Buffon, too. In 1788, at the age of forty-four, Buffon arranged for the position of an assistant for Lamarck. After the French revolution and the foundation of the *Museum National d'Histoire Naturelle*, Lamarck would finally be appointed a professor of zoology, in 1793. Lamarck concentrated on invertebrates, particularly mollusks, and established landmark classifications in his field. Together with Cuvier, he established comparative anatomy, enlarging the focus of biologists to the inner organization of animals. His interests did not stop there, however. Lamarck ventured in a number of fields, publishing on geology, mineralogy and meteorology – sometimes without the empirical knowledge to back up his ideas. Like Buffon, Lamarck sought a comprehensive theory of natural processes and he had a very imaginative mind.

Around 1800, first evolutionary thoughts can be found in Lamarck's lectures. They were probably triggered by the study of a collection of fossil mollusks which Lamarck had inherited from a collaborator and which displayed remarkable similarities to living ones. (Mayr 1984: 276) Around 1805, Lamarck had developed these thoughts into an evolutionary theory, including the first dynamic model for its explanation. He published his ideas in his *Philosophie Zoologique* in 1809, the year in which Darwin was born. Thus, Lamarck had answered Buffon's question in the affirmative; there was evolution, organisms were indeed transformed one into the other.

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207 Assumptions like these make it difficult to assess Lyell's importance for Darwin. On one hand, Lyell paved some of the way for Darwin's gradual explanation in biology by assuming gradual geological change. On the other hand, his steady state geology excluded any irreversible change like Darwin's. Consequently, Lyell vigorously rejected Lamarck and only half-heartedly confessed to evolutionism in the 1860s.

208 While Cuvier assumed a relatively modest number of catastrophes, some of his followers, would argue for more and more catastrophes, cutting biological history in ever thinner slices. The Swiss-born American geologist and zoologist Louis Agassiz (1807-1873) is a case in point.

209 Thus, the choice of the geological paradigm determined what would constitute the challenging objects of biology.

210 I deem it reasonable to draw the line between evolutionary speculations and the first model of evolution between Buffon and de Maillet on one hand and Lamarck on the other hand. The former pair had no empirical evidence on which to test their ideas, thus they speculated. Lamarck, meanwhile, developed the first (scientific) model of evolution on actual empirical evidence (albeit a very limited set). Thus, Lamarck modeled actual regularities between features of empirical objects. As for the question whether Buffon's and de Maillet's speculations might be referred to as 'theories', see (sections 6 vi, vii).

Lamarck did go substantively beyond Buffon when he actually put the taxonomic classifications on a timeline, sorting groups of organisms by complexity. He claimed that taxonomy should not be limited to static distinction but should reflect “the true order” by which nature has produced organisms. (Lamarck 1873a[1809]: 266-8) Lamarck’s taxonomy deviated from the idea of a static and linear scala naturae[211] and suggested a branching scheme[212].

At the base of Lamarck’s scheme were the least complex organisms which were created by continuous spontaneous generation. (Lamarck 1873a [1809]: 82, 214-5) A number of these less complex organisms then gradually develop into more complex ones. In sum, Lamarck’s scheme is best characterized as a pyramid; there are many organisms on the lower end of the scheme and few on the higher end. Interestingly, Lamarck’s scheme included no extinction. [213] Lower organisms were transformed into higher ones or remained as they were but did not become extinct; Lamarck did not preconceive any void in nature. (Perrier 2009 [1884]: 66)

To explain these developments, Lamarck suggested the first dynamic model of evolution. The Object Class of Lamarck’s model comprises both animals and plants although he mainly applied it to animals. (Lamarck 1873a [1809]: 28) Anatomically, it also applies to Man; as the most complex organism, he resembles the primates anatomically. However, he is clearly separated from them by his special properties and his direct relationship to God. (Lamarck 1873a [1809]: 25; Perrier 2009 [1884]: 70) Moreover, Lamarck’s model is centered on individuals.[214] (Perrier 2009 [1884]: 66) The

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[211] In earlier works of the 1770s and 1780s, Lamarck had still clinged to a linear, non-branching line of ascent from the less complex to the more complex organisms. (Lefèvre 2001: 185) The Swiss naturalist Charles Bonnet (1720-1793) had presented such a scale (“échelle des êtres naturels”) in 1745. Already then, Bonnet’s idealized static model did not fit with the available empirics. (Hoßfeld and Junker 2001: 37) Consequently, Lamarck dissociates himself from Bonnet’s scale in his *Philosophie Zoologique*. – For a comprehensive overview over static models of evolution before Darwin and Wallace, see Voss (2007: 95-163).

[212] This branching is regularly depicted by a diverging diagram displaying the relations of large classes of animals. (Lefèvre 2001: 186; Perrier 1873 [1809]: 70) (In Perrier’s text, the diagram seems inserted by the contemporary editors, McBirney, Cook, and Retallak.) Lamarck, however, did not present such a diagram but a set of tables. (Thus, Darwin is probably the first to present an actual diagram of evolutionary relations.) In his tables, Lamarck presented 14 classes of animals, sorted by six degrees of complexity (Lamarck 1873b [1809]: 273-276). All degrees comprise two classes of animals, except for the fourth, which comprises 4 classes. I find it hard to see how this table fits with the idealized schemes provided by Lefèvre and McBirney, Cook, Retallak.

[213] On one hand, extinction was not yet an established paleontological fact. On the other hand, Lamarck did not cite much empirical evidence to support his views, his work was really rather speculative.

[214] Thus, Lamarck relativizes both the notion of varieties and species in favor of individuals and makes the same argument as Wallace and Darwin: varieties and species are somewhat arbitrary sets over individuals. He states that: "We know that species do really have but a constancy relative to the circumstances in which are found all the individuals which do represent the species. Certain of those individuals varied and do now constitute races which differ slightly from their neighbor species. Thus, naturalists chose arbitrarily when they declare some of these to be varieties and others species, for instances individuals observed in different countries and in different situations. From this follows that the determination of species becomes more defective, i.e. more embarrassed and confused, by the day." (My rough translation, his text reads: “ En effet, ne sachant pas que les espèces n'ont réellement qu'une constance relative à la durée des circonstances dans lesquelles se sont trouvés tous les individus qui les représentent, et que certains de ces individus ayant varié constituent des races qui se nuancent avec ceux de quelque autre espèce voisine, les naturalistes se décident arbitrairement [sic!], en donnant les uns comme variétés, les autres comme espèces, des individus observés en différents pays et dans diverses situations. Il en résulte que la partie du travail qui concerne la détermination des espèces, devient de jour en jour plus défectueuse, c'est-à-dire plus embarrassée et plus confuse.” (Lamarck 1873a [1809]: 73)

transforming development occurs on individuals and “races” are formed by all those individuals which are on the same level of development.[215]

The Situation in which the development occurs is a gradually changing environment without great catastrophes; moreover, it is not a steady state. In line with Buffon and Cuvier, Lamarck supposes a high age of the earth. Moreover, Lamarck mentions that organisms compete for resources in order to multiply. Lamarck notices that particularly the lower organisms have very high rates of multiplication and that only nature keeps them in check, otherwise more numerous races could replace less numerous ones. As examples of such checks he mentions the relation of predators and prey and speaks of races “going to war” with each other. (Lamarck 1873a [1809]: 112-3; Perrier 2009 [1884]: 64)

Transformations are triggered by environmental changes. Lamarck presumes that organisms are well-adapted to their environment, a priori. Thus, transformations occur only when the environment changes; only then are animals required to adapt further. This delta between the characteristics of an organism and the demands of its environment then leads to a modification of the organism in question. The organism attempts to lessen the gap between his characteristics and the environment by a modified behavior (for animals) or modified inner processes (for plants). Through repetition these modified actions and processes lead to inheritable modifications of the organism in question and, over time, development in the Lamarckian sense. (Lamarck 1873a [1809]: 23; Perrier 2009 [1884]: 61)[216] Figure 10 provides an overview over Lamarck’s model.

Yet, Lamarck’s theory would not be complete without its underlying narrative.[217] The narrative is centered on a metaphor which Lamarck introduced to illustrate the gap between an organism’s characteristics and the environment; Lamarck speaks of “besoins” which conveys strong humanoid overtones and translates either as ‘desire’, ‘wish’ or ‘need’. (Lamarck 1873a [1809]: 94, 98, 109)[218] This term gives rise to the interpretation that the Agents in Lamarck’s theory are the organisms themselves, who, in a gradually changing environment with limited resources (Scene), use or disuse certain organs (Agency) to volitionally satisfy their “besoins” (Purpose), improve their adaption and develop into higher forms (Act).

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215 Wolfgang Lefèvre argues that, in Lamarck’s scheme, two higher organisms need not be genetically related to the same lower organisms; their predecessors are of the same kind but need not be the same individual. It seems to me that this argument presupposes that the races in Lamarck’s model are populations in the modern sense, i.e. groups of organisms which live and breed together in a specific area at a specific time. This, however, is not Lamarck’s understanding, to whom a race is a set of all individual organisms on the same level of development; members of such a Lamarckian race need not live or breed together. (Lefèvre 2001: 198, 200)

216 In a nutshell, Lamarck expresses his theory thus: “Le produit des circonstances comme causes qui amènent de nouveaux besoins, celui des besoins, qui fait naître les actions, celui des actions répétées qui crée les habitudes et les penchants, les résultats de l'emploi augmenté ou diminué de tel ou tel organe, les moyens dont la nature se sert pour conserver et perfectionner tout ce qui a été acquis dans l'organisation, etc., sont des objets de la plus grande importance pour la philosophie rationnelle.” (Lamarck 1873a [1809]: 28)

217 I do disagree with Wolfgang Lefèvre in that the reception of this narrative is a misinterpretation of Lamarck. At most, it is a reception of Lamarck’s narrative without the underlying model, something which also occurred to Darwin and seems a common phenomenon in the reception of scientific theories. Lamarck’s text clearly conveys this narrative – whether Lamarck intended to do so or not. (Lefèvre 2001: 200)

218 Mayr (1984: 268-9) points out that the use of ‘besoin’ recalls an essay by Denis Diderot where Lamarck might have borrowed the metaphor.

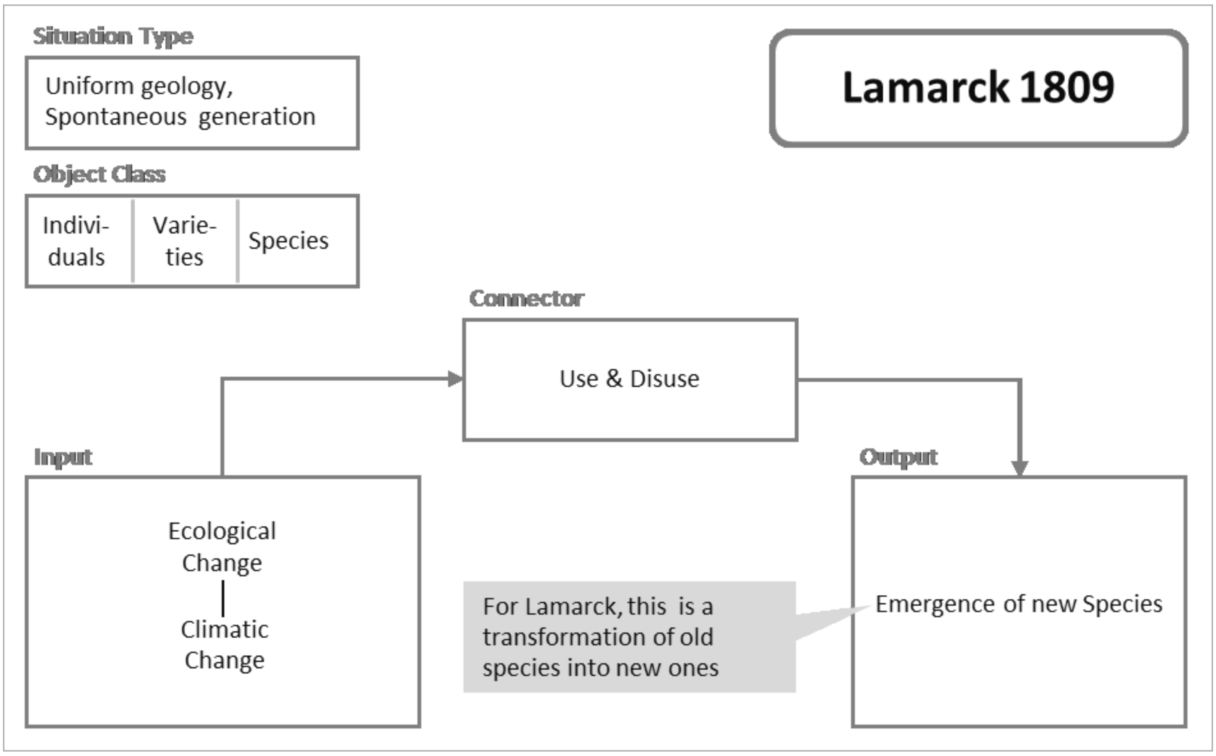

Figure 10: Lamarck's dynamic model of evolution

Certainly, Lamarck's text contains the usual references to God, who, for instance, instituted the natural order (Perrier 2009 [1884]: 68), yet he link God closely enough to the actions which produced the modifications. In line with the French mainstream, Lamarck's God was non-interventionist and remained in the narrative's background. (Lamarck 1873a [1809]: 74)[219] Consequently, it is the former interpretation[220] which shaped the reception of Lamarck's theory and fueled both its dissemination and its rejection: Even if the animals' needs and wills eventually served God's will, it was simply inacceptable to most of Lamarck's readers to grant a will or volitional actions to animals. It is not, however, that Lamarck was merely opposed for the ontological implications of his narrative. Instead, his model was squarely attacked for its shaky empirical grounds, most uncompromisingly by his colleague at the *Muséum National*, Georges Cuvier.

viii. Cuvier: a static nature, governed by divine will

Cuvier (1769-1832) had been raised and educated in the countryside and, as a young adult, devoted himself to independent studies of natural history. It was only in the spring of 1795 that he moved to Paris where he became an assistant in comparative anatomy at the Muséum National. In 1799, he

[219] As for Nature, Lamarck explicitly dismissed that it should be considered an Agent: "La Nature, ce mot si souvent prononcé comme s'il s'agissait d'un être particulier, ne doit être à nos yeux que l'ensemble d'objets qui comprend : 1° tous les corps physiques qui existent; 2° les lois générales et particulières qui régissent les changements d'état et de situation que ces corps peuvent éprouver; 3° enfin, le mouvement diversement répandu parmi eux , perpétuellement entretenu ou renaissant dans sa source, infiniment varié dans ses produits et d'où résulte l'ordre admirable de choses que cet ensemble nous présente." (Lamarck 1873b [1809]: 349)

[220] For a prominent such reading, see Thomas Henry Huxley's 1878 article for the Encyclopedia Britannica. (Huxley 1893a [1878])

succeeded Louis-Jean-Marie Daubenton (1716-1799)[221] as a professor of natural history at the Collège de France. In the first decades of the 19th century he was probably the best-known French naturalist and certainly the most respected throughout Europe.[222] Cuvier was a founding father of both stratigraphy/paleontology (see above) and of comparative anatomy, the latter together with Lamarck.

After initial work on invertebrates Cuvier moved to vertebrates, specializing in mammals. It was here that Cuvier had his greatest anatomical achievements. He identified important new regularities, for instance that no carnivores have horns and that only herbivores bear hooves. He summed such regularities up as the principle of a "correlation of parts" and the knowledge of such regularities enabled him to predict much of the overall form of an organism from relatively few parts – a skill which much impressed the public.

More importantly, however, these regularities provided clear criteria for classification. Cuvier was working much more in a spirit of Linnaeus than Buffon; his goals were to develop classifications which simplified identification and to identify organizing principles behind these classifications: the correlation of parts. In identifying numerous such regularities Cuvier advanced zoological taxonomy greatly[223] and provided many of the principles on which Darwin's explanation could rely.[224]

In line with his catastrophism, Cuvier denied that the geological record displayed anything like increasing perfection or increasing complexity, explicitly attacking Lamarck: while some organs of a given organism increased in complexity, others decreased; there was no overall trend. Moreover, he denied that it was possible to demonstrate continuity even among living organisms. Instead, Cuvier distinguished four major embranchements[225] and several distinct smaller units and disputed that these may be mapped on any kind of continuous scala naturae. Last, he disputed the magnitude of biogeographical effects. While well-aware of the existence of variations, Cuvier denied that they touched any "essential" attributes of a type; they were limited to superficial features as colour or size but did not alter organs or the general proportions of an organism.[226]

When Cuvier published a compilation of his empirical studies in 1811, two years after Lamarck's *Philosophie Zoologique*, he emphasized how "the facts" displayed diversity and difference throughout nature and he rejected all speculation about a general unity in nature or evolution. On Cuvier's account, animals were perfectly adapted to their environment or they developed everything

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[221] Daubenton was an excellent anatomist himself and had worked with Buffon. Moreover, he was an important science manager and selected many of the natural history professors who were appointed in the 1790s in Paris.

[222] Particularly the British were fascinated with Cuvier's systematic empirical work and his restraint in speculation. Unlike Lamarck's and Geoffroy's, Cuvier's work enjoyed an important reception in Britain, most notably *Animal Kingdom* (1817).

[223] Among his many „firsts", animals which he described for the first time, was the charming red panda which Cuvier named *Ailurus fulgens*, cat with shining coat, and which he considered the "most beautiful mammal" on earth. Today, the red panda is an endangered species and the subject of a WWF-campaign against its extinction. #saveredpanda

[224] For Botany, a similar feat was accomplished by the German botanist Friedrich Wilhelm Benedikt Hofmeister (1824-1877), notably in his *Vergleichende Untersuchungen der Keimung, Entfaltung und Fruchtbildung höherer Kryptogamen* (1851). (Mayr 1984: 174)

[225] These embranchements were mollusks, anthropoids, radiata and vertebrates.

[226] One supposed piece of evidence against variability were the mummified animals Geoffroy had discovered in Egypt. (1798) As these animals closely resembled contemporary ones, they seemed to demonstrate the immutability of species.

they needed to survive from preexistent "germs". Thus, their structure always satisfied their respective "conditions of existence" they were designed for the place they occupied in nature. In terms of biological history, the present species had always been what they are; they resemble earlier forms only insofar as these had lived in similar environments and there existed neither intermediate forms nor modified ancestors. (Hoßfeld and Junker 2001: 57)

This view of the animal kingdom complied with Cuvier's overall view of nature as immutable. In-between the occasional catastrophes, Cuvier's models of both geology and biology were static. Consequently, Cuvier never presented a dynamic model to explain the processes of natural history. To him, these processes had nothing unforeseeable and thus displayed nothing which required explanation. Organisms simply filled out the slots in the taxonomic system which they were supposed to fill. *How* organisms came into being after the revolutions was no problem he would discuss.[227]

In sum, Cuvier's was the argument from design: God had designed the earth and all the life on it. His will was visible in all organisms; their purpose was the perfect adaption to their conditions of existence, which, themselves, were a product of divine will. Considering this narrative, it is not surprising that the British admired Cuvier. He married meticulous empirical description to a theistic understanding of nature. Cuvier's God was just the same personal and intervening God as the one in the British natural theology. In sum, Cuvier's narrative was much closer to William Paley's *Natural Theology* than to his Parisian colleagues Lamarck and Geoffroy.

When Cuvier died in 1832, his legacy as an anatomist was unrivalled and he had gained important followers, among them the Swiss-born American Louis Agassiz (1807-1873) and Richard Owen who had stayed with Cuvier in 1831. (see section 3) As Owen recalled in retrospect, Cuvier stayed firm in his positions to the end. (1868: 780-94) In 1830, the year after Lamarck's death he reaffirmed that there was no serious empirical proof for evolutionary changes. Although Cuvier was aware of the evidence which had led Lamarck and, later, Geoffroy (see below) to champion evolution, he dismissed the paleontological record as insufficient to support such claims. In 1832, this position was still a reasonable one: the most challenging fossils for the Cuvier's account would appear after his death, many important ones only after the publication of the *Origin*. Still, at Cuvier's death, evolution had become more than an extravagant thought in Buffon's quiver or an unempirical speculation of German philosophers; it had become a serious scientific hypothesis.

ix. Geoffroy: evolution – in a quieter gown

A major reason for this gain in credibility was its endorsement by another influential Parisian naturalist: Étienne Geoffroy Saint-Hilaire (1772 –1844). Geoffroy had studied natural philosophy in Paris and was appointed one of the twelve professorships at the newly-founded *Muséum National d'Histoire Naturelle* in 1793, at age twenty-one. Geoffroy's professorship was in zoology and his area of expertise was vertebrates. At the same time, Geoffroy was among the pioneers of embryology, exploiting the embryonic development and rudimentary organs as biological knowledge sources. [228] These novel sources would reveal genetic relationships and allow for much more precise taxonomic classifications. (Perrier 2009 [1884]: 84)

[227] Cuvier also dismissed the hypothesis of spontaneous generation.

[228] The Swiss naturalist Charles Bonnet (1720-1793) and the Estonian-German Karl Ernst Ritter von Baer (1792-1876) made other important contributions in the generation before and after Geoffroy.

Contrary to Cuvier's focus on distinction and difference, Geoffroy's ambition was to explain the marked resemblances of animals. From 1795 on, Geoffroy championed ideas of unity in nature. In his eyes, all living beings followed a "unified plan of composition" and this plan can best be seen on the various forms within a class. One indication for the existence of such a plan were rudimentary organs. Geoffroy observed that, within taxonomic groups, certain organs rarely disappear but remain in the body and occupy the same place in it. To Geoffroy, the body was a system, a set of communicating organs and the communication pattern displayed a "unity of type".

Geoffroy's claims of unity stood in direct opposition to Cuvier's claims about the diversity of living forms. Once friends, the two naturalists developed a fierce rivalry throughout the 1820s, which culminated in a celebrated series of debates before the *Académie Royale des Sciences* in Paris. The point of debate was the two organizing principles behind Cuvier's and Geoffroy's theories, i.e. the designed adaption of organisms to their "conditions of existence" versus the "unity of type". Geoffroy stressed the deep resemblance of the internal anatomy of organisms and Cuvier emphasized how closely the structure and function of organisms fitted their environment. In the public eye, Cuvier's static view of nature won the battle but an important group of biologists would stand with Geoffroy.[229]

Parallel to his rivalry with Cuvier and after Cuvier's unexpected dead in 1832, Geoffroy began to develop evolutionary views. In the late 1820s, Geoffroy studied fossil reptiles which showed surprising similarities with recent crocodiles. (Geoffroy Saint-Hilaire 1835: 198; cf. Mayr 1984: 288; Perrier 2009 [1884]: 83) In his essay *Influence du monde ambiant sur les forms animales* (1833) he sought an explanation for these similarities which would integrate the unity of plan but also differences of form and function. Like Lamarck, he came up with an unbroken genetic chain. (Owen 1868: 767) However, he went further than Lamarck; while Lamarck had postulated that the extinct races had been transformed into higher ones, Geoffroy included their extinction in his model. [230]

Geoffroy was well-aware that the paleontological evidence was not yet sufficient to support his views.[231] However, in his late work *Etudes progressives d'un naturaliste* (1835) he furthered his claim, supposing "a single system of creations that are incessantly reworked, perfected, and integrated with previous changes under the all-powerful influence of the external world." (Perrier 2009: [1884]: 86) As Lamarck had twenty-six years earlier, Geoffroy would attempt to provide a dynamic model (explanation) of the changes which had brought about his "single system of creations".

As in Lamarck's, the Input of Geoffroy's model were ecological changes and the Output were modifications, or, alterations of form. Geoffroy, however, did not claim the Lamarckian preservation of species. Instead, in an anticipation of an important feature of Darwin's argument, Geoffroy distinguished between "favorable" and "fatal" modifications. The former would lead to a better adaption to conditions, the latter to the extinction of the type and its replacement by other types. As

229 One of them was Goethe, who avidly followed the Parisian debates and supported views like Geoffroy's.

230 The difference is not big, however, maybe just a question of the reference group. In his own words, Geoffroy claims that "les races actuelles sont le produit de la même création continuellement successive et progressive, et qu'elles sont réellement descendues, par une filiation non interrompue, des anciennes races aujourd'hui perdus." Thus, while the members of the old races have become extinct, some of their descendants now form new races. One might consider this a transformation. (Geoffroy Saint-Hilaire 1835: 117)

231 The lack of gradual transitions in the paleontological record led him to speculate about more abrupt transformations, for instance from lower vertebrates to birds. (Mayr 1984: 289)

for the Connector[232] of his explanation, Geoffroy did not refer to use or disuse but to respiration. He hypothesized that the environment had an influence on the respiration and a modified respiration would lead to gradual – small, step-wise – alterations in form. (Geoffroy Saint-Hilaire 1835: 117-9) These alterations, however, were not random; they were activations of an inherent, pre-existing potential within the realm of the unity of type. (Perrier 2009 [1884]: 83) New material for such modifications was provided by continuous spontaneous generation, similar to Lamarck's model. (See Figure 11)

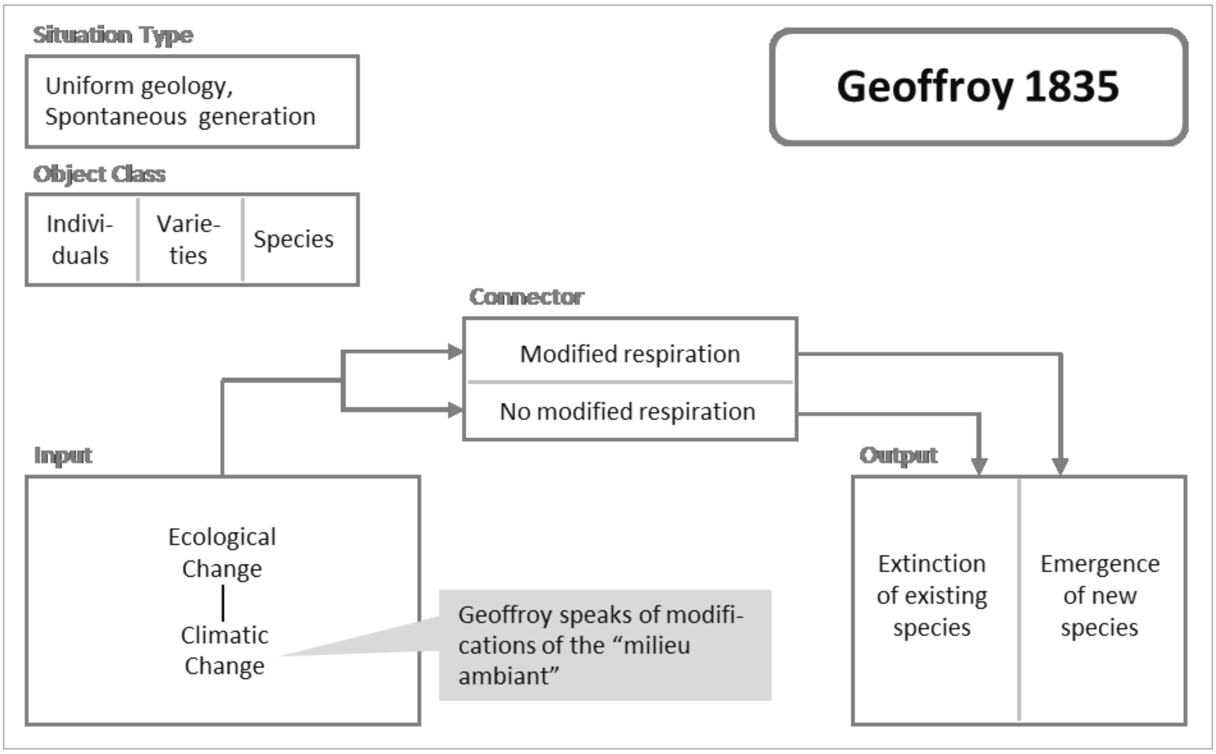

Figure 11: Geoffroy's dynamic model of evolution

Geoffroy's model was embedded in a rather naturalistic narrative. He described Nature – with a capital 'n' – as an "admirable machine" which carries out the biological processes and produces the modifications which result in the single system of creations. (Geoffroy Saint-Hilaire 1835: 132) Geoffroy clearly mentions God and his creation in the "etudes métaphysiques"-section of his book and praises him very explicitly in his conclusion. (Geoffroy Saint-Hilaire 1835: 188-9) Still, this is not the theistic discourse of Cuvier or Paley. Geoffroy's God remains in the background and does not intervene directly.[233] Thus, either God or Nature can be understood as the Agent in Geoffroy's narrative, a twist which Darwin would employ in the Origin, too.[234] The most intuitive reading seems, however, to consider God the Agent. The Purpose is, supposedly, God's Will, the Act are the organism's modifications, the Agency the changes in the environment which trigger the modified

[232] Mayr may be understood such that Geoffroy did not postulate a Connector which would mediate between environmental changes and the resulting physiological modifications. Such a reading is sometimes termed 'Geoffroyism'. It seems inadequate, however, as Geoffroy clearly postulates that the environmental changes lead to a modification of the respiration and only the latter, successively, leads to a modification of organs. (Mayr 1984: 288-9)

[233] Instead, just as Darwin would, Geoffroy alludes to the physical laws of Kepler and Newton and compares his model to theirs.

[234] Darwin seems not to have read the later works of Geoffroy, so there probably exists no direct relation.

respiration of the organisms. The Scene is not much specified but Geoffroy believed in a constantly changing environment without regular catastrophes and new creations.

In order to support the Connector he had postulated, Geoffroy carried out experiments on chicken embryos, subjecting them to different conditions in order to trigger such modifications. He did not find any such proof but he suggested a new research paradigm: the investigation of environmental influences on the structure of organisms. (Perrier 2009 [1884]: 85) Thus, in 1835, Geoffroy suggested that biologists leave the dissecting room and explore the field. At the same Darwin, aboard the Beagle since 1831, was already travelling South America. He was not inspired by Geoffroy, however, as he had not read his later works.[235]

x. Synthesis: the state of biological knowledge and beliefs around 1840

A systematic overview of biological knowledge is best provided by distinguishing three kinds of empirical regularities[236]: (i) regularities on and between different organisms, (ii) regularities of organisms in space, (iii) regularities of organisms in time. These regularities stem from different biological sub-disciplines with different methods: (i) The first kind of regularities was produced by anatomy, histology, morphology, osteology and physiology, among others.[237] These regularities are synthesized in taxonomic classifications which sort organisms by shared anatomical, histological, morphological, osteological or physiological features. (ii) The second kind of regularities was produced by biogeography which studies the distribution of organisms in space.[238] (iii) The third kind of regularities was produced by ontogeny and embryology as well as paleontology, both of which investigate the development of organisms in time. Ontogeny studies the development of an organism during his life-span; embryology focuses on its maturation. Paleontology studies the regularities of fossils to geological strata, which are interpreted as indications of the development of large groups of organisms over long periods of time. – Another kind of regularities in time were principally known to biologists, but not yet integrated in their knowledge: the changes of organisms over generations, particularly the laws of inheritance.[239] For the most part, these regularities remained the knowledge of practitioners, i.e. of breeders and gardeners.[240]

In terms of shared beliefs, (i) there were different interpretations of classifications, displaying some kind of Aristotelian scale or at least an overarching unity, as in Geoffroy's unity of type. Others, as Cuvier, disputed such ideas. (ii) The regularities of biogeography were interpreted as indicative of an adaption of organisms to the environment, which might either indicate underlying principles of divine design or stem from environmental influences. With respect to this environment, quite a number of authors expressed ideas about a war or struggle in nature, throughout the history of

[235] Thus, Geoffroy's work of the 1830s is still not mentioned in the Historical Sketch of the 3rd edition of the Origin of Species. (Darwin 1861: xiii-xix)

[236] They are mentioned in the order in which they were integrated into biology.

[237] Histology studies the microscopic anatomy of cells and tissues of organisms. Morphology studies outward appearances like shape, structure, color or pattern as well as the form and structure of the internal organs. Osteology studies the structure of bones, skeletal elements, and teeth. Physiology studies the functions of organs and entire organisms.

[238] One of the pioneers of the disciplines was the German geologist and paleontologist Christian Leopold von Buch (1744-1853) who was one the first to describe the role of isolation in biology.

[239] As for special cases, the German botanist Friedrich Wilhelm Benedikt Hofmeister (1824-1877) established the alternation of generations (metagenesis) for plants in 1851.

[240] Mendel's revealing experimental results would be published but in the late 1860s. (see below)

biology, among them Aristotle, Linnaeus, Herder, Lamarck and Geoffroy.[241] (iii) As for the regularities in time, many biologists held ideas of spontaneous generation, often as a continuous process which was still at work; others rather believed in a single or in successive divine creations after major catastrophes. In the latter case, the creation usually encompassed all kinds of organisms and implied a static view of nature; outside the creations, organisms did not develop from one form into another. Those who believed in spontaneous generation where more inclined to hold evolutionary beliefs. The most sophisticated evolutionary thinkers, Lamarck and Geoffroy, had suggested dynamic models of evolution. Where a narrative supplemented the static or dynamic models of biology, it contained God as its core Agent. Lamarck, however, had championed secondary Agents, and Geoffroy could be read in the same way, personifying the concept 'Nature'.

Each of the three domains of empirical regularities had produced or was producing *objects which challenged* the established beliefs. (i) Throughout the 19th century, more and more novel organisms were discovered. It was an immense challenge to taxonomists to integrate this endless flow in a pertinent and systematic fashion into existing classifications. Particularly, taxonomists found it difficult to develop a system by which to classify. (Voss 2007: 106-7; Hodge 1972: 128) (ii) Biogeography revealed that the regularities between the type of organisms and the physical environment were not bijective; regions of similar climate and geography sometimes displayed very different organisms. Such, if organisms were adapted to their physical environment, they were not adapted in the same way.[242] (iii) Paleontology produced fossils which did not resemble any living creatures and which differed greatly over geological strata. Finally, embryology revealed that embryos of different species resembled each other much more than the respective adult organisms. In adult organisms, these shared embryonic features were visible in rudimentary organs.

Table 7 summarizes the shared knowledge and knowledge sources, the shared beliefs and mental models as well as the challenging objects, distinguished by types of empirical regularities around 1840.

	Regularities on and between organisms	**Regularities in space**	**Regularities in time**
Shared knowledge from	Anatomy, Morphology, Osteology, Physiology, Histology	Biogeography	Ontogeny (incl. embryology), Paleontology
Challenging objects	Problems of classification of living organisms	Different organisms in regions of similar climate and geography	Rudimentary organs, Intermediate fossils
Important beliefs (interpretation and narrative)	Scala naturae, Unity of type	Divine design, Adaption to the environment	Spontaneous genera-tion, Repeated catas-trophes & repeated

241 I will discuss the question, which one of these authors inspired Darwin in section 5.1 vi. My main line of argument will be that the concept of struggle does not stem from a single author, but was shared and very basal mental model of biology, which Darwin would modify and integrate in his explanation. This goes against Desmond's and Moore's claim that Darwin borrowed the concept from de Candolle's *Organographie Végétale* and, possibly, learned of it during a visit to Darwin in 1839. (Desmond and Moore 1995: 323)

242 Let me highlight that, in principle, this was already formulated in Buffon's law.

			creations OR continuous transformation of organisms and extinctions
Influential beliefs (ontology)	Agents in Biology: God, Nature, Organisms		

Table 7: Shared knowledge, beliefs, mental models, challenging objects in biology ca. 1840

xi. The specificities of the scientific and public debate in Britain around 1840

While the progress of empirical biology accelerated throughout the 1820s and 1830s and evolutionary theories were freely and publicly discussed on the continent, Britain remained in the firm grip of Natural Theology. Moreover, clerical and conservative scientific forces reaffirmed their claims in one famous debate of the 1830s: the Bridgewater Treatises.

Initiated by the Earl of Bridgewater (1756-1829), on his deathbed, the eight treatises were supposed to explore "the Power, Wisdom, and Goodness of God, as manifested in the Creation".[243] The treatises were a stern defense of Paley's Natural Theology against the deistic influences from the continent, particularly from France and Germany. (Amundson 2007: xv-xvi) In their theistic world-views, they combined the argument from design with the idea of divine providence. In the former, one inferred from the order and harmony of nature the existence of a benevolent God. It was argued that if the human mind was able to conceive the natural order and the laws of nature as purposeful then they bore witness to God's purpose. (Ellegård 1958: 114-5,125) The idea of divine providence consisted in the

> "conviction that the world was placed under the watchful guidance of a higher power ... Without Divine supervision, one held, everything would disintegrate into chaos, for only chaos could result if the universe were left to the action of chance and blind, inexorable laws. Design and Purpose, the attributes of a Mind, were needed to create and sustain a Kosmos." (Ellegård 1958: 102)

The overruling goal of the treatises was to demonstrate the applicability of theological thinking to science. Consequently, the eight treatises were devoted to biology (human and zoological), physics (incl. astronomy and meteorology), chemistry, geology and mineralogy. The two most prominent authors were probably the philosopher William Whewell (1794-1866)[244] and the geologist William Buckland (1784-1856). [245]

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243 Their exact title says just that, it reads "The Bridgewater Treatises On the Power Wisdom and Goodness of God As Manifested in the Creation". From his large fortune, the Earl of Bridgewater donated 8.000 £ to finance the treatises.

244 Note that the two quotations which faced the title page of the 1859 *Origin of Species* stemmed from Francis Bacon (1561-1626) and William Whewell and that the Whewell quotation came from his Bridgewater treatise.

245 The eight treatises and their authors are these: Treatise I, by Thomas Chalmers: The Adaptation of External Nature to the Moral and Intellectual Constitution of Man. Treatise II, by John Kidd, On the Adaptation of External Nature to the Physical Condition of Man. Treatise III, by William Whewell. On Astronomy and General Physics. Treatise IV, by Charles Bell. The Hand: Its Connector and Vital Endowments as Evincing Design. Treatise V, by Peter Mark Roget. Animal and Vegetable Physiology Considered with Reference to Natural Theology. Treatise VI, by William Buckland. Geology and Mineralogy Considered with Reference to

Buckland, with Adam Sedgwick (1785-1873), Charles Darwin's geology professor in Cambridge, was among those geologists who opposed deistic models as James Hutton's on religious grounds. To these "clergyman-naturalist" (Rupke 1994: 212), the visible earth had been created after the last great flood and the living animals were descendants of those which had been saved on Noah's ark.[246] Man had been created in God's own image and all other organisms had been designed and placed on Earth specifically for the place which they now occupied.

This practice science directly related to the specifically Mid-Victorian branch of philosophy of science championed by William Whewell.[247] In this branch, scientific explanation consisted in the identification of "real" or "true" causes (*verae causae*), i.e. causes which could be tracked back to God.[248] Whewell expresses this very explicitly:

> "In contemplating the series of Causes which are themselves the effects of other causes we are necessarily led to assume a Supreme Cause in the Order of Causation, as we assume a First Cause in Order of Succession…" (op.cit. Ellegård 1958: 178-9)[249]

Those phenomena which could not be explained by *verae causae*, were explained as direct divine interventions and called 'miracles. In Mid-Victorian science, miracles where fully legitimate explanations.[250]

Unsurprisingly, this scientific establishment in Britain abhorred the theoretical works from the continent. The pious and theory-averse Cuvier, who had died in 1832, was still held in high praise and his *Animal Kingdom* appeared in several English editions throughout the 1840s and 1850s. (cf. Cuvier 1854) The works of his Parisian colleagues Lamarck and Geoffroy or their great predecessor Buffon, however, remained reserved to readers of the original French editions.[251] The same is true for the German theorizing. When Richard Owen, in 1847, initiated a translation of works by the German idealist Lorenz Oken, he caused a public uproar. (Rupke 1994: xiv)

Consequently, British the natural sciences were decidedly cautious about theorizing and hypothetical reasoning of their own:

> "Speculation about unobserved causes was discouraged. Unlike the question of species origins, the form function debate concerned observable body parts, not

Natural Theology. Treatise VII, by William Kirby. On the History Habits and Instincts of Animals. Treatise VIII, by William Prout. Chemistry, Meteorology, and the Function of Digestion.

246 When geological evidence began to contradict the previously held 6.000 years (see above), conservative geologists like Sedgwick and Buckland modified their accounts of the geological history since the great flood, but they clung to their biblical framework.

247 The other great British philosophers of the time, John Stuart Mill (1806-1873) and astronomer-philosopher John Herschel (1792-1871), held much more liberal and progressive views.

248 Considering God an Agent in a scientific theory was quite intuitive to most of Darwin's contemporaries; after all, they had grown up in the spirit of Natural Theology and "had been accustomed to look at their study as a parallel to that of theology." (Ellegård 1958: 102) To them, Natural Theology was supposed to furnish the "empirical grounds for religious belief" (Ellegård 1958: 114).

249 'Supreme Cause' and 'First Cause' are other names for God here. (Ellegård 1958: 178-9, cf. Hull 1973: 56) The term 'First Cause' dates back at least to Thomas Acquinas (1225-1274) and reflects Aristotle's concept of the unmoved mover, i.e. the ultimate cause of all things.

250 For instance, in his reception of the *Origin of Species,* Adam Sedgwick explicitly supports miracles as explanations. (Sedgwick 1973[1860]: 161)

251 As it is in history, one is never sure that something does not exist. I know of no English translations of Lamarck, Geoffroy or Buffon nor of any mention of them. Therefore, I suppose that they do not exist.

> historically remote events. The discovery of law-like generalizations about observable bodies was thought to be a more suitable goal for a conscientious scientist than the quest for ultimate causes." (Amundson 2007: xv)

Such reserve was even more pronounced in biology and geology than in physics. The closer the science to Man, the less theorizing seemed adequate. Thus, biology

> "meetings and journals were filled with papers on systematics, notes on sightings of rare forms in Britain, and long descriptive accounts of the flora and fauna of exotic and domestic locales. These empirical studies were supported by the philosophical dicta proclaimed in addresses, prefaces, and debate: since induction was the only way to do natural history, no empirical observation was useless; and natural theology was the ultimate justification for the close study of nature. 'Through Nature to Nature's God' was not only a common epigraph emblazoned on title pages, it was a deep, shared assumption of most gentlemen naturalists.[252]" (England 1997: 270)

It is not that this conservative mainstream was not opposed in Britain. The Bridgewater Treatises received harsh criticism and some scorn, for instance by Robert Knox (1791-1862), an Edinburgh surgeon and morphologist, who referred to them as "Bilgewater Treatises".[253] Another remarkable opponent was the mathematician and Church of England priest Baden Powell (1796-1860). He was an outspoken deist, advocating mechanistic explanations in the sphere of biology and claiming that the belief in miracles was atheistic. (Desmond and Moore 1995: 467) Powell publicly expressed support for evolution and would defend both Robert Chambers and Charles Lyell in his writings.[254]

However, while known to many scientists and parts of the educated public, such opposition did not reach the mainstream public, where evolutionary ideas were associated with radical movements and ignored. As Richard England puts it, they were

> "rarely found among gentlemen. Just as its proponents - radicals of various stripes - transgressed against social codes, so the doctrine of transmutation transgressed against the philosophical codes of natural history. Transmutationism[255] [evolution] was speculative rather than inductive, and promoted a less-than-orthodox view of God's creative action." (England 1997: 270)

To the less educated, the question was simpler. Evolution, whatever it exactly implied, definitely contradicted a literal understanding of the bible:

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252 One explanation for the continuous dominance of conservative positions in the British natural sciences might be the social composition of its community. British scientists of the time mostly still were gentlemen amateur scientists like Charles Darwin. The professionalization of the French or the German sciences would reach Britain only in the 1850s and 1860s when men like botanist Henry Walter Bates (1825-1892), zoologist Thomas Henry Huxley (1825-1895) or Alfred Russel Wallace (1823-1913) climbed the institutional ranks of science and occupied important posts despite coming from modest social backgrounds. Richard Owen (1804-1892) is an early exception to the rule of the 1830s and 1840s as he made a career just like Huxley or Wallace would make two decades later.

253 Another notable critic was the American writer Edgar Allan Poe (1809-1849).

254 In his contribution to the orthodox collection *Essays and Reviews*, in early 1860, Powell would also praise Darwin's *Origin*. He did not live, however, to experience the Darwinian revolution, dying weeks before the 1860 meeting of the British Association for the Advancement of Science with its debate between Huxley and the Bishop Samuel Wilberforce (1805-1873). (Desmond and Moore 1995: 365-6)

255 The term 'transmutationist' is one of the several synonyms for views which, today, we call 'evolutionary'.

> "Christian or heathen, most people, and above all the uneducated paid much more attention to the theory's contradiction of the plain statements of the Scriptures. The ordinary religious man [in Britain] hardly accepted the existence of any other religion than the revealed religion of the Bible. Abstruse philosophical arguments on final causes and supernatural interpositions meant little to him: the Bible meant the more." (Ellegård 1958: 155)

In the same spirit, both, the educated and the uneducated public, dismissed one possible consequence of evolution, namely that Man had descended from the apes instead of Adam. Despite the arrival of the first ape specimen in Britain in the 1830s[256], such views seemed too improbable. (Ellegård 1958: 299, 332, 311-329; Hull 2005: 149)

In this climate, Robert Chambers and Richard Owen published their first evolutionary works and set the tone of the first large controversy in the 1840s. In Wallace's and Darwin's work of the late 1850s and 1860s, the debate would culminate.

[256] Richard Owen published on dissections of an Orang in 1831 and of a chimpanzee in 1835. (Rupke 1993: 428)

3 Comparative analysis of theories: The revolution which Darwin suggested

3.1 Robert Chambers: Vestiges of the Natural History of Creation

The most popular British book on evolution and the one which might have shaped most the public reception of Darwin's Origin stemmed from a layman or, at best, an amateur scientist. In 1844, the publicist Robert Chambers published his *Vestiges of the Natural History of Creation* and landed an immediate and spectacular success.

Chambers had been born to a middle-class family but his family suffered financial reverses when he was still young. To earn a living, Robert and his older brother William started an antiquarian book business and went into publishing. First they printed books of general knowledge; however, in 1832 they established *Chamber's Edinburgh Journal*, a successful weekly which had a considerable influence on the intellectual life in Edinburgh and Britain.[257] (Schwartz 1990: 128-9; Ruse 1979: 99; Lynch 2000a: x)

Chambers was "a self-taught amateur naturalist"[258] with an expertise in Scottish history and some in geology and biology. (Schwartz 1990: 127-9) He had received no formal training in the sciences[259] but displayed a profound interest in scientific phenomena, their interpretation and ontological implications. He frequently discussed scientific topics and presented rudimentary ideas of evolution in his journal. (Schwartz 1999: 343)

In October 1844, Chambers published *Vestiges* – anonymously. The book appeared in eleven editions from 1844[260] to 1860 and in one posthumous edition in 1884, which finally revealed the author's name. It sold more than 28.000 copies, 21.000 of which before the publication of the *Origin of Species* in 1859.[261] Additionally, Chambers published six editions [CHECK] of *Explanations*, a sequel which addressed his main criticism and was supposed to provide further explanation and explication of his model of evolution and its ontological implications.

The popularity of both his books was much fueled by the anonymity of its author:

[257] Lynch describes the journal as "an eight-page weekly costing three halfpence, [which] reached a circulation of approximately 60,000 during its first ten years" and quotes Chambers with the mission of providing "a meal of healthful, useful and agreeable mental instruction" for even the "poorest labourer in the country". (Lynch 2000a: x)

[258] As Lynch points out, Chambers did not see himself as a scientist but rather as a natural philosopher; his ambition was to "synthesize the writings of the professionals in a manner that was not only novel but in a form that would educate the masses". (Lynch 2000a: xix; cf. Hodge 1972: 132)

[259] Chambers had, however, access to scientific publications and scientists themselves due to his membership in learned societies.

[260] Darwin had already written his sketch in 1842 and his essay in 1844, thus his principal ideas were not influenced by the *Vestiges*.

[261] The editions in December 1860 and 1884 still accounted for one fourth of the total sales.

> "For many readers, the most arresting feature of Vestiges was the lack of an author on the title page. More than anything else, this rendered it a sensation. Here was a work dealing with the most profound questions of existence, apparently in command of a dozen different sciences, but written by an unknown author." (Secord 2000: 17)

In *Vestiges*, Chambers seeks answers to two questions (Hodge 1972: 137; Lynch 2000a: xv): (i) How did life originate on earth? (ii) How did the present species develop from these first forms of life?

Thus, Chambers goes further than his scientific counterparts Darwin and Owen (see below): he seeks to explain not only the formation of different species but, generally, the origin of life. From his point of view, such an explanation would identify laws governing the living world for "the cosmological world has evolved through law, [thus], by analogy it is reasonable to suppose that the organic world also evolved through law." (Ruse 1979: 100)[262]

To make his case, Chambers offers a *tour de force* through a simplified, popularized version of the scientific knowledge of his time. (Secord 2000: 10; Lynch 2000b) He begins by describing the wonderful harmony in the solar system and citing a Laplacean model to explain how planets could have formed from nebulae of matter[263]:

> "Of nebulous matter in its original state we know too little to enable us to suggest how nuclei should be established in it. But, supposing that, from a peculiarity in its constitution, nuclei are formed, we know very well how, by virtue of the law of gravitation, the process of an aggregation of the neighboring matter to those nuclei should proceed, until masses more or less solid should become detached from the rest." (Chambers 1845 [1844]: 9)

Chambers states that "the formation of bodies in space is still at present in progress" and claims that the laws governing such formations "are established on a rigidly accurate mathematical basis. (Chambers 1845 [1844]: 15) Proportions of numbers and geometrical figures rest at the bottom of the whole." (Chambers 1845 [1844]: 16-7) In Chemistry, Chambers identifies the same harmony, identifying fifty-five chemical elements. (Chambers 1845 [1844]: 21) After an extensive discussion of geology and paleontology Chambers proceeds to biology and again identifies a lawful and "general progress of organic development throughout the geological ages" (Chambers 1845 [1844]: 110) which had produced perfect and harmonious unity (Chambers 1845 [1844]: 123).

Given all this lawfulness and harmony, Chambers argues that there must be a "First Cause" behind those secondary causes discernible by Man, a "Great Being" acting through law (Chambers 1845 [1844]: 19):

> "The masses of space are formed by law; law makes them in due time theatres of existence for plants and animals; sensation, disposition, intellect, are all in like manner developed and sustained in action by law. It is most interesting to observe into how small a field the whole of the mysteries of nature thus ultimately resolve

262 Hodge identifies this as Chambers core problem: "Given a lawfully formed earth, to get all its life onto it, lawfully." (Hodge 1972: 137)

263 Chambers here follows the then-fashionable theory that "the solar system was formed from a molten mass of matter (a nebula), out of which planets condensed as the mass rotated and cooled. The production of the universe from a primordial cloud …" (Lynch 2000a: xvi) When better telescopes dissolved the observed nebulae into distinct stars, Chambers weakened the reference to this "nebular hypothesis".

themselves. The inorganic has been thought to have one final comprehensive law, GRAVITATION. The organic, the other great department of mundane things, rests in like manner, on one law, and that is DEVELOPMENT. Nor may even these be after all twain, but only branches of one still more comprehensive law, the expression of a unity, flowing immediately from the One who is First and Last." (Chambers 1845 [1844]: 251)

3.1.1 Description: What evidence did Chambers present how?

Neither in *Vestiges* nor in *Explanations*, did Chambers present original or novel evidence. Moreover, what he does present is second-hand – except maybe for geology, where he had carried out some field research of his own and provides rather detailed descriptions of higher geological strata and the traces of organic life found in them. Specifically, he mentions sea plants and corals (Chambers 1845 [1844]: 39-46), fishes (Chambers 1845 [1844]: 47-55), land plants (Chambers 1845 [1844]: 56-68), reptiles & birds (Chambers 1845 [1844]: 69-75), mammals (Chambers 1845 [1844]: 76-84), transitional periods in which superior types appear: "a clear progress throughout, from humble to superior types of being" (Chambers 1845 [1844]: 90) and the present species appear (Chambers 1845 [1844]: 99-107).

Chambers mentions a number of scientific theories and models of the time, but this is mostly name-dropping; he provides few detailed descriptions of concepts such as spontaneous generation or the nebular hypothesis and he fails to link them to empirical evidence. Moreover, in their application, Chambers committed several serious scientific blunders, most of which, however, would be corrected in later editions with the help of sympathizing scientists. (Schwartz 1990: 130, 140)

3.1.2 Classification: How did Chambers aggregate and denote evidence?

Considering how superficial and unspecific his descriptions of organisms are, it is not surprising that Chambers employed a very much idealized scheme to organize them, namely the 'quinary' system of the British entomologist William Sharp Macleay. Macleay's system neatly classified all organisms "into sets of five distinct types, each divided into five subsets, and so on…" and had enjoyed a brief period of popularity[264] among British naturalists. (Ruse 1979: 104; Lynch 2000a: xiv; Chambers 1845 [1844]: 181)[265]

Among these harmonically arranged specimen, Chambers identified a clear progress "from simpler to higher forms of organization"; to him "there is no room to doubt of a general advance of organization". (Chambers 1845 [1844]: 90, 110, 144; cf. Ruse 1979: 108) As Darwin would a couple of years later, Chambers admits that the geological record does still display some "obscure passages",

[264] When Chambers published the *Vestiges, however*, it was already falling out of favor because less regular schemes fit the available evidence better.

[265] References to a botanical scale can be found in (Chambers 1845 [1844]: 65; Chambers 1846 [1845]: 47, 66, 74), to an animal scale in (Chambers 1845 [1844]: 91, 96, 143, 144, 150, 152, 171, 233, 241, 242, 270; Chambers 1846 [1845]: 47, 66, 74) and to a general scale or "scale of creation" in (Chambers 1845 [1844]: 81, 144, 171-2, 180, 241; Chambers 1846 [1845]: 94, 115, 137, 205). Chambers presents an overview on his mapping taxonomic groups on the scale in 1845: 172, in near full compliance to the quinary system.

yet these blanks could be filled by “a candid mind”. (Chambers 1845 [1844]: 111) Consequently, Chambers specifies clear hierarchies among organisms:

> “Amongst plants, we have first sea weeds, afterwards land plants; and amongst these the simpler (cellular and cryptogamic) before the more complex. In the department of zoology, we see, first, traces all but certain of infusoria; then polypiaria, crinoidea, and some humble forms of the articulata and mollusca; afterwards higher forms of the mollusca; and it appears that these existed for ages before there were any higher types of being. The first step forward gives fishes, the humblest class of the vertebrata; and, moreover, the earliest fishes partake of the character of the lower sub-kingdom, the articulata. Afterwards come land animals, of which the first are reptiles, universally allowed to be the type next in advance from fishes, and to be connected with these by the links of an insensible gradation. From reptiles we advance to birds, and thence to mammalia, which are commenced by marsupialia, acknowledgedly low forms in their class. That there is thus a progress of some kind, the most superficial glance at the geological history is sufficient to convince us. Indeed the doctrine of the gradation of animal forms has received a remarkable support from the discoveries of this science, as several types formerly wanting to a completion of the series have been found in a fossil state.” (Chambers 1845 [1844]: 110-1)

Chambers justifies these hierarchies by anatomical resemblances, particularly in rudimentary organs and by resemblances between foetal features of different classes. (Chambers 1845 [1844]: 148, 71; Hodge 1972: 141) Thus, he highlighted that “various as may be the lengths of the upper part of the vertebral column in the mammalia, it always consists of the same parts.” (Chambers 1845 [1844]: 148) Likewise, he emphasized resemblances between embryonic fish and fossils and interpreted them as indicative of evolutionary links. (Chambers 1845 [1844]: 160)[266]

The evolutionary relations among these types and classes, however, he depicted as more complex than proponents of a classical scala naturae because he assumed: “…the gradation [in organisms] is much less simple and direct than is generally supposed. It certainly does not proceed, at all parts of its course at least, upon one line …” (Chambers 1845 [1844]: 143; Chambers 1846 [1845]: 69) Thus, instead of a single ascending line, Chambers suggests a line with deviations.[267]

These deviations are restricted, however. Organisms may deviate from the line of hierarchical ascent but such deviations will lead to specific and well-defined classes:

> “The foetus of all the four classes may be supposed to advance in an identical condition to the point A. The fish there diverges and passes along a line apart, and peculiar to itself, to its mature state at F. The reptile, bird, and mammal, go on

[266] In these arguments, Chambers considers classes of organisms as representative of single types and ignores their individual differences. Thus, he ignores the empirical evidence on which Darwin and Wallace built their models and the Darwinian theory. (cf. Hodge 1972: 146; sections 3.3.1, 3.4.1)

[267] Richards, among others, argues that the form of the diagram was inspired by a diagram which the English zoologist William Carpenter employed to depict the embryology of Karl Ernst von Baer, the Estonian naturalist and founding father of embryology. (Richards 1987a: 137)) Carpenter’s diagram resembles Chambers’ closely with the two exceptions (i) that the deviating lines do not point upwards but deviate in a right angle from the main line and (ii) that Carpenter organized the classes differently on the joints.

> together to C, where the reptile diverges in like manner, and advances by itself to R. The bird diverges at D, and goes on to B. The mammal then goes forward in a straight line to the highest point of organization at M. This diagram shows only the main ramifications, but the reader must suppose minor ones, representing the subordinate differences of orders, tribes, families, genera, & if he wishes to extend to the whole varieties of being in the animal kingdom." (Chambers 1845 [1844]: 160)

In the sequel to *Vestiges*, the 1846 *Explanations*, specified his scheme and introduced subordinate lines[268] to the main ones of his original diagrams. (Chambers 1846 [1845]: 70-1; Ruse 1979: 101)

> "…development has not proceeded, as is usually assumed, upon a single line which would require all the orders of animals to be placed one after another, but in a plurality of lines in which the orders, and even minuter sub-divisions, of each class, are ranged side by side." (Chambers 1846 [1845]: 69; cf. Lynch 2000a: xv)

Thus, within each class, one may construct other small trees through which the orders, tribes, genera etc. are divided. Figure 12 depicts both the original taxonomic scheme from *Vestiges* and a possible visualization of the modified scheme which is described in *Explanations*.

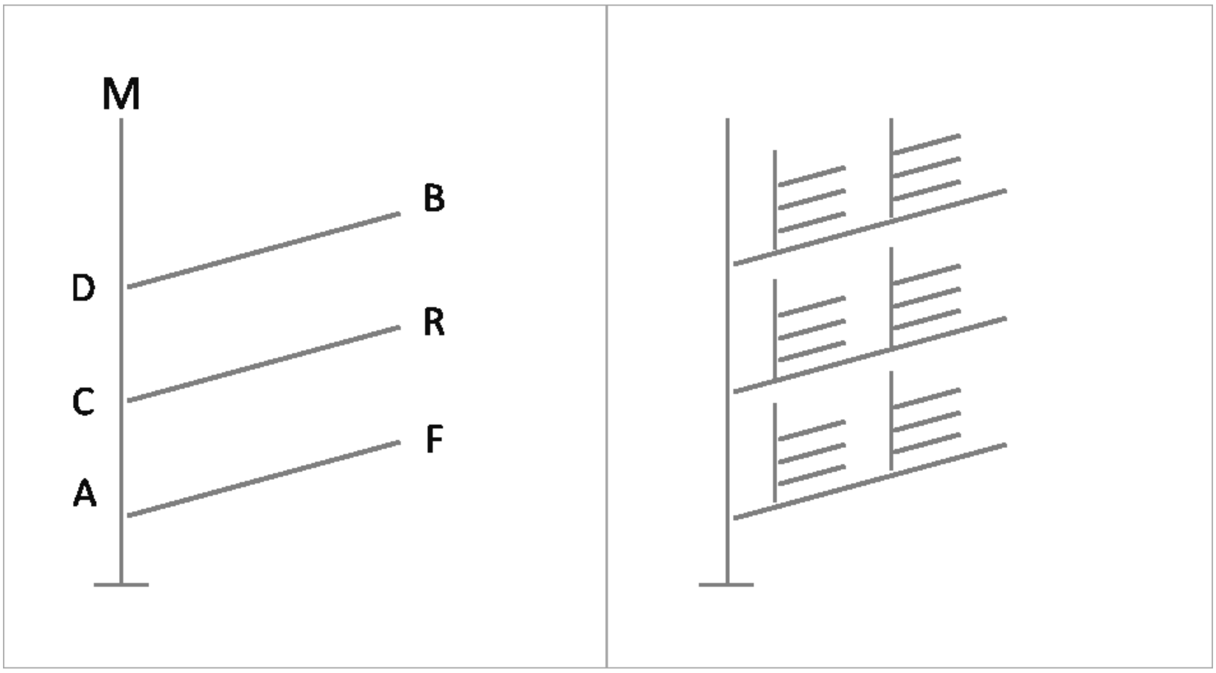

Figure 12: Chambers' model of evolution in Vestiges (left) and Explanations (right) [269]

Man, being the highest organized mammal, is at the top of Chambers' diagram. He appeared only when "the land and sea had come into their present relations, and [land]… had acquired the irregularity of surface necessary for man". (Chambers 1845 [1844]: 113) According to Chambers, Man is set apart from the plants and animals by his ability to speak. (Chambers 1845 [1844]: 216)

[268] Chambers referred to the subordinate lines as 'stirpes'. (Chambers 1846 [1845]: 70)

[269] The figure on the left is a reproduction of Chambers' actual diagram in the *Vestiges*. The letters denote: F – fish, R – reptile, B – bird, M – mammal. A, C and D denote generic diverging points. – The right-hand image is described in *Explanations*, but not actually depicted. I attempt to visualize Chambers' description here without fully complying with the quinary system (the number of branches is not dividable by five). I am unsure as of how to do this and Chambers did not specify this point in *Explanations*.

Moreover, Chambers employs language as a criterion of distinction among humans. In his view, higher races have more complex languages, i.e. more syllables. (Chambers 1845 [1844]: 219) Thus, by degree of development he distinguishes:

> "1. The Caucasian, or Indo-European, which extends from India into Europe and Northern Africa; 2. The Mongolian, which occupies Northern and Eastern Asia; 3. The Malayan, which extends from the Ultra-Gangetic Peninsula into the numerous islands of the South Seas and Pacific; 4. The Negro, chiefly confined to Africa; 5. The aboriginal American." (Chambers 1845 [1844]: 193)

In sum, Chambers aggregates classes of plants and animals as well as orders tribes, genera etc. in a clear-cut hierarchical scheme. He interprets ascents in this scheme as a development from lower to higher forms. – How does he model and explain this development?

3.1.3 Logical explanation: How did Chambers model evolution?

i. Object Class: groups of organisms, but no individuals

First of all, the objects of Chambers' model are species and varieties. He refers to both throughout his works, although less to varieties. He does not specifically mention individuals or individual differences. (Chambers 1845 [1844]; Chambers 1846 [1845]) In compliance with the static model of his theory, Chambers understands his Object Class as the first beings and all their successors. He does not describe them in detail nor does he endow them with specific capacities to trigger evolution – although he grants them the "inherent qualities" to undergo it. (Chambers 1845 [1844]: 251)

ii. Situation Type: gently developing environment

Chambers embeds his explanation in a geological framework which holds references to both Cuvier's catastrophism and Lyell's uniformitarianism, but more to the former. Thus, while Chambers claims that "the same laws and conditions of nature now apparent to us have existed throughout the whole time", he does not claim that they operate at the same intensity; instead some of the conditions may have "come to a settlement and a close." (Chambers 1845 [1844]: 109) Thus, he is not limited to the linear and uniform geological time-frame which Lyell championed. Moreover, Chambers clearly supports the idea of an early general "destruction of many forms of organic being previously flourishing, particularly of the vegetable kingdom" (Chambers 1845 [1844]: 67), and he speculates about "a universal submersion" which likely had led to extensive destruction of land animals (Chambers 1845 [1844]: 105-6). From this, Chambers concludes that "the creation of our own species is a comparatively recent event and one posterior (generally speaking) to all the great natural transactions which have been here described." (Chambers 1845 [1844]: 107)

As for the environment in which the organisms now live, Chambers considers nature to be generally stable and well-designed. Therefore, organisms fit their environment, they are "appropriate" to the "external physical circumstances". (Chambers 1845 [1844]: 153-4) They are not, however, specifically adapted to it. (Ruse 1979: 116) Instead, when one type differs from another one in similar climate or geography, one type is more advanced than the other, i.e. higher on the hierarchy of Chambers diagram:

> "Development has not gone on to equal results in the various continents, being most advanced in the eastern continent, next in the western, and least in Australia, this inequality being perhaps the result of the comparative antiquity of the various regions, geologically and geographically." (Chambers 1845 [1844]: 190-1)

The environment is not static, it undergoes change. It is important, however, that this change is lawful. Chambers devotes the first part of *Vestiges* to present his popularized version of the laws of the physical and chemical world and the processes that formed the earth to demonstrate just how lawful the physical world "evolves" (sic!); it all follows the divine plan.

Chambers addresses the idea of a continuous spontaneous generation and the question of the origin of life. In Chambers view, the "first step in the creation of life upon this planet was a chemico-electric operation by which simple germinal vesicles were produced". (Chambers 1845 [1844]: 154-5) This reaction has taken place on different places simultaneously (Chambers 1845 [1844]: 190) and its Agent was God:

> "That God created animated the beings, as well as the terraqueous theatre of their being, is a fact so powerfully evidenced, and so universally received, that I at once take it for granted. […] The ordinary notion may, I think, be described as this,- that the Almighty Author produced the progenitors of all existing species by some sort of personal or immediate exertion." (Chambers 1845 [1844]: 115)

Chambers does not exclude further spontaneous generation but limits it to the lower organisms for one could only

> "expect to find the life-originating power at work in some very special and extraordinary circumstances, and probably only in the inferior and obscurer departments of the vegetable and animal kingdoms." (Chambers 1845 [1844]: 132)"

Thus, Chambers dismisses traditional and religiously motivated explanations in the British context which suggested that every novel species occurred by special creation. However, if spontaneous generation produced only lower organisms, Chamber had to suggest an explanation of how species had evolved from the first living forms into the higher ones. (Ruse 1979: 101)

iii. Output: evolved lower animals

Chambers understands the development of organisms as the realization of potentials which were already present in the organisms.[270] Hence, Chambers sees an analogy between the development of a single organism and the development of classes of organisms: the first develop by growing into mature beings, the latter by producing a higher type.[271] (Ruse 1979: 99; Hodge 1972: 138)

This led him to borrow the term 'evolution' to denote the result of his development.[272] (Chambers 1845 [1844]: 257, 277; Chambers 1846 [1845]: 24, 143, 151) It no longer refers only to development within the life-span of a single individual but to the development of classes of individuals over several

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[270] This much resembles Owen's claims about laws of development and its modern reception in evolutionary developmental biology. (See section 5.2 iv)

[271] Chambers discusses this analogy himself in the autobiographical preface of the 10th edition of *Vestiges*.

[272] Note that both words have the same linguistic.

life-spans. This is a clear case of metábasis, a reinterpretation of an existing concept, and leads Chambers to employ 'evolution' in the sense in which we employ it today and in which, later, Darwin's theory would be called the "theory of evolution".

Consequently, higher organisms can be understood as evolved forms of lower ones, or, in Michael Ruse's terminology, overdeveloped forms: "An overdeveloped fish is hence no longer a fish but a reptile, and so on." (Ruse 1979: 103)[273] This transmutation progresses step-wise along the lines of Chambers' diagram:

> "The idea, then, which I form of the progress of organic life upon our earth – and the hypothesis is applicable to similar theatres of vital being – is, *that the simplest and most primitive type, under a law to which that of like-production is subordinate, gave birth to the type next above it, that this again produced the next higher, and so on to the very highest*, the stages of advance being in all cases very small – namely, from one species only to another; so that the phenomenon has always been of a simple and modest character." (Chambers 1845 [1844]: 170-1; his emphasis)

The common root of organisms, however, is still visible in the embryo:

> "…in the reproduction of the highest animals, the new being passes through stages in which it is successively fish-like and reptile-like. But the resemblance is not to the adult fish or the adult reptile, but to the fish and reptile at a certain point in their foetal progress…" (Chambers 1845 [1844]: 160; cf. Ruse 1979: 103)

These common features, in return, lead Chambers to stress the continuous relation between higher animals and their lower counterparts; all of them are

> "products of the Divine Conception, as well as ourselves. All of them display wondrous evidences of his wisdom and benevolence. […]" (Chambers 1845 [1844]: 179)

This continuity goes so far that Chambers postulates the possibility that an organisms recedes back to the type from which it developed. (Chambers (1845: 16) Distinctions, however, are still possible and justified, particularly with respect to Man:

> "The leading characters … of the various races of mankind are simply representations of particular stages in the development of the highest or Caucasian type." (Chambers 1845 [1844]: 214)

There is one important obstacle to Chamber's idea of clear saltations, however. The visible similarities between organisms do not display clear distinctions. Therefore, Chambers denies the validity of such visible similarities:

> "In reality, [similarities between species] are only identical characters demanded by common conditions, or resulting from equality of grade in the scale. True affinities –

[273] Chambers hardly provides any specific evidence for these saltations. First, he describes cases were oat seemingly had regressed into rye. (Chambers 1845 [1844]: 166; cf. Ruse 1979: 104) Second, he describes how larva of worker bees can be modified to bear a queen, a case of advancement in Chambers' logic. (Chambers 1845 [1844]: 162; Ruse 1979: 104)

> and these are the affinities of genealogy – are not to be looked for horizontally amongst orders, but vertically, from an order in one class to the corresponding order in the class next higher." (Chambers 1846 [1845]: 72-3)[274]

One part of the Output, however, is hardly discussed: extinctions. Chambers mentions them several times in *Vestiges* and *Explanations*, but does not attempt to explain them in any detail. (Chambers 1845 [1844])

iv. Input: changing climatic conditions, exhaustion of prolific energy

It is lawful change which triggers this advancement of organisms through evolution. In the beginning, species and the climate all over the earth were uniform. Only with a diversification of the climate did species begin to diversify:

> "… the geographical distribution of plants and animals was very different in the geological ages from what it is now. Down to a time not long antecedent to man, the same vegetation overspread every clime, and a similar uniformity marked the zoology." (Chambers 1845 [1844]: 192)

After the initial "chemico-electric operation"[275] advancement occurred "under favor of peculiar conditions"[276]. (Chambers 1845 [1844]: 155) Hence,

> "the multitudes of locally peculiar species only came into being after the uniform climate had passed away. It may have only been when a varied climate arose, that the originally few species branched off into the present extensive variety." (Chambers 1845 [1844]: 192)

What specifically constitutes such "peculiar conditions", Chambers did only speculate.[277] Moreover, some conditions can lead either to an advancement towards a higher type and or the retrogression towards a lower one: "Give good conditions, it advances; bad ones, it recedes." (Chambers 1845 [1844]: 164)

With respect to extinctions, Chambers offers only very vague possible triggers. In *Explanations*, he speculates that a species may become extinct when its "prolific energy" is exhausted. (Chambers 1846 [1845]: 187) However, Chambers does not explain how the term 'prolific energy' relates to empirical observations. Therefore, I do not consider it part of his model.[278]

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[274] This passage reminds of Owen's homologies but is probably no reception. Owen introduced the concept of homology in 1843, but the dissemination within the scientific community began only in the 1850s (section 4.3.3). An amateur like Chambers would probably have received it still much later.

[275] This is a synonym for 'spontaneous generation'.

[276] Chambers asks a similar question to the one Darwin would later ask. He argues that there exist "striking proofs of the effect of conditions upon organic development. Who is to say where this power of conditions has its limit?" (Chambers 1845 [1844]: 169)

[277] For instance, he suggested that an increased concentrations of oxygen or light were responsible for the advancement from one type to another. (Chambers 1845 [1844]: 175)

[278] One might consider it to be part of the narrative but Chambers does not develop his narrative with respect to extinctions as a possible Act. Thus the "exhaustion of prolific energy" is not developed as an Agency but remains an isolated metaphor.

v. Connector: the law of development, longer gestation

In Chambers' model, this environmental change triggers the operation of a "law of development in the generative system" (Chambers 1845 [1844]: 164) and an inherent potential finds its expressions. Normally, like produces like but "…sometimes, because of external conditions, the embryonic stage is prolonged so that the organism develops … into the embryo of a higher organism, and thus a new species is created." (Ruse 1979: 103; Schwartz 1990: 129; Hodge 972: 142)[279]

One might wish to call this process 'saltational' because, in Chambers' logic, there are 'jumps'[280] from one type to another without intermediate forms.[281] Chambers is rather vague about the process supposed to produce these jumps. On the one hand he mentions "slight delays in gestation" which may be understood as a reference to Geoffroy's model. On the other hand "inherent qualities" and the "organization" of the organism which are responsible for the transmutation, which sounds more like a design idea. (Chambers 1845 [1844]: 251; Lynch 2000a: xv) In Explanations, he speaks of extinctions being the result of laws. (Chambers 1846 [1845]: 95)

What Chambers does, however, is introduce the fancy name 'development' for his process, an analogy from physics:

> "The masses of space are formed by law; law makes them in due time theatres of existence for plants and animals; sensation, disposition, intellect, are all in like manner developed and sustained in action by law. It is most interesting to observe into how small a field the whole of the mysteries of nature thus ultimately resolve themselves. The inorganic has been thought to have one final comprehensive law, GRAVITATION. The organic, the other great department of mundane things, rests in like manner, on one law, and that is DEVELOPMENT. Nor may even these be after all twain, but only branches of one still more comprehensive law, the expression of a unity, flowing immediately from the One who is First and Last." (Chambers 1845 [1844]: 251, his emphasis)

vi. Summary

In sum, Chambers presents a clear-cut but incomplete dynamic model: if climate change occurs and triggers the law of development (by addressing the inherent qualities of organisms for longer gestation), then higher organisms evolve from lower ones in an orderly succession. Extinction, is not linked to any discernible empirical Input. The Situation Type is best characterized by spontaneous generation and a mixture of uniformitarianism and catastrophism. The Object Class are varieties and species. Figure 13 provides an overview over Chambers' model.

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279 This may be a reception of Geoffroy, who describes modified respiration as leading to structural changes. (See section 2.3 ix) There is no direct reference to him but Chambers dissociates himself from Lamarck (Chambers 1845 [1844]: 176-7) and not from Geoffroy. Assuming that he received both, this is remarkable.

280 Obviously, the length of the jumps depends on the number of different types and sub-types that are distinguished, a matter on which Chambers is not very precise.

281 These supposed saltations are also one of the rare cases were Chambers provides explicit empirical evidence. First, he describes cases were oat was believed to have regressed into rye. (Chambers 1845 [1844]: 166; cf. Ruse 1979: 104) Second, he describes how larva of worker bees can be modified to bear a queen, a case of advancement in Chambers' logic. (Chambers 1845 [1844]: 162; Ruse 1979: 104)

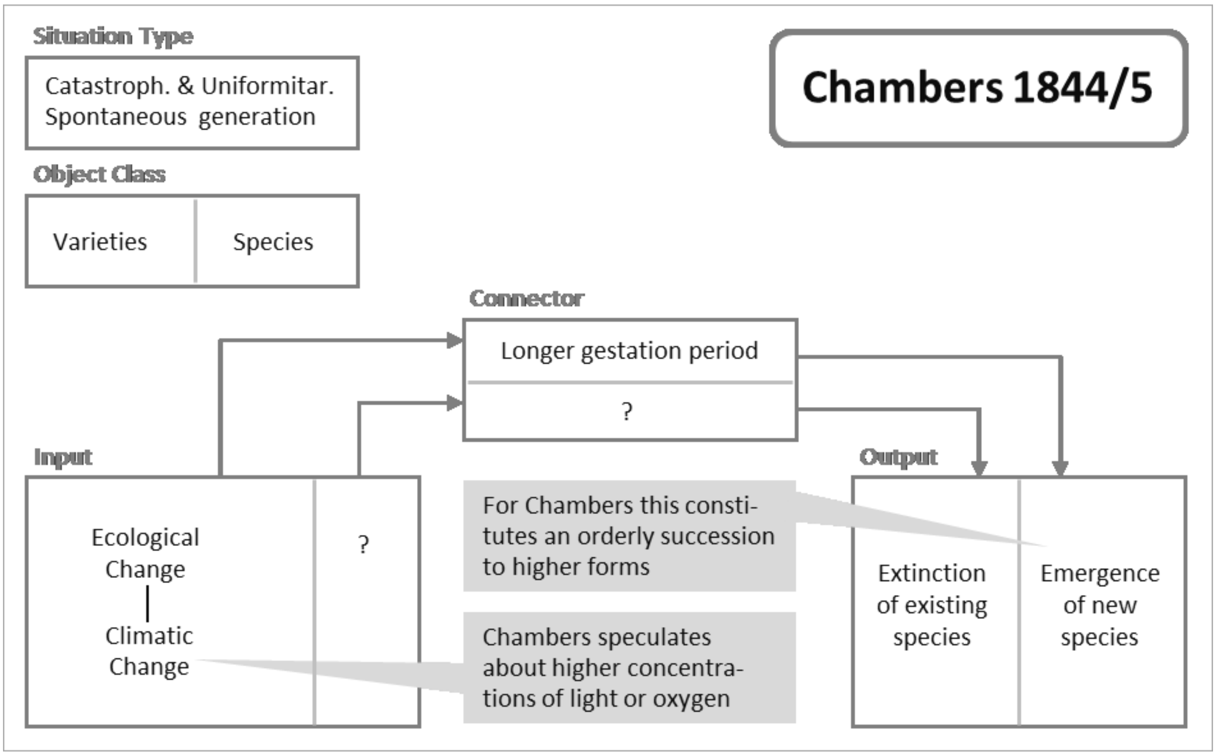

Figure 13: Chambers' dynamic model

3.1.4 Narrative explanation: How did Chambers tell evolution?

Additionally, Chambers conveys a strong narrative by providing both an Agent and a Purpose to the event sequence covered by his dynamic model.

i. Agent: God

God is everywhere in *Vestiges*; to Chambers, any lawful process is divine and any event the outcome of divine intention and plan. God is the mindful, thorough and methodical Creator behind everything Chambers describes, he is the “divine programmer” analogous to Charles Babbage’s *Analytic Engine*. (Lynch 2000a: xv)

In this view, God remains the sole Agent, but not in the sense that he constantly intervenes in every process but by developing laws which guide all processes to the ends he intends. In this sense, Lynch believes that, above all else, “Chambers was attempting to formulate a theodicy and to understand the mind of god. Vestiges, far from reflecting atheistic ideology, clearly assumes that a unitary divine being was responsible for the natural laws that brought everything into being ...” (Lynch 2000a: xxi)

Chambers is aware that he thus propagates a novel image of God, which went against the idea of divine providence, i.e. the idea that a caring God constantly intervenes and takes care of his creatures. (see below) Therefore, Chambers did his best to dissipate such reservations and stressed how much more glorious the idea of a lawmaker-God:

> “It is the narrowest of all views of the Deity and characteristic of an humble class of intellects, to suppose him constantly acting in particular ways for particular occasions. […] for [i]t lowers him towards the level of our own humble intellects.

> Much more worthy of him it surely is, to suppose that all things have been commissioned by him from the first, though neither is he absent from a particle of the current of natural affairs in one sense, seeing that the whole system is continually supported by his providence." (Chambers 1845 [1844]: 117-8)

Chambers' text provides some minor indications of a possible second author besides God, particularly, when he describes that "inherent qualities" in the organisms allow for longer gestation and thus evolution. (Chambers 1845 [1844]: 251) Such interpretation would point in the direction of the popular understanding of the Lamarckian argument. Historians agree, however, that Chambers considered the idea untenable that "needs and wishes in the animals" may have dictated the course of evolution. (Lynch 2000a: xiv; Hodge 1972: 145) Moreover, Chambers stresses that the very "inherent qualities" in the organisms were designed by God. (Chambers 1845 [1844]: 251) Thus, the literary analysis leaves no room for doubt: the Agent in Chambers' narrative is God.[282]

ii. Scene: Lawfully developing environment

The Scene in which God acts is the universe, which is subject to him in all its aspects. He is almighty and rules the domains of the material world (physics, chemistry, geology) as well as the world of the living (biology). Thus, all features of the world bear his mark; everything is lawful and intended change, everything displays harmony and design, the world suits its components.

Such, man did not appear on earth until its physical features allowed to accommodate him:

> "the land and sea had come into their present relations, and [land]… had acquired the irregularity of surface necessary for man". (Chambers 1845 [1844]: 113)

iii. Agency: climate change, inherent qualities

The means by which god acts, are his laws, the observable processes are "represented primarily and pre-eminently as flowing from commands and expressions of will, not from direct acts." (Chambers 1845 [1844]: 117) This is true for both physics and biology:

> "Thus, as one set of laws produced all orbs and their motions and geognostic arrangements, so one set of laws overspread them all with life. The whole productive or creative arrangements are therefore in perfect unity." (Chambers 1845 [1844]: 123)

The laws operating on life, however, are less definite than the laws of mechanics; they can lead to a wide range of phenomena and even to negative effects. The sex passion or excessive eating and drinking are cases in point. (Chambers 1845 [1844]: 253-60)

282 I have also looked for references to a Vital Force in the sense of the German idealist, but those references are rare and the Vital Force is always presented as subdued to God. (Chambers 1846 [1845]: 184, 188; Chambers 1845 [1844]: 136, 209)

iv. Purpose: Design[283]

The Purpose behind the observable processes is God's will for all of the natural laws "are expressions of his will." (Chambers 1845 [1844]: 116) All events on earth (or in the universe) were "devised and arranged for beforehand" and display "preconception and forethought". (Chambers 1845 [1844]: 177) In other words, they are designed (Ruse 1979: 112) and God's design conveys God's intent that "everything should be very good" (Chambers 1845 [1844]: 170-1).

Overall, "Chambers saw the biological world as evidence for the action of a divine hand and, like Whewell, Sedgwick and others, he felt that it was his place to uncover the laws by observing nature (albeit in his case, in a largely second-hand fashion)." (Lynch 2000a: xxi) Consequently, the advancement to man as the top of the creation is planned as well. (Ruse 1979: 104)

v. Act: Evolution as mindful and prearranged development

In the light of this Purpose, evolution appears as a mindfully prearranged process:

> "The whole train of animated beings, from the simplest and oldest up to the highest and most recent, are, then, to be regarded as a series of advances of the principle of development, which have depended upon external physical circumstances, to which the resulting animals are appropriate. I contemplate the whole phenomena as having been in the first place arranged in the counsels of Divine Wisdom …" (Chambers 1845 [1844]: 153-4)

In return, the production of new forms

> "…has never been anything more than a new stage of progress in gestation, an event as simply natural, and attended as little by any circumstances of a wonderful or startling kind, as the silent advance of an ordinary mother from one week to another of her pregnancy. Yet, be it remembered, the whole phenomena are, in another point of view, wonders of the highest kind, in as far as they are direct effects of an Almighty will…" (Chambers 1845 [1844]: 170-1)

In sum, the main vehicle of Chambers' explanation is the Agent: God. Everything in his explanation is tailored to God. He acts trough laws and modifies the physical conditions on earth (Agency), triggering organism to give birth of more developed organisms (Act) according to a law inscribed in them by God (Agency). Neither the Scene nor the Purpose provide much explanatory value; the former being little specified and depending from God's modifications, the latter referring back to God's inscrutable will.

3.1.5 Implications: What did Chamber's explanation imply about the world?

Chambers seems to have been very aware of the possible ontological implications of Vestiges; remarkably, he addressed most of them explicitly. On his account, Man remains atop of Nature –

[283] This version of design bears little resemblance to modern intelligent design, as championed by Michael Behe, for instance. Chambers ' design is rather mindfulness and closer to Paley's ideas.

relatively, but possibly also absolutely for it is questionable whether "the human race will ever advance far beyond its present position in intellect and morals". (Chambers 1845 [1844]: 268-9) The human race might be "of one stock" (Chambers 1845 [1844]: 197, cf. 206), but this is still an open question as

> "The leading characters, in short, of the various races of mankind, are simply representations of particular stages in the development of the highest or Caucasian type." (Chambers 1845 [1844]: 214; cf. 207)

Thus, it is one possible implication of *Vestiges* that the ancestors of the British gentlemen and ladies had lived in the same "barbarian" state as some of the "uncivilized" peoples, even more as Chambers' puts Man in one continuous series with the lower animals, all of which are

> "part products of the Divine Conception, as well as ourselves. All of them display wondrous evidences of his wisdom and benevolence. […] Let us regard them in a right spirit, as parts of a grand plan which only approaches its perfection in ourselves, and we shall see no degradation in the idea of our genetic connection with them, but, on the contrary, reason incontestable for treating them in the manner which we already feel that a high morality demands." (Chambers 1845 [1844]: 179)

> "The very faintest notion of there being anything ridiculous or degrading in the theory – how absurd does it appear when we remember that every individual amongst us actually passes through the characters of the insect, the fish, and reptile (to speak nothing of others); before he is permitted to breathe the breath of life!" (Chambers 1845 [1844]: 178)

Hence, Chambers champions a unity of nature and presents this unity as a positive image.

God clearly is the sole Agent in Chambers' universe and despite the naturalness of Chambers' evolution and the lack of divine interventions therein, Chambers' God maintains a close relationship with Man:

> "Something in our nature – as it appears to me – tells us that the Author of the universe is nearer to us, is in a more familiar and paternal relation to us than would seem to be implied by a theory which represents him as only an author of laws." (Chambers 1845 [1844]: 274-5)[284]

Since around 1800, ideas of evolutionism had been denounced in Britain as examples of dangerous materialism, which undermined natural theology and the argument from design, threatening the current moral and social order. In this sense, the dynamic and egalitarian nature of Chambers' Vestiges could be understood as a threat to the stable social order of Victorian Britain (or other hierarchical and vastly unequal societies), as both Secord and Lynch point out:

> "[Vestiges] is a book about evolution for the people, and the evolving self-identity of 'the people'. […] Reading about evolutionary progress offered common questions to bridge divides that threatened the nation's stability. Controversies about class and

[284] This much resembles the modern position of the Catholic Church, exemplified for instance by this statement of Joseph Ratzinger, the later pope Benedict XVI., in his Schöpfungsglaube und Evolutionstheorie. (Ratzinger 1977)

> gender-among many potentially explosive issues-could thereby be subsumed into discussions of nature's progress. Hence the significance of the Vestiges sensation for new literary forms such as popular science and the realist novel, and its larger role in making "the people" a central category of the industrial order.” (Secord 2000: 5)

“Chambers, along with Lyell and Darwin, was in the forefront of those who fought against this static view of nature, … Chambers' mechanism of rapid saltational (almost revolutional) change no doubt directly confronted this viewpoint, despite his belief in distant divine control.” (Lynch 2000a: xvi)

3.2 Richard Owen's accounts of evolution between 1848 and 1868

Richard Owen was born in 1804, in Lancaster, as one of six children of a merchant. His father, however, died when Owen was five years and he had to begin his career from modest means. In 1820, after grammar school, Owen was apprenticed to a local surgeon and first witnessed post-mortem dissections. In 1824, he enrolled at Edinburgh University as a medical student but remained only half a year, quickly moving to the St. Bartholomew's Hospital in London, where he was appointed prosector to the lectures of the eminent surgeon John Abernethy and could specialize in anatomy. In 1825, he became a member of the Royal College of Surgeons and one year later, at the age of 22 was made assistant curator at the Hunterian Museum, occupied with the preparation of the catalogues of the Hunterian collections. In 1831, Owen spent several months with Georges Cuvier in Paris, a formative influence.

Owen would remain employed at the Royal College of Surgeons until 1856 when he was appointed Superintendent of the natural history departments of the British Museum. It is during these years at the Royal College that Owen built his career and reputation through a never-ending stream of publications and lectures. In these, he aimed at elevating the status of his discipline to the heights of physics or chemistry, to law-like science. (Padian 2007: lxxxii)

By the 1840s, he was considered the most eminent British naturalist and, in 1856, the Times declared that "[t]han Professor Owen there is not a more distinguished man of science in the country". (op. cit. Rupke 1994: 1) He was admiringly named the "British Cuvier", no less. Around this time, "Owen had become the most publicly visible scientist of the British empire. Seated in the hub of a colonial network of specimen supply, he was the keeper and interpreter of the imperial collections. […] The tide of his popularity with the public and his patrons had risen higher than ever." (Rupke 1994: 97)

Owen employed this power to pursue his second great project besides anatomy: the construction of a museum for the British collections of natural history, equivalent to the *Muséum National d'Histoire Naturelle* in Paris. It was largely due to Owen's incessant campaigns that the natural history collections at the British Museum would be devoted their very own museum, a landmark building in South Kensington. Owen secured the political endorsement and the funds for this tremendous project. At the same time, he changed the public understanding of what a museum should be because he regarded the public as its main addressee and he conceived exhibitions as directed at interested laymen. Nicolaas A. Rupke, in his landmark biography how much of Owens professional career was devoted to these "museum politics". [285] (Rupke 1994) Owen oversaw the museum's construction and would remain its superintendent for two more years after its opening in 1881. He retired in 1883 and died in 1892.

In the 20th century, Owen was mostly known as a formidable anatomist and an opponent to the Darwinian theory of evolution. A more adequate appraisal of his life would focus on his anatomy and

[285] Hence, one could make a case that Owen was an underestimated "popularize of science", a role usually ascribed to the likes of Huxley or Spencer. As Rupke argues, "…for the advancement of Owen's museum plans it was necessary that he reach a far wider audience – an audience that included not only the scientific trustees, but also the politically powerful ex officio ones, and a public whose opinion could be influenced to sway that of the politicians. Reaching such an audience could be achieved only by public lectures, so Owen combined his curatorial duties and scientific studies with an energetic programme of lecturing." (Rupke 1994: 88)

museum politics for his opposition to Darwin was but an episode and even during the tumultuous early 1860's it was not the main focus of Owen's work.[286] Thus, considering Owen "eclipsed by Darwin" is off-target. The topic of evolution was not Owen's focus; his "grand strategy was not to counter Geoffroy, or, much later, Darwin, but to build the most precious collection of museum objects [in order] to force the hands that held the public purse strings." (Rupke 1994: 75) That Owen succeeded in this pursuit there is no question; one result continues to stand tall and proud on South Kensington's Exhibition Road.

Moreover, throughout his career, Owen published more than 600 papers and books, among them many "firsts", i.e. descriptions of formerly unknown organisms.[287] In terms of volume, his body of work outclasses all of his contemporaries, including Darwin. When one flips through the British journals of the time, the number of Owen's papers is impressive; in some volumes, he authored more than half of the papers.

Most of Owen's papers are case studies of single organisms or small groups of organisms. Additionally, Owen published several systematic studies of entire classes of organisms; the best-known are probably his *History of British Fossils* and his *Anatomy of Vertebrates*. Owen never wrote a major theoretical treatise like Chambers' *Vestiges* or Darwin's *Origin*. The 1848 *On the Archetype and Homologies of the Vertebrate Skeleton* and his 1849 *On the Nature of Limbs* are probably his most theory-heavy books and both are long and detailed anatomical studies with a small theoretical discussion in the end.

It is not that Owen had no talent for generalization but he applied it, as Rupke puts it, at a "more specific level" than Darwin. (Rupke 1994: 238) Owen's work focuses on the lower two levels of my framework: description and classification. He provided meticulous descriptions of numerous organisms and a static model according to which he aggregated and interpreted these descriptions. This model, Owen's archetype, was inspired by one of the great biological debates of the nineteenth century – yet not by evolution. Instead, Owen developed the archetype in view of the Cuvier-Geoffroy debate, the confrontation of functionalism and structuralism. (Amundson 2007: xv, xx-xxi) Owen's aim was to reconcile the two sides. (Rupke 1994: 117) Thus, when he compared the feet of the camel and dromedary in his 1849 *Nature of Limbs*, he saw evidence for both design (function) and the unity of plan (structuralism):

> "The comparison of the bones of the extremities is replete with these beautiful evidences of design; but our present purpose is to gather the indications of that which has been sometimes, but wrongly, regarded as the antithetical principle, viz. the unity of plan which lies at the bottom of all the adaptive modifications." (Owen 2007 [1849]: 34)

From Owen's point of view, both principles need not exclude each other:

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286 Actually, (Rupke 1994: 105) points out that Owen's harsh criticism of Darwin in his 1860 review might also be rooted in political conflicts. In mid-1858 "Huxley, Darwin and others had attempted to sabotage Owen's plans" for the Natural History Museum. (Rupke 1994: 97) adds that Owen's institutional power might have fueled the conflict with the Darwinians. It was not merely a struggle over a theoretical concept but probably also about politics and power, particularly in the case of Huxley.

287 Among the most popular are the Dodo, the Gorilla and the Archaeopteryx.

> "Those physiologists who admit no other principle to have governed the construction of living beings than the exclusive and absolute adaptation of every part to its function, are apt to object to such remarks as have been offered regarding the composition of the skeleton of the whale's fin and of the chick's head, that' nothing is made in vain;' and they deem that adage a sufficient refutation of the idea that so many apparently superfluous bones and joints should exist in their particular order and collocation in subordination to another principle; conceiving, quite gratuitously in my opinion, the idea of conformity to type to be opposed to the idea of design."
> (Owen 2007 [1849]: 84)

In sum, Owen's work integrates in a "program intended to build up a 'natural system' out of the artificial taxonomic classifications that had been popular in the eighteenth century", he related his work to Cuvier and Geoffroy, not to Lamarck. (Camardi 2001: 482; cf. Amundson 2007: xxii)

Evolution – or 'transmutation' or 'development', as he called it – did not take center-stage in Owen's research. Throughout the 1830s, Owen had been an advocate of the creation of species and dismissed evolutionary accounts, focusing his critique mainly on Lamarck.[288] Yet, the last time Owen explicitly stated his support for creation was in 1841, in a report to the British Association for the Advancement of Science (BAAS). (Rupke 1994: 221)

Following the publication of Chambers' *Vestiges*[289], Owen changed this position; apparently, Chambers slowly brought him towards a view of transformation – and not an adaptionist one.[290] (Rupke 1994: 223; Cosans 2009: 30; Richards 1987: 130) This showed when Owen turned down several requests to publicly criticize *Vestiges*. Although he disagreed with specific elements, Owen refused to dismiss the entire theory.

In 1848 and 1849, by then well-established in the British scientific system, Owen dared his first step towards evolution, with some cautious passages in *On the Archetype* and in *On the Nature of Limbs*. (Richards 1987a: 158) However, the establishment's critical reaction, particularly the warnings of some prestigious friends in Oxford and Cambridge, quickly stopped Owen in his tracks. In the following years he scattered hints at his position[291] over a couple publications but never wrote down anything close to a consistent theory.

These publications appeared between 1848 and 1868. The period begins with Owen's two important publications on the archetype and concludes in 1868, when the Darwinian revolution was essentially achieved and Owen hardly published on the topic anymore, instead focusing instead on his institutional career. (Rupke 1994: 219) The following important publications fall in this period:

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288 For an analysis of Owen‘s position to transmutation in the 1830s, see Desmond (1985) or Richards (1987), for a comparative analysis of Darwin and Owen describing and interpreting one and the same fossil in the 1830s, see (Rachootin 1985).

289 (Richards 1987: 150) dates Owen's first transmutational thoughts to around 1837, i.e. after Geoffroy's evolutionary work. In his publications, however, the first clear statements seem to appear in the 1840s and, thus, after *Vestiges*.

290 (Hall 2007a: xiii) claims that Owen's view was anti-adaption. I disagree with him, considering how much Owen still embedded his understanding of evolution in arguments from design. (see below)

291 Remember that I will analyze what Owen published on the topic of evolution, hence what could be received. I am not analyzing in what he privately thought. For an analysis which takes into account his position in private letters see (Richards 1987).

1848	On the Archetype of the Vertebrate Skeleton
1849	On the Nature of Limbs
1850	On Didornis
1851	On the Osteology of the Chimpanzees and Orangs
1858	President's Address to the BAAS of 1858[292]
1859	On the Extinction of Species (the Conclusion of the Fullerian Lectures for 1859)
1859	On the Orang, Chimpanzee, and Gorilla. With Reference to the 'Transmutation of Species'
1860	Palaentology
1862	On the aye-aye
1866	On the Osteology of the Dodo
1868	The Anatomy of the Vertebrates

Table 8: Owen's important publications between 1848 and 1868

These publications will be supplemented by others where suitable. Obviously, scattered remarks and single passages impede giving a consistent account of Owen's position on evolution; indeed, Owen provides no such thing as a coherent theory. Moreover, there is ample discussion on just how close Owen's concept of evolution came to that of Darwin or Wallace.[293] The consensus seems to be that Owen could agree with much of Chambers' account but stopped somewhere short of Darwin.[294] Let me specify this with the help of my framework.

3.2.1 Description: What evidence did Owen present how?

Owen was a formidable empirical scientist and published an impressive amount of empirical studies. He was not in the position to tap a fully new source of biological knowledge in the sense that Buffon had tapped into biogeography, Lamarck and Cuvier into comparative anatomy, Cuvier into paleontology, or Geoffroy into embryology. Owen did, however, enlarge the domain of embryology; not only did he consider snapshots of young animals but series of development from younger to more mature to mature animals. Thus, Owen could not only describe how the young exemplars of a species differed from the mature ones but describe the developmental (ontogenic) process which led from one to the other. This was a very resourceful field as, in some species, the young and adult species differed considerably. (Cosans 2009: 21)

Moreover, Owen's institutional position allowed him to access many previously unknown species and to describe them for the first time. Some of the most contested "missing links" in the Darwinian account of evolution[295], had first been described Owen. Among them are the Archaeopteryx, which Owen interpreted as a bird and not as a missing link between birds and reptiles (Owen 1863 [1862]), as well as the Chimpanzee, Gorilla, Orangutan and Aye-Aye. (Owen 1848b; Owen 1859a; Owen 1865; Owen 1862a [1851]; Owen 1866a [1862]).

[292] Owen held the speech three months after the publication of the joint Darwin Wallace paper.
[293] See for instance Richards 1987a; Camardi 2001; Brooke 1977; MacLeod 1965; Cosans 1994; Cosans 2009; Rupke 1993; Rupke 1994; Amundson 2007; Padian 2007; Ruse 1979; Himmelfarb 1959.
[294] Remember that I am not interested in what Owen privately thought or meant about evolution but what he published and what part of his publications was received as relevant for the question of transmutation.
[295] It is important that the Darwinians never contested Owen's descriptions of these "missing links", only Owen's interpretations as them belonging to one specific class and not in between two. (See section v;)

The question of apes was particularly important as it touched the self-image of Man. The possible relation of Man and the apes was already debated in the mid-1830s when “Western science was acquiring some of the first specimens of orangutans and chimpanzees, [and] it was recognized that of all animals these species had the greatest similarity to humans.” (Cosans 2009: 15) At the Hunterian Museum of the Royal College of Surgeons, Owen had access to ape specimens and published on the question from 1837 on. (Cosans 2009: 15)

He compared humans and apes based on three types of features, first of all, qualitative anatomical features of the skull and the brain. In his 1848 article on the Gorilla, Owen identified thirty characteristics in which Man and apes differ, most notably that “gorilla has a smaller brain case, larger supraorbital ridges …. and ‘much larger and longer canines’”. (Cosans 2009: 36-7) In 1857, in a paper read to Linnean society he concentrated on “a peculiar posterior lobe, which is characterized by the posterior horn of the lateral ventricle and the hippocampus minor.”[296] (Cosans 1994: 142) To validate his findings Owen carried out special observations on humans with brain defects and on the brains of blacks and compared both to the Apes. (Cosans 2009: 23, 51)

Owen did not stop there; he underpinned his qualitative findings with quantitative measures:

> “To quantify the differences in brain size between human races and apes, Owen presented tables of cranial capacities. He reproduced a chart in which Wyman (1850) summarizes data[297] collected by Morton, on a total of 464 human skulls ... and in another table he showed the cranial capacities of live gorillas, five chimpanzees, and three adult orangutans.” (Cosans 1994: 141)

Moreover, Owen pursued his extension of Geoffroy’s embryology and cited developmental processes of the brain. He argued that more than qualitative and quantitative absolute measures on adult organisms the dynamics of brain development distinguished apes and humans.

3.2.2 Classification: How did Owen aggregate and interpret evidence?

Owen’s longest-lasting contribution was not an empirical but a systematic one and is still in use today: He introduced the concept of homologies to systematize certain anatomical similarities. (Hall 2007a: x; cf. Hall 2007b) By introducing two basic distinctions, Owen distinguished different kinds of similarities and clarified in what respects organisms could resemble each other, a point which had confused his predecessors, most notably Cuvier and Geoffroy.

First, Owen distinguished analogous similarities and homologous similarities.[298] He defined an analogue as a “part or organ in one animal which has the same function as another part or organ in a different animal” and a homologue as the “same organ in different animals under every variety of form and function”. (op. cit. Amundson 2007: xxii; cf. Ruse 1979: 118-119) These two kinds of similarities reflected the two concepts which had clashed in the Cuvier-Geoffroy-debate. Analogues were supposed to display a similarity of function and thus Cuvier’s adaption to the conditions of

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[296] The latter feature would become the target of Huxley’s criticism in 1860 and would trigger the most prominent debate of the Darwinian revolution. (See section v)

[297] Owen provided a table with the exact measurements from Wyman, a rarity at the time.

[298] Darwin was unaware of this distinction while composing his essay of 1843 but integrated it in his later work, for instance in the Origin. (Amundson 2007: xxiii)

existence. Homologues, on the other hand, reflected Geoffroy's unity of type in that they highlighted how much certain organ resembled each other anatomically without independently of their function.

Second, Owen distinguished three kinds of homologies: homology, special homology and general homology. Reflecting his desire to transform biology into a law-like science[299], Owen did formulate them in laws of homology. (Owen 2007 [1849]: 57; Owen 1848a: 171) They can, however, simply be described as empirical regularities between parts of organisms, most notably vertebrates. Such, serial homology denotes the similarity of repeated elements in an individual body, for instance between the ribs of a rib cage. Special homology is the correspondence between single body parts of organisms of different species, for instance between the fins of fishes and the limbs of mammals.[300] General homology is a combination of the former two, denoting the fact that the special homologies within the body of one species are also homologous to the special homologies in other species, i.e. that the similarities between human ribs exist as well in dogs. Thus, it describes the correspondence of special homology relations between bodies of different species. [301] (cf. Amundson 2007: xxv, cf. Ruse 1979: 118-119)

Based on these distinctions, Owen demonstrated "the entire skeletons of vertebrate groups could be shown to correspond, bone for bone, with those of other vertebrate groups." (Amundson 2007: xxiii) While previous morphologists had noticed some of these similarities, Owen provided the first large-scale systematic account.[302] Moreover, he took this as a starting point for a substantial renaming project in vertebrate anatomy:

> "In The Archetype and Homologies of the Vertebrate Skeleton (1848), Owen catalogued the names by which various vertebrate bones had been designated by the specialist anatomists who had named them [… and] tabulated the various names and descriptions by which all of the bones were (separately) known. He then assigned the corresponding bones the same name, in many cases replacing a long anatomical description with a brief name. Plate I in Limbs contains a numbered list of these

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299 Owen's fascination with laws bore somewhat absurd fruit when he reformulated established empirical regularities as laws. Such he restated biogeographical knowledge in a "law of special modification and adaption … to the exigences and habits and sphere of life of the species" (Owen 1848a: 106), paleontological findings in a law "which has governed the successive introduction of specific forms of living beings into this planet" (Owen 1848a: 106) or a "law of the more generalized character of extinct species" (Owen 1868: 790) or "the progressive departure from general type as exemplified in the series of species from their first introduction to the present time" (Owen 1860a: 407) and, finally, embryonic resemblances in a "law of closer retention of type in the embryo" (Owen 1868: 768). (cf. Padian 2007: lxxxiv)

300 The discovery of this homology was a milestone of Owen's work. (Hall 2007a: x)

301 Amundson points out that the general homology of a bone "extends in three dimensions: serially in the animal's body, especially in its relation to homologues in other vertebrates, and developmentally in the centrum's special relation with the notocord during embryogenesis. The complexity of this illustration shows the importance of general homology to Owen. It would be central to his thought on species origins." (Amundson 2007: xxvii)

302 For instance, Goethe in his „Erster Entwurf einer allgemeinen Einleitung in die vergleichende Anatomie", describes the aspiration of morphology thus: „Die Erfahrung muss uns vorerst die Teile lehren, die allen Tieren gemeinsam sind, und worin diese Teile verschieden sind. Die Idee muss über dem Ganzen walten und auf eine genetische Weise das allgemeine Bild abziehen" und weiter „Indem wir jenen Typus aufstellen und als eine allgemeine Norm, wonach wir die Knochen der sämtlichen Säugetiere zu beschreiben und zu beurteilen haben, … setzen wir in der Natur eine gewisse Konsequenz voraus, wir trauen ihr zu, dass sie in allen einzelnen Fällen nach einer gewissen Regel verfahren werde." (op.cit. Richter and Wirkner 2012) Owen acknowledge Goethe's work in the Archetype. (Owen 1848a: 8)

> names, and the numbers are used throughout the book to designate the homologous bones in all species under discussion." (Amundson 2007: xxiii-xxiv)

Ron Amundson points out an interesting point about this denotative project: Owen carried out his renaming "as if it were a simple matter of commonsense pragmatism and British empiricism". (Amundson 2007: xxiv) Owen claimed that

> "To substitute names [of bones] for phrases is not only allowable, but I believe it to be indispensable to the right progress of anatomy; but such names must be arbitrary, or at least, should have no other signification [sic!] than the homological one, if anatomy, as the science of the structure of all animals, is to enjoy the inestimable benefit of a steady and universal nomenclature." (Owen 1848a: 3)

Is this the whole truth? Was Owen's project a neutral one, consisting in an intuitive and pragmatic aggregation? In one sense it was: Owen simply systematized affinities which were visible to other observers as well, he aggregated empirical regularities and introduced technical names for these regularities providing little interpretation. It is in this sense that the terms 'homology' and 'homologous' are still in use today: as nominal (arbitrary) operational definitions.[303]

In another sense, however, Owen's terms conveyed a strong interpretative bias. As Amundson stresses,

> "The underlying theoretical assumption of the entire project is that all vertebrates are built on a single body plan. Homologies are the elements of this body plan." (Amundson 2007: xxiv)

Calling two things alike conveys the impression that they are alike. Thus, Owen's denotation implies a fundamental "sameness" beyond anatomical similarities. It conveyed the idea that Owen's denotative project and his homologies were not simply pragmatic aggregations of empirical regularities but expressed fundamental relations beyond the realm of empirics. In this sense, the concept of homologies had a strong interpretative component and it is in this sense that Owen linked it to his static model, the Vertebrate Archetype. [304] (See below)

Owen first presented his static model, the Archetype, in a report to the British Association for the Advancement of Science (BAAS) in September 1846 and elaborated it in his 1848 *On the Archetype and Homologies of the Vertebrate Skeleton*, where he described it as "an ideal pattern or archetype of the vertebrate endoskeleton, as shown in a side view of the series of typical segments or 'vertebrae' of which it is composed" (Owen 1848a: 176). (Rupke 1993: 233) Owen provided an actual graphic scheme of this vertebrate archetype; a drawing supposed to visualize those segments which all vertebrates share in the arrangement shared by all vertebrates.[305]

Hence, the archetype expressed the same "belief in the fundamental relatedness" as the homologies. (Rupke 1994: 188) More precisely, while the homologies are one-word summaries of empirical

[303] This does not exclude, however, that this operational definition was interpreted in very different theoretical frameworks. Owen himself did not utilize the archetype in his definitions of homologies; he did not refer to it during throughout the introductory parts of the *Archetype*. (Owen 1848a: 1-18)

[304] The implication of this "theory-ladenness" will be addressed in section 6 iv.

[305] This would be the only specific representation of an archetype that Owen ever provided.

regularities, the archetype is a one-word summary of the homologies; and as the homologies interpret the empirical regularities, the archetype interprets the homologies. On Owen's view,

> "Just as an individual vertebrate body is a series of variations on the theme of the ideal vertebra, distinct species are variations on the Vertebrate Archetype." (Amundson 2007: xxx)

Owen's concept has several roots. The term 'archetype' was first employed with respect to anatomy by the anatomist Joseph Maclise, but in a different sense.[306] The scheme by which Owen visualized the archetype, was probably inspired by the German natural philosopher Carl Gustav Carus.[307] The morphological approach itself is closest probably closest to the work of Geoffroy. Actually, it was through Owen's archetype that Britain closed a knowledge gap to the continent.

The Britons had fancied Cuvier and his "conditions of existence" which complied so well with the design of Natural Theology and the ideas of Paley. At the same time, they had ignored the morphological research of Geoffroy and the theorizing of German natural philosophers, condemning both as speculative.[308] Therefore, much of the morphological knowledge acquired on the continent was not yet shared by the Britons and it required Owen's Nature of Limbs to bring

> "mainstream British biology in line with the continent. It did so in part by expressing structuralist biology in a conservative way. Owen's conservatism had two aspects. The first was dutifully religious: he padded his structuralist conclusions in pious rhetoric (though this rhetoric did not dilute his radical conclusions). The second was epistemological: Owen did his best to present his views as having been arrived at on the basis of good British empiricism and inductivism. He acknowledged the continental morphologists for their ideas, but blamed them for their speculative excesses and pointed out empirical errors. He admitted that very little morphology had been done in Britain (Limbs, 4), but was careful to list the speculative flaws in the work of continental morphologists (Limbs, 41, 81). This had to be done in order to overcome the principle of the empirical accessibility of function. Owen insists that the Vertebrate Archetype and homologies are "no mere transcendentalist dream, but true knowledge and legitimate fruit of inductive research" (Limbs, 70). Radicals and lesser figures had already argued the point, but it was Owen who brought the argument home, and made structuralism palatable to mainstream British science." (Amundson 2007: xx-xxi)

Considering he was being called the "British Cuvier", it is interesting how much Owen approached Geoffroy here and how much he criticized Cuvier.[309] Owen argued that Cuvier's anatomy and its focus on design and the conditions of existence was incomplete:

> "The attempt to explain, by the Cuvierian principles, the facts of special homology on the hypothesis of the subserviency of the parts so determined to similar ends in

[306] For a discussion, see (Rupke 1993: 251; Rupke 1994: 197).

[307] For Carus' morphological scheme see Rupke 1993: 241 or Rupke 1994: 195.

[308] As Lamarck, Geoffroy seems not to have been translated to English. Owen's attempt to translate Oken's *Lehrbuch der Naturphilosophie* caused a scandal.

[309] This reflected the fact that, after his distinction of Cuvier's analogies and Geoffroy's homologies, Owen's research focused on the latter.

> different animals, – to say that the same or answerable bones occur in them because they have to perform similar functions – involve many difficulties, and are opposed by numerous phaenomena." (Owen 1848a: 73; cf. Ruse 1979: 118)

Therefore, from Owen's point of view, one had to consider both, (i) the exigencies of the environment in which an organism lived and (ii) the morphological similarities which persisted independent from the "conditions of existence", i.e. Geoffroy's "unity of type". Those could be described and predicted with the help of Owen's homologies. (Padian 2007: lxxxi-lxxxii)

Beyond the conflict between Cuvier and Geoffroy, Owen attempted to integrate his archetype in a larger philosophical context by relating it to Platon's concept of ideas. This led to an interesting volte. In his first presentations of the archetype, in 1847 and 1848, Owen presented the archetype as an "all-pervading polarizing force" which acted "in antagonism" with a Platonic vital force. (Owen 1848a: 171; cf. Rupke 1993: 243-5; Amundson 2007: xxxii))In this conception, the archetype acted as a conservative force which preserved the general "unity of type" from too much adaption to Cuvier's "conditions of existence", which could be understood as the Platonic vital force. Owen argued that a body develops by interaction of both forces: "the adaptive or special organizing force" and the "general and all-pervading polarizing force". (Owen 1848a: 171-2; cf. Rupke 1993: 243; Rupke 1994: 198; Amundson 2007: xxxii)

This antagonism of an organizing force, which preserved the "unity of type", and a polarizing force which fueled the adaption to "conditions of existence" complied well with Owen's application of the archetype to taxonomy. On Owen's account, there was no specimen who actually corresponded to the archetype; he did not identify any actual fossil with the archetype. He argued, however, that by tracking higher forms back to more primitive ones, one is approaching the archetype. According to Owen, there is a "closer adhesion to the archetype" in lower vertebrates, but a "superior influence of the antagonizing power of adaptive modification" in higher ones. (Owen 2007 [1849]: 59) These modifications produce the features which taxonomists employ for classification. At his archetype figure in the *Nature of Limbs*, Owen

> "indicated the first steps of those modifications that, depending on kind and degree, give the archetype the characters of a class, order, genus, and species. In the same plate he presented figures of the full modifications of the archetype that characterize fish, reptile, bird, mammal, and human, each the typical skeleton of its respective taxonomic group." (Rupke 1993: 234)

In his 1849, Nature of Limbs, however, Owen suddenly turned on his heels and presented the archetype as a Platonic idea, as a "predetermined pattern, answering to the 'idea' of the Archetypal World in the Platonic cosmogony" (Owen 2007 [1849]: 2-3), "a divine forethought, a blueprint of design for the formation of animal life" (Rupke 1994: 199). It seems that Owen bowed to political pressure powerful Oxbridge scholars and that his friend, the conservative geologist William Daniel Conybeare (1787-1857), had advised him on his about-turn. (Rupke 1994: 202; Amundson 2007: xxxii) The British scientific mainstream was still too much rooted in theism and Design to embrace a concept which opposed all of Cuvierian anatomy and Paleyian design and Platonic idealism.[310] If

[310] In the 1840s and early 1850s Geoffroy and the German speculative morphologists were still considered scandalous. (cf. Rupke 1994: 201)

Owen's archetype was the organizing model behind his anatomy, it better complied with the dominant theistic narrative. (see below)

Owen justified his shift by constructing the archetype not as a basal embodiment of the organizing force, but as a possibility space. In the *Nature of Limbs,* Owen argued that the archetype is something like the totality of possible modifications and that these

> "are very far from being exhausted by any of the forms that now inhabit the earth, or that are known to have existed here at any period." (Owen 2007 [1849]: 83; cf. Rupke 1994: 155)

It is doubtful, whether this turn-around made much philosophical sense[311], however, it allowed to restore Man's place atop of creation and to interpret his anatomical complexity as a product of divine providence. All throughout the considered period, from 1848 to 1868, Owen considered Man to be clearly separated from the apes. In the early *Vertebrate Archetype* and the *Nature of Limbs*, Owen regarded man as the highest form, i.e. the one that departs most from the vertebrate archetype. (Owen 1848a: 132; Owen 2007 [1849]: 56, 109, 172; cf. Rupke 1993: 243; cf. Rupke 1994: 155)

In this early period, Owen still focused on qualitative anatomical differences, notably in the skull, and drew quite a sharp line between humans and apes:

> "Humanity was not only the sole species of its genus, it was the only member of the Bimanaus ("two-handed") order. In contrast, all the anthropoid apes share the order Quadrumana ("four-handed") along with even less human-like simians. Owen declares that this implies that the division between human and ape results from distinctions as great 'as those which mark the primary (unguiculate) division of the placental subclass of Mammalia'." (Cosans 2009: 39; cf. Owen 1848b: 414)[312]

Quickly, however, Owen moved to the morphological features of the brain which, to Owen, was "at the core of what it is to be a mammal". (Cosans 2009: 53) Moreover, Owen abandoned absolute qualitative features and focused on developmental processes and quantitative measures instead. Thus, in a 1851 memoir, *On the Osteology of the Chimpanzees and Orangs*, Owen cited data by Wyman and Morton on skull sizes. Concentrating on averages instead of extreme expressions, he

> "concluded that the great gulf between ape and human brains size outweighs any difference which may be found between human races. Wyman's chart implies the

[311] Rupke remarks that "Whereas a Platonic idea is the highest, most perfect reality, the vertebrate archetype represented the opposite, namely the simplest and least perfected conception of a vertebrate. In one sense, Owen's archetype was all potentiality, and as such his position more Aristotelian than Platonist, and close to the 'entheism' of Carus." (Rupke 1994: 197) – Whether this mattered to Owen is doubtful. He was not much of philosopher, as (Rupke 1994: 200) points out: "It is erroneous to believe that Owen was directly influenced by any philosopher at all, whether it be Plato, Spinoza, Kant, Fichte, Schelling, Hegel or Schopenhauer […] Owen simply did not have a philosophical turn of mind. To try and make a coherent system of philosophy out of Owen's various theories would be an unjustified and futile undertaking." (Rupke 1994: 200; cf. Ruse 1979: 122)

[312] The strict distinction between humans and apes was not an extreme position. In the 1940s, humans were still believed to have diverged from the apes about 8-9 million years ago. Today, the gap is insofar smaller as chimpanzees are considered closer related to humans than to any of the other apes. (cf. Keith 1948: 158-9)

> mean cranial capacity for Europeans is 91 cubic inches and that of native Australians as 75 cubic inches. Because of the scarcity of ape material, Owen compared the human averages with record ape brain size. The largest ape capacity is 34 and 112 cubic inches, found in a male gorilla. Hence, the record ape capacity is less than one half the lowest mean for a group of humans. Owen found the larger human brain size even more remarkable because the male gorilla has a much larger body than a man." (Cosans 1994: 141)

A similar arguments is pursued in Owen's 1858 paper in the *Journal of the Linnean Society*, *On the characters, principles of division and primary groups of the class Mammalia* (Owen 1858: 1-37) and in his 1859 monograph *On the Classification and Geographical Distribution of the Mammalia* (Owen 1859b; Owen 1859a: 97, 103), both of which were published in knowledge of the joint paper by Darwin and Wallace but before the publication of the *Origin of Species*. (cf. Fishman 1997: 105ff.)

Furthermore, in his 1857 paper "On the Characters, Principles of Division, and Primary Groups of the Class Mammalia", Owen analyzed four distinct stages of brain development and argued that they provided clear criteria for distinguishing the higher mammals. (Cosans 1994: 141)[313] However, Owen now lessened his stance on the position of humans, no longer suggesting a progression up to Man. (Ruse 1979: 137) This interpretation seems to follow from his anatomical research on novel ape specimen which revealed that there is no ape species which is closest to humans with respect to all relevant anatomical criteria, but that different species share different features with Man. (Owen 1859c: 74-5) Thus, man is "no longer the measure of all things" and each taxonomic group is being considered in its own right. (Ruse 1979: 137)

What still sharply distinguished humans from apes were the brain's psychological and mental power. However, this was no absolute boundary; the human intelligence, soma and psyche were merely indicators of relatively more developed brain. Owen specifically stressed that the different mental capacities of chimpanzees, mentally disabled humans and blacks were not "of a nature so essential as to preclude a comparison between them, or as being other than a difference of degree". (Owen 1857: 20; cf. Cosans 2009: 57-9; Cosans 1994: 144)

Thus, the more ape and human specimen the anatomists acquired and the more knowledge they produced, the less poignant became the differences between both.[314] In the end, Owen's classification was not based on absolute anatomical differences but on differences of degree and on capacities which supposedly resulted from such differences of degree. This is all the more remarkable as Owen never carried out any systematic research on the intelligence of apes, their

313 Cosans summarizes these differences as follows: "While an infant ape's skull has proportions similar to those of a human, it loses much of the resemblance as the ape grows larger. In maturing apes, the brain ceases its growth and the jaws expand greatly after the first set of teeth develop; in the developing human, by contrast, the brain continues to grow larger while the jaws expand only modestly. Consequently, adult chimpanzees and orangutans have proportionally smaller brains and larger jaws than those of adult humans. Rather than viewing the jaw as an isolated part, Owen considered how it fits into each organism's way of life." (Cosans 2009: 21)

314 It seems that Owen's insistence on the distinction of humans and apes was also an argument for the unity of the human race and against slavery. Owen opposed classifications which saw non-Western races as intermediate between the highly developed Caucasian race and higher apes, opposing Chambers on this point. (See section 3.1.2) For a discussion of this point, see (Cosans 2009: 25-28, 51-59)

soma or psyche; the first systematic studies on the intelligence of apes would appear only decades later.[315] As Owen himself uttered it in 1868:

> "How the brain works in producing thought or soul is as much a mystery in Man as Brutes is as little known as the way in which ganglions and nerves produce the reflex phenomena simulating sensation and volition." (Owen 1868: 824)

3.2.3 Logical explanation: How did Owen model evolution?

Identifying a dynamic model in Owen's texts is a difficult task as he never described a complete or consistent such model, particularly no Connector. In the discussion of evolution, Owen rarely went beyond the archetype, particularly, he never presented a coherent dynamic model to explain how evolution happened. (Padian 2007: lxviii; Rupke 1994: 238) Instead, Owen embedded his static model, the archetype, directly in a narrative explanation, without an intermediate dynamic model.

Although not suggesting a model of his own, Owen expressed evolutionary views, discussing to what extend in what manner groups of organisms might change over time.[316] Moreover, he discussed several ideas of what might trigger evolution, thus describing different options for the Input. I will systematize these ideas in an attempt to grasp what account and explanation of evolution Victorian readers might have drawn from Owen's writings between 1848 and 1868. I will begin by describing what Owen understood by evolution, or – as he preferred – 'development' or 'derivation', describing the objects which underwent the process and the results it yielded: the Object Class and Output of my model of dynamic models. I will continue by analyzing the different factors ("causes") he considered as being able to trigger evolution, my Input. Finally, I will analyze what kinds of a Connector and Situations Owen considered in his writings and what role they played in his explanation.

i. Output: Deviation within limits & extinction

Owen's 1848 *On the Archetype and Homologies of the Vertebrate Skeleton* is still much centered around static modeling and interpretation (level two of my model). Owen's ambition is to describe and interpret the common and distinct features of organisms as well as their variation in space and time, i.e. evolution, as variations of the archetype – or a future, more advanced model:

> "To trace the mode and kind and extent of modification of the same elementary parts of the typical segment throughout a large, natural series of highly organized animals. like the vertebrata; and to be thus led to appreciate how, without complete departure from the fundamental type, the species are adapted to their different offices in creation, brings us, as it were, into the secret counsels that have directed

[315] It seems that the first systematic studies on the topic were carried out in the early 20th century. Two notable first works are *Intelligenzprüfung bei Menschenaffen* (1917/1921) by Wolfgang Köhler of Germany and *The Mental Life of Monkeys and Apes. A Study of Ideational Behaviour* (1916) by the American R.M. Yerkes.

[316] As (Rupke 1994: 225) points out, one should not be confounded by passages in which Owen speaks out against transmutation (or evolution). While not expressing his own position clearly, Owen considered different – "no fewer than half a dozen" – explanations for evolution and dismissed them. This did not mean however, that Owen held or expressed creationist views.

> the organizing forces, and is one of the legitimate courses of inquiry by which we may be permitted to gain an insight into the law which has governed the successive introduction of specific forms of living beings into this planet." (Owen 1848a, 106; cf. Amundson 2007: xxx)

In this conception evolution was no completely orderly process as Chambers' but it remained within clear boundaries. While Owen clearly suggested that the vertebral archetype allowed for forms besides those that had been observed (Owen 1848a: 102; Owen 2007 [1849]: 83; Ruse 1979: 123), he clearly did not suggest evolution beyond the archetype. (Hall 2007a: viii) Organisms did not transform beyond their type. Particularly, Owen discussed this question with respect to apes and humans the same year. (Owen 1848b) There, Owen addressed

> "the often-mooted and lately-revived[317] hypothesis of the origination of the species of animals by gradual transmutation of specific characters, and that in a progressive or ascending direction." (Owen 1848b: 414)

He discussed whether gorillas and humans could be changed into one another and argued that the results of dog breeding indicated that new forms could only be produced within "the general law of development", i.e. the range of the archetype. (Owen 1848b: 415; cf. Cosans 2009: 38) Instead, he claimed that

> "No known cause of change productive of varieties of mammalian species could operate in altering the size, the shape and the connections of the premaxillary bones, which so remarkably distinguish the great Troglodytes Gorilla, not from Man only, but from all other anthropoid apes. We know as little the conditions which protract the period of the obliteration of the sutures of the premaxillary bones in the Tr. Gorilla [gorilla] beyond the period at which they disappear in the Tr. Niger [chimpanzee], as we do those that cause them to disappear in Man earlier than they do even in the smaller species of Chimpanzee. There is not, in fact, any other character than those founded upon the developments of bone for the attachment of muscles, which is known to be subject to change through the operation of external causes : nine-tenths therefore of the differences … distinguishing the great Chimpanzee from the human species, must stand in contravention of the hypothesis of transmutation and progressive development until the supporters of that hypothesis are enabled to adduce the facts and cases which demonstrate the conditions of the modifications of such characters." (Owen 1848b: 417; cf. Cosans 2009: 23)

An interesting point here is how Owen analyses the question of evolutionary links between the gorilla and Man: He does not ask, as Darwin would, whether there might have been a common ancestor of which the descendants evolved into both the gorilla and man. Instead, Owen asked whether the gorilla was an ancestor of Man. Figuratively speaking, Owen was looking for a line which linked Man and gorilla, while to Darwin they were the ends of a fork.

This asymmetry is observable in Owen's work from 1837[318] to 1868 (see below), and makes most sense if one assumes that Owen was thinking in a static model like the one by Chambers, i.e. one of

[317] Owen presumably refers to Chambers here.

linear progressions. Like Chambers, Owen allowed for a limited branching within one species like Man or gorilla (see Figure 15). However, transmutations between species, e.g. the transition from gorilla to Man, could consist but in saltational advances along a line of development from lower to higher forms. Figure 14 visualizes the asymmetry between Owen's and Darwin's and Wallace's approach to the problem of descent.

In *The Nature of Limbs*, Owen made a surprising turn, dipping his archetype in transmutational ideas:

> "Just a year after divorcing human and ape, Owen essentially remarried human to bat and fish. In the Nature of Limbs, Owen offers reflections on deep anatomical similarities that indicate that all vertebrates, be they humans, dogs or even lampreys, share some basic developmental laws. He argues that the anatomical structure of all vertebrates was derived from a common archetype, key aspects of which can be seen by a detailed consideration of the skeletal structure of the limbs. […] In some ways, the Nature of Limbs has the feel of a more empirical, technically precise, and scientifically rigorous version of the *Vestiges*, which leads the reader to ponder the possibility of evolution from a bone-by-bone consideration of vertebrate limbs and skeletons." (Cosans 2009: 39)

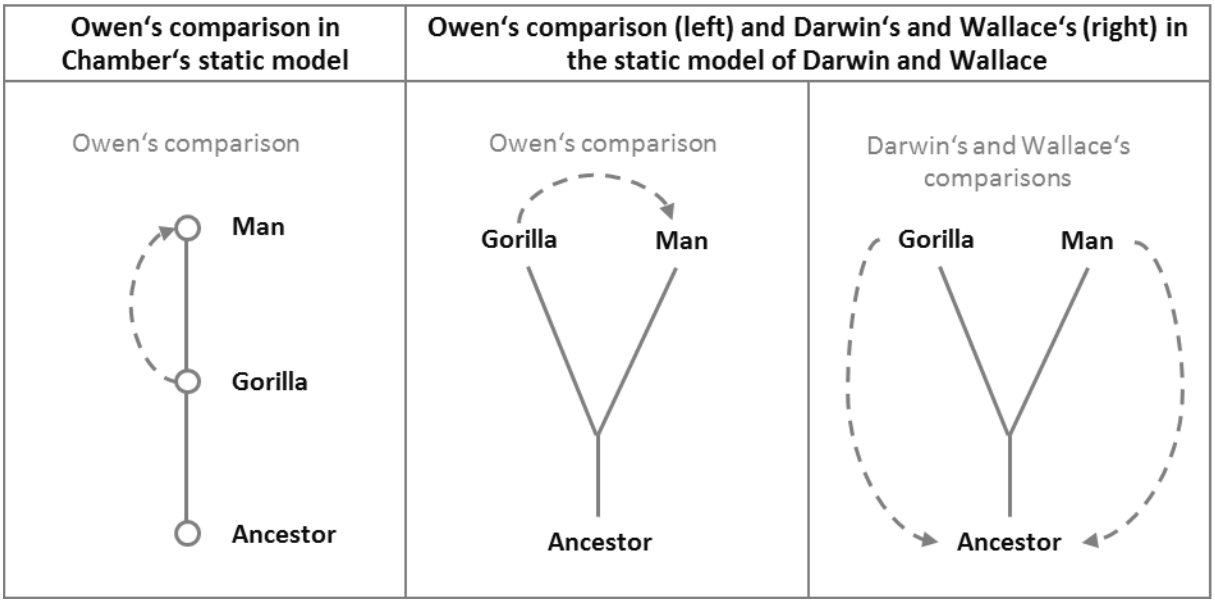

Figure 14: Owen's and Darwin's perception of the possible relation between humans and gorillas

Although Owen preferred to speak of 'development', this was clearly an evolutionary position. (Owen 2007 [1849]: 82; cf. Cosans 2009: 43) He argued along the lines of Lamarck and Geoffroy: organisms were changing over time. Owen claimed, however, that his conversion was not the result of French or German speculation but of sober British empirics:

318 Cosans argues that, in 1837, Owen discussed whether apes could transmute into humans. "He cites a total of twenty-one characters that distinguish the chimpanzee and orangutan from humans. Since they are deeply entrenched in development, 'these differences result from original formation, and are not liable to be weakened in any material degree, either, on the one hand, by a degradation of the human species, or, on the other, by the highest cultivation of which the anthropoid Apes are susceptible' (Owen 1835, 370)." (Cosans 2009: 22)

> "It is no mere transcendental dream, but true knowledge and legitimate fruit of inductive research, that clear insight into the essential nature of the organ, which is acquired by tracing it step by step from the unbranched pectoral ray of the lepidosiren to the equally small and slender but bifid pectoral ray of the amphiuma, thence to the similar but trifid ray of the proteus, and through the progressively superadded structures and perfections in higher reptiles and in mammals. If the special homology of each part of the diverging appendage and its supporting arch are recognisable from Man to the fish, shall we close the mind's eye to the evidences of that higher law of archetypal conformity on which the very power of tracing the lower and more special correspondences depend?" (Owen 2007 [1849]: 70)

Owen imagined the archetype to advance throughout geological history "in slow and stately steps ... from the first embodiment of the Vertebrate idea under its old Ichthyic vestment, until it became arrayed in the glorious garb of Human form." (Owen 2007 [1849]: 86; Cosans 2009: 45) Over time, the archetype branched and diversified to cater to specific environmental niches.

The concept of an archetypal branching did not imply, however, that Owen had overcome the asymmetry to Darwin, he still thought in terms of a step-wise ascension towards more complex forms. Thus, in his 1850 paper on didornis, Owen discussed whether this extinct giant bird of New Zealand might have given rise to smaller but similar birds which were still indigenous to New Zealand of the time. Owen dismissed the "degeneration" hypothesis because fossil remains of the smaller birds were found associated with those of the extinct bird. He argued that the appearance of one species did not follow from the other; there was no evolutionary link between them:

> "The actual presence, therefore, of small species of animals in countries where larger species of the same natural families formerly existed, is not the consequence of any gradual diminution of the size of such species, but is the result of circumstances…; the smaller and feebler animals have bent and accommodated themselves to changes which have destroyed the larger species." (Owen 1862b[1850]: 15; Rupke 1994: 233-4)

It is important to understand what Owen's argument was here because he would use it several more times, also against Darwin. In his understanding of "development" or evolution, one species could only develop from another if the former ceased to exist; they could never exist at the same time. In other words, a species could not give rise to another one with which it then coexisted with. This is clearly linked to the fork asymmetry above (Figure 14); as Owen did not consider species to diverge and develop independently at the same time, he could not imagine that exemplars of such a diverging line could exist at the same time as the original type or exemplars of another diverging line.

At the same time, Owen diversified his view, considering independent and continuous evolution in different branches of zoology, abandoning ideas of an evolution of all animals towards Man. (Ruse 1979: 103) Thus, in his 1851 review of Charles Lyell's *Principles of Geology*, Owen spoke of a "succession of animal forms on our planet" or a "successive" and "progressive" development from less complex to more complex ones, he clarified that this included supposed lower forms as fish:

> "Palaeontology demonstrates that there has been not only a successive development in this class [the class of fish], but, as regards their vertebrate skeleton, a progressive one." (op. cit. Ruse 1979: 137)

Thus, he distanced himself from Chambers, on whose account the evolution of lower types could only lead to a higher form, not to a novel lower form.

Within one type, however, Owen still thought in terms of a linear and step-wise ascent. This became clear in the late 1850s and early 1860s when Owen answered to the challenge of the 1858 joint paper by Darwin and Wallace and the *The Origin of Species* of 1859. In his 1859 Fullerian Lecture *On the Extinction of Species*, Owen expressed this very clearly. While he spoke of "successive extinction" and "introduction of much more numerous, varied, and higher-organised forms" within distinct mammal classes (Owen 1859c: 58), he clarified that the earlier forms disappear when they transform in the later ones:

> "So far, however, as any general conclusion can be deduced from the large sum of evidence above referred to, … Organic remains, traced from their earliest known graves, are succeeded, one series by another, to the present period, and never re-appear when once lost sight of in the ascending search. As well might we expect a living Ichthyosaur in the Pacific, as a fossil whale in the Lias[319] : the rule governs as strongly in the retrospect as the prospect. And not only as respects the Vertebrata, but the sum of the animal species at each successive geological period has been distinct and peculiar to such period." (Owen 1859c: 60; cf. Rupke 1994: 237)

In a paper *On the Orang, Chimpanzee, and Gorilla. With Reference to the 'Transmutation of Species'* of the same year, Owen stated that:

> "The unity of the human species is demonstrated by the constancy of those osteological and dental characters to which the attention is more particularly directed in the investigation of the corresponding characters in the higher Quadrumana. Man is the sole species of his genus, the sole representative of his order and subclass. Thus I trust has been furnished the confutation of the notion of a transformation of the ape into man, which appears from a favourite old author to have been entertained by some in his day." (Owen 1859a: 103)

The following year gave Owen the opportunity to answer Darwin's Origin by a systematic work of his own. In *Palaentology or A Systematic Summary of Extinct Animals and their Geological Relations*, repeats his formula of "successive extinction" and "introduction" and provides a table which

> "expresses the sum of the observations at the present date, on the succession, appearance and geological relations of the several orders of the Mammalian class" (Owen 1860a: 407-8)

and displays, among others, the principles of the archetype and deviation from the archetype:

> "the law of irrelative or vegetative repetition: the law of unity of plan or relations to an archetype: … the progressive departure from general type as exemplified in the series of species from their first introduction to the present time." (Owen 1860a: 407)

319 Darwin's model did not exclude such living fossils. (See section 3.4.3 iv)

Figure 15 reproduces Owen's table and displays how different orders of the mammalian class were perceived as neatly separated by Owen.

These orders may branch to some extent but they do not mix with the neighboring orders. And while the branching within one type[320] is a slow and steady movement, the evolution from one archetypal from to another requires some saltational transmutation, i.e. "considerable and sudden" steps. (Owen 1868: 795) Thus,

> "Owen clearly had transmutational thoughts, but these were organized on the concept of the archetype, not on descent." (Richards 1987a: 150)

Owen interpreted the deviation from the archetype as "perfect adaptations and endowments" for

> "in what have those contrasted limbs, hoofs, paws, fins, and wings, so variously formed to obey the behests of volition in denizens of different elements, different from the mechanical instruments which we ourselves plan with foresight and calculation for analogous uses, save in their greater complexity, in their perfection, and in the unity and simplicity of the elements which are modified to constitute these several locomotive organs?" (Owen 1860a: 413)

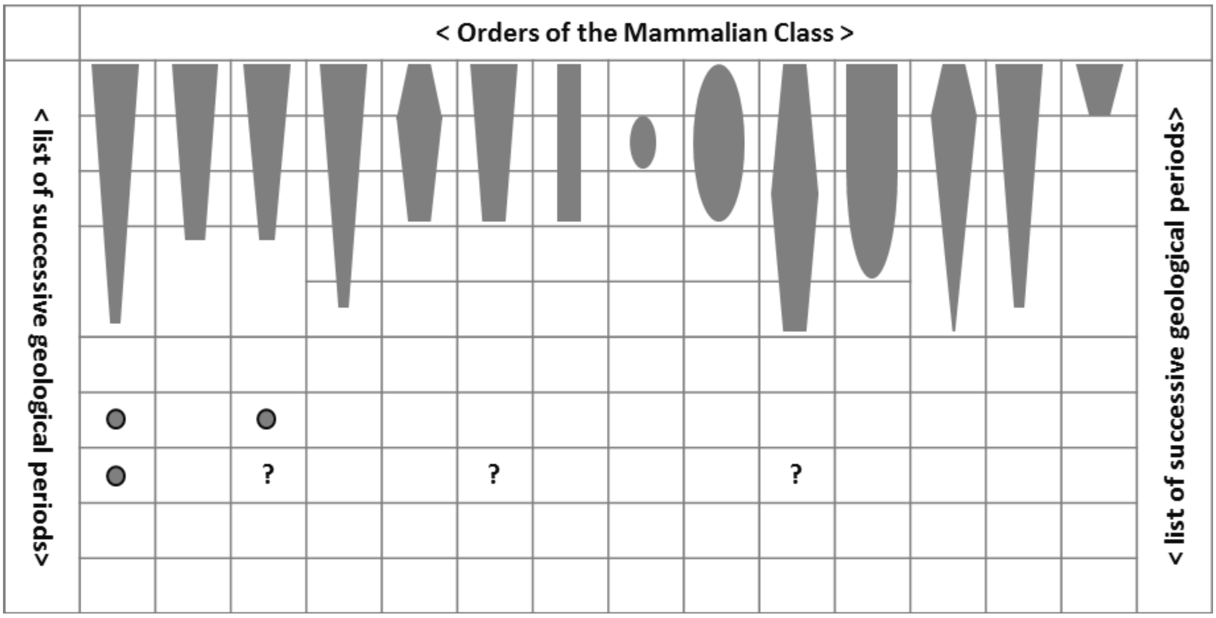

Figure 15: Owen's "Table of Geological Distribution of Mammalia" (Owen 1860a: 407)[321]

At the same time, however, Owen disputed the crucial Input of Wallace's and Darwin's models: favorable variations. In a discussion of Wallace, Owen seems[322] to deny that varieties might be better adapted to their environment than their original type:

[320] I know of no classification of archetypes by Owen. However, if there is supposed to exist a vertebrate archetype, then neither mammals as a class nor any mammalian order can constitute an archetype of their own.

[321] I could not obtain a good scan of Owen's figure, particularly the labels for the geological periods and mammalian types were difficult to decipher. Therefore I have reproduced the table without the specific labels. The question marks come from Owen.

[322] I am not fully certain whether to read this as a mistaken representation of Wallace or Owen's critique of Wallace but I tend to the latter.

> "Wallace, assuming that varieties may arise in a wild species, shows how such deviations from type may tend to adapt a variety to some changes in surrounding conditions, under which it is better calculated to exist, than the type-form from which it deviated. No doubt the type-form of every species is that which is best adapted to the conditions under which such species at the time exists; and as long as those conditions remain unchanged, so long will the type remain; all varieties departing therefore being of the same ratio less adapted to the environing conditions of existence. But, if those conditions change, then the variety of the species at an antecedent date and state of things will become the type-form of the species at a later date, and in an altered state of things." (Owen 1860a: 405)

Such denial would indeed comply with Owen's idea of an archetype around which varieties are organized and to which they return. For instance, in Figure 15, some of the representations of evolution resemble rhombuses in which variations disappear and re-center on the archetype.

In his publications throughout the 1860s, Owen upheld this idea of an orderly ascension within archetypes. Thus, in his 1862 memoir on the Aye-aye, he spoke of a "long succession of organized species" and claimed that despite some seemingly random variations within the archetype, forms would still evolve in orderly, step-wise manner:

> "The succession of species by continuously operating law is not necessarily a "blind operation". Such law, however dimly discerned in the properties and successions of natural objects, intimates, nevertheless, a preconceived progress. Organisms may be evolved in orderly succession stage after stage…" (Owen 1866a [1862]: 91, cf. 95-6)

This orderly, step-wise evolution, he refers to as a "progressive departure from a general to a special type". (Owen 1866a [1862]: 95-6)[323]

Owen reaffirmed his position in the third volume of his *On the Anatomy of Vertebrates,* in 1868, when the Darwinian theory had already become the mainstream biological theory. While he agreed with the Darwinians on the fact that species evolved, he disagreed on the extent of this evolution. Referring to his stay in Paris with Cuvier, Owen recollects how Cuvier had denied that "existing [species] are modifications of extinct species" for lack of fossil evidence. Owen then admits that this evidence has since been provided:

> "The progress of Palaeontology since 1830 has brought to light many missing links unknown to the founder of the science. My own share in the labour led me, after a few years' research, to discern what I believed, and still hold, to be a tendency to a more generalised, or less specialised, organisation as species recede in date of existence from the present time." (Owen 1868: 790)

However, Owen is somewhat selective as to what evidence he counts as supportive of evolution. There is no mention of the Archaeopteryx which had been discovered in 1861 and described by

[323] In this characterization of genealogical relations, Owen was much closer to Chambers notion of 'development' than to Darwin's 'common descent'.

Owen in 1862, although it was susceptible to threaten Owen's evolution within the archetype.[324] Instead, Owen provides a lengthy discussion of the series of horse types from Palaeotherium, Paloplotherium, Anchitherium, Hipparion, and Equus, which he can easily interpret as a series of evolutionary steps within a common archetype:

> "One cannot doubt, also, that every well-marked species of these genera paired within itself, and that they exemplified respectively the character of a 'group of individuals descended from common parents, or from such as resembled them as closely as they resembled each other.' They did not, however, exist as species, during the same periods of time, far less so from the beginning of things.' The single-hoofed Horse- family cannot be traced further back than the pliocene tertiary period : the tridactyle equine species have not been found in strata earlier than miocene, and disappear in the upper eocene : the heavier-bodied shorter-legged species with three functional hoofs to each foot belong to upper and middle eocenes. Furthermore, in the oldest eocene (London clay, super-cretaceous Conglomerates and Plastic clay at Meudon, Paris), we get evidence of Ungulates (Pliolophus, Hyracotherium, Coryphodori), in which the perisso- and artio-dactyle characters were less differentiated than in Palaeotherium and Anoplotlierium, affording additional significant evidence of progressive departure from generalized type. Thus, the succession in time accords with the gradational modifications by which Palaeotherium is linked on to Equus." (Owen 1868: 792-3)

Moreover, Owen repeated his assessment that varieties could only be better adapted than their original type if and after physical change has occurred. He implies that under the same conditions, variations could not be favorable in the sense of Darwin's and Wallace's model and could not successively replace their patent-type. (Owen 1868: 793) Furthermore, deviations from the archetype[325] would be "sudden and considerable". (Richards 1987a: 146; cf. Owen 1868: 795)

In sum, Owen had now approached Chamber's account of evolution very much. There were independent lines of development (types) which branched within a narrow range but could develop into other forms only by "sudden and considerable" deviations from their parent-type.

ii. Object Class: Varieties and species, but no individuals

Throughout his works Owen highlights that his domain of expertise are vertebrates, particularly higher vertebrates, mammals, apes. (cf. Owen 1859c: 60) Thus, his evolutionary statements and his restraint from such statements should be understood in light of this Object Class – an important reservation considering that Lamarck and Geoffroy developed their evolutionary views on mollusks and reptiles respectively.

Beyond this, I can find only one important restriction of the Object Class by Owen. In his 1859 Fullerian Lecture *On the Extinction of Species*, he restricts his statements about extinction to land animals:

[324] While the Darwinians interpreted the Archaeopteryx as a link between reptiles and birds, Owen had classified it as a bird. Owen mentions it several times in the main body of text but not in the conclusion. (Owen 1868: 13, 38, 74, 586)

[325] Direct references to the Archetype did decrease, however, in Owen's works in the mid- and late 1860s. In volume III of his Anatomy of Vertebrates, I count 7 references on ca. 800 pages. (Owen 1868)

> "On the problem of the extinction of species I have little to say; and of the more mysterious subject of their coming into being, nothing profitable or to the purpose. As a cause of extinction in times anterior to man, it is most reasonable to assign the chief weight to those gradual changes in the conditions affecting a due supply of sustenance to animals in a state of nature which must have accompanied the slow alternations of land and sea brought about in the aeons of geological time. Yet this reasoning is applicable only to land-animals; for it is scarcely conceivable that such operations can have affected sea-fishes." (Owen 1859c: 55-6)

He seems to have given up this position in 1868, when he discussed the coral species of the red sea and claimed that most of them would "exist under the same conditions", thus implying that the environmental changes might, in principle, apply to sea animals as well.

However, the most important difference to Wallace and Darwin but also to Lamarck and Geoffroy is this: Owen never discussed individuals or small groups beneath varieties. His evolutionary claims were always supposed to apply to larger groups as varieties, species or classes.

iii. Input: Climatic change and isolation

By frequently side-stepped dynamic modeling and directly embedded his static model in his narrative, Owen often discussed what Agent might produce evolution[326], but much less often and less clearly, what events might precede it and might be employed to explain it. This should not, however, obscure that Owen was clearly aware of what preceded evolutionary change. Owen knew that organisms changed in space and time and he mentioned the empirical regularities of biogeography and paleontology. In my analysis of potential Inputs in Owen's explanations, I will identify these regularities, but I will also demonstrate how Owen avoided presenting their first parts as Inputs of a dynamic model, opting instead to solely embed them in an explanatory narrative.

In 1850, in his discussion of Didornis, an extinct giant bird of New Zealand, Owen discussed whether this species could become extinct if they failed to adapt to their circumstances. (Owen 1862b [1850]: 15) A couple of pages later Owen gave some examples of what he understood by "circumstances". Moreover, he used a metaphor not unlike Darwin's struggle for life: a "contest against surrounding agencies". Owen argued that, in this contest, species would become extinct if they did not adapt to environmental changes as climate change or the introduction of enemies, i.e. the end of isolation[327]. This was particularly true for larger organisms:

> "…the difficulty of the contest which, as a living organized whole, the individual of such species has to maintain against the surrounding agencies that are ever tending to dissolve the vital bond, and subjugate the living matter to the ordinary chemical and physical forces. Any changes, therefore, in such external agencies as a species may have been originally adapted to exist in, will militate against that existence in a degree proportionate, perhaps in a geometrical ratio, to the bulk of the species. If a dry season be gradually prolonged, the large Mammal will suffer from the drought

[326] For instance, "In the 1835 and 1848 papers on apes, he explicitly attacks the doctrine that transmutation could be caused by external forces, but says nothing about whether species could change as a result of some process that involved the internal dynamics." (Cosans 2009: 39)

[327] The introduction of enemies is the opposition of what Darwin refers to as 'isolation'; I will refer to it as the 'end of isolation'.

> sooner than the small one if such alteration of climate affect the quantity of vegetable food, the bulky Herbivore will first feel the effects of stinted nourishment : if new enemies are introduced, the large and conspicuous quadruped or bird will fall a prey, whilst the smaller species conceal themselves and escape. Smaller animals are usually, also, more prolific than larger ones. The actual presence, therefore, of small species of animals in countries where larger species of the same natural families formerly existed, is not the consequence of any gradual diminution of the size of such species, but is the result of circumstances, which may be illustrated by the fable of the 'oak and the reed'; the smaller and feebler animals have bent and accommodated themselves to changes which have destroyed the larger species." (Owen 1862b [1850]: 1-20)

Thus, Owen dropped his resistance to employ environmental changes in his explanation of evolution. Moreover, Owen began to measure organisms by "the efficiency with which [they] specialize and adapt themselves to their own particular niches." The same holds for his address to the *British Association for the Advancement of Science* of 1858. There, Owen referred favourably to the joint paper three months earlier seeing them support his own claim that environmental changes caused extinction; he even cited a generic example of Darwin. He warned, however, from going too far in speculations about how much organisms could change, how high their degree plasticity was. He stated that he himself had always refrained such speculations and that one should instead continue the empirical work under the concept of the archetype in order to "discover the 'ante-types' from which varieties might have originated". (op. cit. Rupke 1994: 236-7)

In his 1859 paper *On the Orang, Chimpanzee, and Gorilla. With Reference to the 'Transmutation of Species'*, Owen reaffirmed his stance, stating that he would not speculate on Inputs or Connectors to explain evolution:

> "No known cause of change productive of varieties of mammalian species could operate in altering the size, the shape, or the connexions of the premaxillary bones, which so remarkably distinguish the Troglodytes gorilla, not from man only, but from all other anthropoid apes. We know as little the conditions which protract the period of the obliteration of the sutures of the premaxillary bones in the Tr. gorilla beyond the period at which they disappear in the Tr. niger, as we do those that cause them to disappear in man earlier than they do even in the smaller species of chimpanzee. There is not, in fact, any other character than those founded upon the developments of bone for the attachment of muscles, which is known to be subject to change through the operation of external causes; nine-tenths, therefore, of the differences, especially those very striking ones … must stand in contravention of the hypothesis of transmutation and progressive development, until the supporters of that hypothesis are enabled to adduce the facts and cases which demonstrate the conditions of the modifications of such characters." (Owen 1859a: 102)[328]

In his Fullerian Lecture *On the Extinction of Species* of the same year, he did speculate a trifle – but only on extinctions. He cited geological changes as a likely Input, dismissing Cuvierian catastrophes:

[328] This argument shows that Owen is aware of what a scientific explanation of evolution should look like: a dynamic model. He just does not suggest one.

> "On the problem of the extinction of species I have little to say; and of the more mysterious subject of their coming into being, nothing profitable or to the purpose. As a cause of extinction in times anterior to man, it is most reasonable to assign the chief weight to those gradual changes in the conditions affecting a due supply of sustenance to animals in a state of nature which must have accompanied the slow alternations of land and sea brought about in the aeons of geological time. Yet this reasoning is applicable only to land-animals; for it is scarcely conceivable that such operations can have affected sea-fishes." (Owen 1859c: 55-6)

> "Not that the extinction of such forms or species was sudden or simultaneous: the evidences so interpreted have been but local: over the wider field of life at any given epoch, the change has been gradual; and, as it would, seem, obedient to some general, but as yet, ill-comprehended law. In regard to animal life, and its assigned work on this planet, there has, however, plainly been 'an ascent and progress in the main'." (Owen 1859c: 60; cf. Rupke 1994: 237)"

Still, a couple of pages later he weakened this acknowledgement and retreated to his ominous notion of "laws":

> "That species should become extinct appears, from the abundant evidence of the fact of extinction, to be a law of their existence; whether, however, it be inherent in their own nature, or be relative and dependent on inevitable changes in the conditions and theatre of their existence, is the main subject for consideration. But, admitting extinction as a natural law which has operated from the beginning of life on this planet, it might be expected that some evidence of it should occur in our own time, or within the historical period. Reference has been made to several instances of the extirpation of species, certainly, probably, or possibly, due to the direct agency of man; but this cause avails not in the question of the extinction of species at periods prior to any evidence of human existence; it does not help us in the explanation of the majority of extinctions as of the races of aquatic invertebrate which have successively passed away." (Owen 1859c: 56-7)

Moreover, he dismissed the explanation which Wallace and Darwin had sketched the year before, and he did so asking for a purpose in this explanation, i.e. a narrative component:

> "As to the successions, or coming in, of new species, one might speculate on the gradual modifiability of the individual; on the tendency of certain varieties to survive local changes, and thus progressively diverge from an older type; on the production and fertility of monstrous offspring; on the possibility, e.g. of a variety of auk being occasionally hatched with a somewhat longer winglet, and a dwarfed stature; on the probability of such a variety better adapting itself to the changing climate or other conditions than the old type of such an origin of Alca torda, e. g. ; but to what purpose? Past experience of the chance aims of human fancy, unchecked and unguided by observed facts, shows how widely they have ever glanced away from the gold centre of truth." (Owen 1859c: 58)

Owen stuck to this line in his 1860 Paleontology. He refrained from providing his own dynamic model of evolution but dismissed Darwin, Lamarck for theirs. Particularly, with respect to the higher organism Owen refuses such speculation. (Owen 1860a: 404)

> "As to the successive appearance of new species in the course of geological time, it is first requisite to avoid the common mistake of confounding the propositions, of species being the result of a continuously operating secondary cause, and of the mode of operation of such creative cause. Biologists[329] may entertain the first without accepting any current hypothesis as to the second." (Owen 1860a: 403)

Owen's alternative is the "axiom of the continuous operation of the ordained becoming of living things." (Owen 1860a: 3)

Moreover, Owen now seemed to publicly support the doctrine of spontaneous generation. In his review of the Origin of Species, he argued that

> "The monad that by 'natural selection' has ultimately become man, dates from the farthest point in the remote past, upon which our feigners of developmental hypotheses can draw with unlimited credit: the monad which by its superficial vibratile cilia darted across the field of the micro-scope we were looking through this morning, is the result of the collocation of particles which, without 'sudden flash,' took place under the operation of the heterogeneous organising force of yesterday. "
> (Owen 1860b [1860]: 195; Cosans 2009: 101-2)

In his BAAS speech on the aye-aye, Owen affirmed his support for evolution in general but refused to adopt either the Darwinian or Chambers' explanation, instead embedding it in a divine narrative. Owen thrice points out, that he does not consider the random variations in Darwin's model an acceptable explanation:

> "So neither would the phenomena of the long succession of organized species justify the notion, nor do I believe they would suggest, that they were the result of blind chance [sic!], if it should be demonstrated that they, too, are the result of secondary influences operating through long ages. It may be true that many of the aims of derivative tendencies miss their end: but myriads of germs never reach perfection; and the proportion of such short-coming is much greater in the phenomena of human life. These serve to exemplify abundantly in how small a degree the doings of the highest created agent here square with the ideal of the aim and end of his existence: yet he is not, therefore, argued to be a thing of chance [sic!]. The succession of species by continuously operating law is not necessarily a "blind operation" [sic!]. Such law, however dimly discerned in the properties and successions of natural objects, intimates, nevertheless, a preconceived progress. Organisms may be evolved in orderly succession stage after stage, towards a foreseen goal; and the broad features of the course may still show the unmistakeable impress of divine volition" (Owen 1866a [1862]: 91)

[329] Note that Owen here speaks of 'biology' as a discipline. This use became frequent in the 1860s.

Moreover, Owen specifies his concept of spontaneous generation and guided evolution afterwards. Yet, he specifies no specific Input to trigger evolutionary change, again refraining from a dynamic model of evolution:

> "What I have termed the ' derivative hypothesis ' of organisms, for example, holds that these are coming into being, by aggregation of organic atoms, at all times and in all places, under their simplest unicellular condition ; with differences of character as many as are the various circumstances, conditions, and combinations of the causes educing them,—one form appearing in mud at the bottom of the ocean, another in the pond on the heath, a third in the sawdust of the cellar, a fourth on the surface of the mountain rock, &c., but all by combination and arrangement of organic atoms through forces and conditions acting according to predetermined law. The disposition to vary in form and structure, according to variation of surrounding conditions, is greatest in these first-formed beings; and from them, or such as them, are and have been derived all other and higher forms of organisms on this planet. And thus it is that we now find energizing in fair proportions every grade of organization from Man to the Monad. Each organism, as such, also propagates its own form for a time under such similitude as to be called its kind. Specific characters are those that have been recognized in individuals of successive generations, propagating similar individuals, as far back as observation has reached; and which characters, not being artificially produced, are ascribed to nature. Instead of referring such characters to an originally distinct creation, the derivative hypothesis, whilst admitting their transmissibility and their maintenance for an unknown period through generative powers obstructive of departure from such characters, holds that observation has not yet reached the actual beginning of such species, nor the point at which variation stops." (Owen 1866a [1862]: 92)

Owen then discusses different possible explanations from Buffon to Lamarck to Darwin. He dismisses all of them; in the case of Darwin he admits that the explanation of the joint paper is plausible but warns that the "varieties of condition of the human mind are manifold" and not supported by fact. In the case of the aye-aye, no evidence existed for a shortage of food or other selective pressures. (Rupke 1994: 235-6) Therefore, he champions his own explanation based on the archetype which he terms "creation by law" but still falls short of a dynamic model:

> "…is the more probable, from the kind and degree of similitude between the species that succeeds and the species that disappears, never to return as such; the similitude being, in the main, of a nature expressed by the terms of "progressive departure from a general to a special type". Creation by law is suggested by the many instances of retention of structures in palaeozoic species which are embryonal and transitory in later species of the same order or class; and the suggestion acquires force by considering the analogies which the transitory embryonal stages in a higher species bear to the mature forms of lower species. (Owen 1866a [1862]: 95-6)

In the first Volume of the Anatomy of Vertebrates, Owen repeats the allusion from his Fullerian lecture that environmental changes might indeed trigger extinction (but not transmutation):

> "Concomitant changes of climate, and other conditions of a country affecting the sustenance or well-being of its indigenous animals, may lead not only to their

> modification but to their destruction. I have, in another work, pointed out the characters in the animals themselves calculated to render them most obnoxious to such extirpating influences ; and have applied the remarks to the explanation of so many of the larger species of particular groups of animals having become extinct, whilst smaller species of equal antiquity have remained." (Owen 1866b: xxxiii-xxxiv)

In the third volume, two years later, Owen specified this point, although in different terminology and, again, dismissed catastrophes as an explanatory Input:

> "Each successive parcel of geological truth has tended to dissipate the belief in the unusually sudden and violent nature of the changes recognisable in the earth's surface. In specially directing my attention to this moot point, whilst engaged in investigations of fossil remains, and in the reconstruction of the species to which they belonged, I was, at length, led to recognise one cause of extinction as being due to defeat in the 'contest[330] which as a living organised whole, the individual of each species had to maintain against the surrounding agencies which might militate against its existence'." (Owen 1868: 798)

Moreover, he renewed his support for continuous spontaneous generation[331], which he opposed to the "doctrine of primary life by miracle" allegedly held by Darwin. (Owen 1868: 714) Owen's argument here was that Darwin refused to explain the origin of life, limiting himself to evolutionary change among living organisms. Owen thus argued that Darwin had to suppose a miraculous first creation of life, while he, Richard Owen, attempted to explain both the origin of life and the origin of species (evolution) by natural laws.

With respect to transmutations, however Owen disputed the model of Darwin and Wallace. He claimed that deviations from the archetype would be 'sudden and considerable', i.e. saltational. He illustrated this on the relation of the modern horse to two of his ancestors, the Hipparion and the Paleotherium. (Richards 1987a: 146; cf. Owen 1868: 795) Owen highlighted how some modern horses were sometimes born with an additional hoof, just like their ancestors. From this Owen concludes that evolutionary change was

> "sudden and considerable : it opposes the idea that species are transmuted by minute and slow degrees. It also shows that a species might originate independently of the operation of any external influence ; that change of structure would precede that of use and habit ; that appetency, impulse, ambient medium, fortuitous fitness of surrounding circumstances, or a personified 'selecting Nature,' would have had no share in the transmutative act." (Owen 1868: 795)

A couple of pages later, he points out how many variations occur independent of environmental changes, which he considers evidence for his "sudden and considerable" change:

> "'The majority of species, originating in uncalled-for, unstimulated, unselected departures from parental structure, establish themselves and flourish independently of external influences. All classes of animals exemplify this independence: the

330 For a discussion of Owen's "contest", see below.

331 Owen specifically addressed Pasteur's experiments on spontaneous generation and discussed possible shortcomings. (Owen 1868: 814-5)

> Cetaceans, under an extraordinary and likely graduated range of generic and specific modifications; and the same may be said of most Fishes.
> So, being unable to accept the [Lamarckian] volitional hypothesis, or that of impulse from within, or the selective force exerted by outward circumstances [Darwinian natural selection], I deem an innate tendency [sic!] to deviate from parental type operating through periods of adequate duration, to be the most probable nature, or way of operation, of the secondary law, whereby species have been derived one from the other.' (Owen 1868: 807; cf. Richards 1987a: 146)

Thus, Owen rejects the Darwinian model with reference to Darwin's accidental variations. On Owen's account, however, this is no contradiction as these variations are not accidental but evidence of "a secondary law". Moreover, as they often precede environmental changes they cannot be triggered by environmental changes[332]:

> "Of the 120 kinds of coral enumerated by Ehrenberg in the Red Sea, 100, at least, exist under the same conditions. The majority of species, originating in uncalled-for, unstimulated, unselected departures from parental structure, establish themselves and flourish independently of external influences. All classes of animals exemplify this independence: the Cetaceans, under an extraordinary and nicely graduated range of generic and specific modifications ; and the same may be said of most Fishes.
> So, being unable to accept the volitional hypothesis, or that of impulse from within, or the selective force exerted by outward circumstances, I deem an innate tendency to deviate from parental type, operating through periods of adequate duration, to be the most probable nature, or way of operation, of the secondary law, whereby species have been derived one from the other." (Owen 1868: 807)

In sum, while Owen had refrained from providing a dynamic model of evolution in the 1840s and 1850s, he devoted most of his testimonials in the 1860s to challenge the Inputs of Darwin's and Wallace's model: environmental changes and accidental variations.

iv. Situation Type: Weak metaphors only

The Situation Type never occupied an important place in his dynamic model and he never developed it systematically. I do not even find a clear and continuous support of uniformitarianism or spontaneous generation in his writings. However, some of his accounts of nature can be read in the sense of a constant struggle as I have already identified it with Aristotle, Linnaeus, or Geoffroy.[333] (See section 2.3 x)

The earliest mention of such an idea can be found in the fourth part of a memoir on the giant bird Didornis which was published in the Transactions of the Zoological Society in 1862 but had already been presented by Owen in 1850. Here Owen speaks of a

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332 This point was very important to Owen, who "traced development to regular and interrelated processes. In contrast to Geoffroy, he held that these processes were internal to the organism and could not be altered by external conditions." (Cosans 2009: 22)

333 In the joint Darwin-Wallace paper, Darwin would point to De Candolle, W. Herbert, and Lyell. (Darwin 1858b [1857]: 51)

> "…the difficulty of the contest which, as a living organized whole, the individual of such species has to maintain against the surrounding agencies that are ever tending to dissolve the vital bond, and subjugate the living matter to the ordinary chemical and physical forces." (Owen 1862b [1850]: 1-20)

Owen repeated similar formulations in his 1859 Fullerian Lecture *On the Extinction of Species*, speaking of "the contest which the animal has to maintain against the surrounding agencies that" (Owen 1859c: 56) He repeated a similar formulation in the Preface of the first Volume of his *Anatomy of Vertebrates*. (Owen 1866b: xxxiv) but began shifting his wording towards a more Darwinian metaphor and spoke of of a "contest for existence" or a "battle for life" (Owen 1869 [1866]: 80; Owen 1866b: xxxiv, 183) This switch was interpreted by reviewers as at least a partial adoption of the Darwinian theory. However, Owen was quick to point out his using a similar expression in 1850 and denied any such allegations in a 1867 dictionary article as well as the conclusion of the third volume of the *Anatomy of Vertebrates*. (Owen 1868: 798-9; Rupke 1994: 247-8)[334]

Second, Owen emphasized that such "contest" could only be explanatory in the case of extinctions, not for the emergence of new species:

> "Each successive parcel of geological truth has tended to dissipate the belief in the unusually sudden and violent nature of the changes recognisable in the earth's surface. In specially directing my attention to this moot point, whilst engaged in investigations of fossil remains, and in the reconstruction of the species to which they belonged, I was, at length, led to recognise one cause of extinction as being due to defeat in the 'contest which as a living organised whole, the individual of principle has received a large and most instructive accession of illustrations from the extensive knowledge and devoted labours of Charles Darwin each species had to maintain against the surrounding agencies which might militate against its existence.' This principle has received a large and most instructive accession of illustrations from the extensive knowledge and devoted labours of Charles Darwin : but he aims to apply it not only to the extinction but the origin of species. Although I fail to recognise proof of the latter bearing of the 'battle of life,' the concurrence of so much evidence in favour of extinction by law is, in like measure, corroborative of the truth of the ascription of the origin of species to a secondary cause." Owen 1868: 797-8; cf. Rupke 1994: 247-8)

This distinction is justified. First, the "contest" or "struggle" as he describes it, is not a constant background-regularity as in Darwin's and Wallace's model. (See sections 3.3.3, 3.4.3) It is closer to an Input. Second, the term did not have a discernible empirical referent; it remains unclear what it might refer to. In sum, the role of Owen's "contest" or remains very limited and it does not provide for much in Owen's dynamic model.

[334] The discussion is to be found in the lengthy footnote which starts on page 798.

v. *Connector: Laws of development*

None of the dynamic models his contemporaries suggested satisfied Owen. By his own account, he had considered – “no fewer than half a dozen” – different explanations for evolution (Rupke 1994: 225) yet he would dismiss all of them as speculative, be it Lamarck’s, Geoffroy’s or Darwins.[335]

Owen himself preferred not to speculate or not to express himself clearly, neither in *On the Archetype* nor in *The Nature of Limbs.*[336] In the *Archetype*, Owen suggested two forces to produce evolution. These two forces represented the conservative force of Geoffroy’s “unity of type” and the progressive force of Cuvier’s adaption to “conditions of existence” (cf. Ruse 1979: 121), i.e. the two concepts which molded Owen’s early work.

In the *Nature of Limbs* book, he suggests an analogy from mechanics to the laws governing biology only to not spell it out:

> “The naturalist and anatomist, in digesting the knowledge which the astronomer has been able to furnish regarding the planets and the mechanism of the satellites for illuminating the night-season of the distant orbs that revolve round our common sun, can hardly avoid speculating on the organic mechanism that may exist to profit by such sources of light and which must exist, if the only conceivable purpose' of those beneficent arrangements is to be fulfilled. But the laws of light, as of gravitation, being the same in Jupiter as here, the eyes of such creatures as may disport in the soft reflected beams of its moons will probably be organized on the same dioptric principles as those of the animals of a like grade of organization on this earth. And the inference as to the possibility of the vertebrate type being the basis of the organization of some of the inhabitants of other planets will not appear so hazardous, when it is remembered that the orbits or protective cavities of the eyes of the Vertebrata of this planet are constructed of modified vertebrate. Our thoughts are free to soar as far as any legitimate analogy may seem to guide them rightly in the boundless ocean of unknown truth. And if censure be merited for here indulging, even for a moment, in pure speculation, it may, perhaps, be disarmed by the reflection that the discovery of the vertebrate archetype could not fail to suggest to the Anatomist many possible modifications of it beyond those that we know to have been realized in this little orb of ours.
> The inspired Writer, the Poet and the Artist alone have been privileged to depict such.” (Owen 2007 [1849]: 83-4)

When, in 1860, Darwin’s Connector and its powerfully connotative name ‘Natural Selection’ became the subject of intense public debate, Owen still refused to suggest an alternative, particularly with respect to higher organisms (Owen 1860a: 404):

> “As to the successive appearance of new species in the course of geological time, it is first requisite to avoid the common mistake of confounding the propositions, of species being the result of a continuously operating secondary cause, and of the

[335] Particularly, he did not speak out for either metagenesis, the alternation of generations in reproduction.
[336] Cosans traces this position back to Owen’s 1837 Hunterian Lectures. (Cosans 2009: 45)

> mode of operation of such creative cause. Biologists may entertain the first without accepting any current hypothesis as to the second." (Owen 1860a: 403)

Only in the second half of the 1860s did Owen soften his stance. In his 1866 *On the Osteology of the Dodo* and the third volume of the *Anatomy of Vertebrates* he employed an evolutionary Connector in explanation. Interestingly, he did borrow from Lamarck, not from Darwin[337]:

> “If the great Ground-dove of the Mauritius gradually gained bulk in the long course of successive generations in that uninhabited thickly-wooded island, and, exempt from the attacks of any enemy, with food enough scattered over the ground, ceased to exert the wings to raise the heavy trunk, then, on Lamarck's principle, the disused members would atrophy, while the hind limbs, through the increased exercise by habitual motion on land, with increasing weight to support, would hypertrophy.” (Owen 1869 [1866]: 70; cf. Rupke 1994: 247

> “The Dodo exemplifies Buffon's idea' of the origin of species through departure from and the known consequences of the a more perfect original type by degeneration ; disuse of one locomotive organ and extra use of another indicate the nature of the secondary causes that may have operated in the creation of this species of bird, agreeably with Lamarck's philosophical conception of the influence of such physiological conditions of atrophy and hypertrophy, as small as in the Dodo : and the most intelligible conception of its mode of origin is that to which I have alluded in the description The young of all Doves are hatched with wings that species retained the immature character. The main condition making possible the production and continuance of such a species in the island of Mauritius was the absence of any animal that could kill a great bird incapable of flight. The introduction of such a destroyer became fatal to the species which had lost such means of escape. The Mauritian Doves … that retained their powers of flight continue to exist there.” (Owen 1869 [1866]: 80-1)

> “All these muscles of the human external ear exemplify the Lamarckian law of degeneration from disuse, In the primitive men of the stone-period,' they probably existed in normal size and force.” (Owen 1868: 245)

As with his “contest for existence”, it seems that Owen consider disuse to explain only the degeneration of species, and in the long run, their extinction. In the first Volume of the Anatomy of Vertebrates, Owen denied that neither a Darwinian nor a Lamarckian Connector could account for the emergence of new species (transmutation):

> “The Tadpole … affords a significant example of the transmutation of a natatory to a saltatory type of hind-limb, irrespective of efforts and exercises through successive generations producing and accumulating small changes, and independently of any selection by nature of such generations as were enabled, through the accidental variety of a slightly lengthened hind-limb, to conquer in the battle of life, and to transmit the tendency towards such disproportion to their posterity.” (Owen 1866b: 182-3, cf. xxxiii)

[337] Darwin also employed use and disuse in his dynamic model the Origin (section 3.4.3 v), but both clearly stem from Lamarck.

In sum, Owen never championed a overarching Connector to explain evolution. Until the mid-1860s he refused to speculate on the topic and when he employed Lamarckian disuse he did so only with respect to extinction, not evolution (development). This is not fully surprising as he did not have any empirical Input which would trigger such a Connector.

vi. Synthesis[338]

First, Owen's Object Class are varieties and species, no individuals – a deviation from his predecessors Geoffroy and Lamarck, but also from Wallace and Darwin. Like all important evolutionists before him, Owen supported spontaneous generation and uniformitarianism as part of the Situation Type. Although he employed the metaphor of a struggle or contest, he never developed it into a Situation Type, i.e. an empirically discernible observation in the background of the modeled regularities. Moreover, he only mentioned it with extinctions only, not with the emergence of new species.

The same is true for the Connector and, partly, the Input: Owen developed a full-fledged dynamic model only with respect to extinctions. Ecological change, which comprises changes with respect to climate or isolation, trigger evolution, possibly through disuses; they do not trigger the emergence of new species. For such emergence, Owen named no Input but only provided a name for the Connector which would lead to such events: laws of development. – Figure 16 provides an overview over Owen's model.

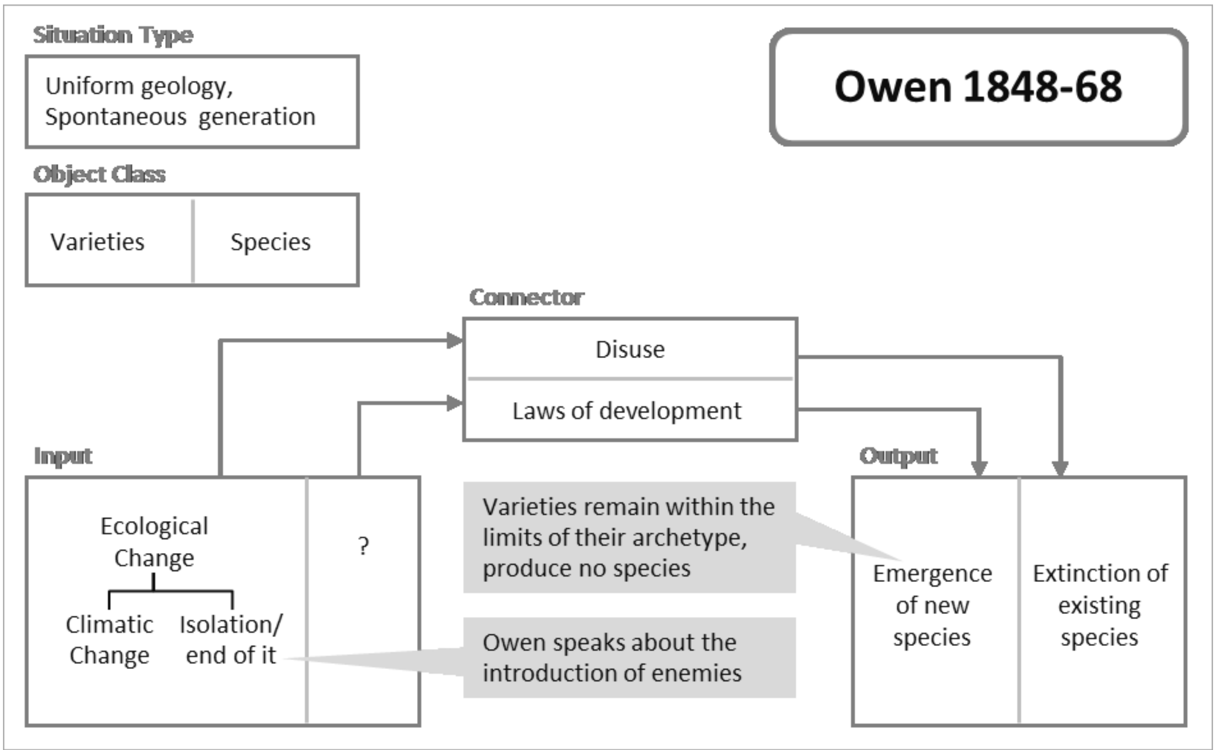

Figure 16: Owen's dynamic model of evolution

338 With Owen, it is most difficult to summarize his model of evolution; he changed positions too often and his writing was generally of limited clarity. Of Owen's many statements and positions, I will select those which are closest to Darwin because they are most informative for the questions which I pursue. Admittedly, this renders my synthesis something of a collage with Darwin as its focal point.

3.2.4 Narrative explanation: How did Owen tell evolution?

In contrast to his various sketches of a dynamic model, the basic form of Owen's narrative is much easier to grasp and describe. Over time, it remained pretty much constant in its key elements, the Agent and Purpose. What changed with the model were Agency, Act and Scene but these carried much less explanatory burden than for instance in Darwin's narrative. (See section 3.4.4) In its basic form, Owen's narrative was very close to Chambers'. It was centered around God and God's will. Therefore, in Owen's explanations, it is always clear that there is but one agent in Nature and that Nature expresses but one purpose: God's will, foresight and benevolence.

i. *Agent and Purpose: God & his will*

These views can be traced in his Hunterian Lectures, where he claims that the organization of organisms follows

> "determinate laws, which manifest in the highest degree the wisdom and design of the Law-giver; – the Great First Cause" (Owen 1992 [1837]: 221; cf. Cosans 2009: 27).

In the Archetype, he links his concept directly to God, claiming that the "archetypal ideal" had existed "in the mind of the Creator" (Padian 2007: lxxxvi; Rupke 1995: 218) and citing the Argument from Design:

> "The beneficent Author of all, who has created other revolving orbs, with relations to the central source of heat and light like our own, may have willed that these also should be the seat of sentient beings, suited to all the Conditions of animal enjoyment existing in such planets; basking, perhaps, in the solar beams by day, or disporting in the soft reflected light of their earth's satellites by night. The eyes of such creatures, the laws of light being the same, would doubtless be organized on the same dioptric principles as ours; and. if the vertebral column should there, as here, have been adopted as the basis of the higher animal forms, it may be subject to modifications issuing in forms such as this planet has never witnessed, and which can only be conceived by him who has penetrated the mystery of the vertebrate archetype, and recognised the kind and mode and extent of its modifications here." (Owen 1848a: 102)

> "With regard to the 'adaptive force,' whatever may be the expressions by which its nature and relations, when better understood, may be attempted to be explained, its effects must ever impress the rightly constituted mind with the conviction, that in every species co ends are obtained and the interests of the animal promoted, in a way that indicates superior design, intelligence and foresight; but a design, intelligence and foresight in which the judgement and reflection of the animal never were concerned; and which, therefore, with Virgil, and with other studious observers of nature, we must ascribe to the Sovereign of the universe, in whom we live, and move, and have our being." (Owen 1848a: 172)[339]

[339] In the same passage, Owen opposes his views to narratives centered around a "vital force" as they were championed by the German idealists. (Owen 1848a: 172) I find few explicit references to a vital force

> "The satisfaction felt by the rightly constituted mind must ever be great in recognising the fitness of parts for their appropriate functions; but when this. fitness is gained, as in the great toe of the foot of man and the ostrich, by a structure which at the same time manifests a harmonious concord with a common type, the power of the One Great Cause of all organization is appreciated as fully, perhaps, as it is possible to be by our limited intelligence." (Owen 1848a: 197)

Thus, according to Owen, nature works indeed according to a Plan "the Plan is one of organization, not of optimality of function." (Padian 2007: lxxxiv) In the *Nature of Limbs*, Owen claimed that

> "the recognition of an ideal Exemplar for the Vertebrated animals proves that the knowledge of such a being as Man must have existed before Man appeared. For the Divine mind which planned the Archetype also foreknew all its modifications.
> The Archetypal idea was manifested in the flesh, under divers such modifications, upon this planet, long prior to the existence of those animal species that actually exemplify it." (Owen 2007 [1849]: 85-6)

Thus, he "demonstrated the pre-existence of the archetypal ideal in the mind of the Creator and thus refuted the argument of the old Pantheists and atheists that mind did not precede matter" (Richards 1987a: 165; cf. Padian 2007: lxxvi; Rupke 1994: 220) The Archetype virtually displays the Divine Purpose.

In his 1858 address to the BAAS, after the publication of the joint Darwin-Wallace paper, he argued in favor of retaining the idea which "we call 'creation', viz. that the process of [spontaneous generation] was ordained and had originated from an all-wise and powerful First Cause of all things." (op. cit. Rupke 1994: 236) In the Fullerian Lectures of 1859 expressed his hope that he had

> "fulfilled one object which I had in view, viz. to set forth the beneficence and intelligence of the Creative Power.
> If I have been able to demonstrate a uniform plan pervading the osteological structure of so many diversified animated beings, I must have enforced, were that necessary, as strong a conviction of the unity of the Creative Cause.
> If, in all the striking changes of form and proportion which have passed under review, we could discern only the results of minor modifications of the same few osseous elements, surely we must be the more strikingly impressed with the wisdom and power of that Cause which could produce so much variety, and at the same time such perfect adaptations and endowments, out of means so simple.[…]
> Everywhere in organic nature we see the means not only subservient to an end, but that end accomplished by the simplest means. Hence we are compelled to regard the Great Cause of all, not like certain philosophic ancients, as a uniform and quiescent mind, as an all pervading anima mundi, but as an active and anticipating intelligence." (Owen 1859c: 62)

He even specifies that he will not accept a second Agent besides God, i.e. no Natural Selection, for

afterwards, one exception being the third volume of *The Anatomy of Vertebrates*. (Owen 1868: 315, 514, 809, 817, 819, 823)

> "the highest generalizations in the science of organic bodies, like the Newtonian laws of universal matter, lead to the unequivocal conviction of a great First Cause, which is certainly not mechanical." (Owen 1859c: 63)

In *Palaeontology*, Owen ascribes the geographical distribution to God, claiming that

> "the creative force has not deserted the earth during any of the epochs of geological time that have succeeded to the first manifestation of such force; and that, in respect to no one class of animals, has the operation of creative force been limited to one geological epoch; and perhaps the most important and significant result of paleontological research has been the establishment of the axiom of the continuous operation of the ordained becoming of living things." (Owen 1860a: 3)

His intent was to "set forth the beneficence and intelligence of the Creative Power" (Owen 1860a: 412) for

> "Everywhere in organic nature we see the means not only subservient to an end, but that end accomplished by the simplest means. Hence we are compelled to regard the Great Cause of all, not like certain philosophic ancients, as a uniform and quiescent mind, as an all-pervading anima mundi, but as an active and anticipating intelligence. By applying the laws of comparative anatomy to the relics of extinct races of animals contained in and characterizing the different strata of the earth's crust, and corresponding with as many epochs in the earth's history, we make an important step in advance of all preceding philosophies, and are able to demonstrate that the same pervading, active, and beneficent intelligence which manifests His power in our times, has also manifested His power in times long anterior to the records of our existence." (Owen 1860a: 413)

He then repeated the dismissal of mechanical explanations in biology from the Fullerian Lectures. (Owen 1860a: 414)

In the memoir on the Aye-aye, Owen continued on the same teleological course:

> "The succession of species by continuously operating law is not necessarily a "blind operation." Such law, however dimly discerned in the properties and successions of natural objects, intimates, nevertheless, a pre- conceived progress. Organisms may be evolved in orderly succession stage after stage, towards a foreseen goal; and the broad features of the course may still show the unmistakeable impress of divine volition." (Owen 1866a [1862]: 91)

> "So, also, conditions of existence have a creative cause, as well as the animals related to those conditions. Constructed as we find them, animals are necessarily so related, and must be affected by every change in such conditions. But if we can conceive such conditions to change agreeably with the laws of their being,—the crust of the earth, e. g., having been created to move up and down, affecting its relations to water, air, temperature, and other circumstances influencing living beings, —these beings and their dwelling-place having been created as they are, with such interdependencies, the changes are necessary, may be called fatalistic, and yet are not the less a preordained result of the Creator of the arrangements, foreseeing the consequences

> of a long-continued series of operations and influences, educing new adjustments and developments out of efforts and exercises of organs stimulated by surrounding changes, or out of slight departures from parental form; which change of organs by change of exercise, and which congenital deviations or varieties, were equally a foreordained property of the living species." (Owen 1866a [1862]: 90)

The same view is reflected by his 1867 dictionary entry where "evolution was a teleological process, a movement towards a pre-ordained goal; and mutations were not randomly useful or useless, but a logical embroidering of the archetype." (Rupke 1994: 249; cf. 250) Finally, in The *Anatomy of Vertebrates*, Owen's teleological position came to maybe its bluntest expression. Owen was not far from the crudest supporters of Design when he claimed that it was no accident that the modern horse had appeared at about the time as the human race was no coincidence:

> "No one can enter the 'saddling ground' at Epsom, before the start for the 'Derby', without feeling that the glossy-coated, proudly stepping creatures led out before him are the most perfect and beautiful quadrupeds. As such, I believe the horse to have been predestined and prepared for Man. It may be weakness; but, if so, it is a glorious one, to discern, however dimly, across our finite prison wall, evidence of the 'Divinity that shapes our ends', abuse the means as we may." (Owen 1868: 769; Rupke 1994: 249-50)

Thus, despite his struggles with his model, Owen's narrative displayed an obvious and unambiguous Agent and Purpose throughout: evolution was carried out by God and according to his will. "On Owen's view, god created the laws responsible for the generation of life forms at the same time as he created the laws of physics." (Cosans 2009: 102)

ii. Agency and Act: Secondary causes and laws materialize the archetype

Given this analogy to physics, it is no surprise then, what Owen considered the means by which God achieved evolution. He did not act through direct intervention but through "natural laws" [340], i.e. "secondary causes" or "forces". This idea can be seen in On the Archetype, where Owen speaks of a "law that the Archetype is progressively departed from as the organization is more and more modified in adaptation to higher and more varied powers and actions" (Owen 2007 [1849]: 49) and opposes two antagonistic forces

> "The platonic idea or specific organizing principle or force would seem to be in antagonism with the general polarizing force, and to subdue and mould it in subserviency to the exigences of the resulting specific form.
> The extent to which the operation of the polarizing or vegetative-repetition-force is so subdued in the organization of a specific animal form becomes the index of the grade of such species, and is directly as its ascent in the scale of being. The lineaments of the common archetype are obscured in the same degree: but even in Man, where the specific organizing force has exerted its highest power in controlling

[340] Padian remarks that Owen's talk of the "law-like operation of secondary causes, bizarre as it must have sounded to many in his audience, was intended to ensure that Owen could bring biology into the same realm of predictability that physics and chemistry enjoy. In the same spirit, he attacks the notion that "nothing is made in vain," the hyperadaptive claim of the Design advocates; nature works according to a Plan, but the Plan is one of organization, not of optimality of function." (Padian 2007: lxxxiv)

the tendency to type and in modifying each part in adaptive subserviency to, or combination of power with, another part, the extent to which the vegetative repetition of segments and the archetypal features are traceable indicates the degree in which the general polarizing force may have operated in the arrangement of the parts of the developing frame: and it is not without interest or devoid of significance that such evidence should tie mainly manifested in the system of organs in whose tissue the inorganic earthy salts most predominate." (Owen 1848a: 172)[341]

In *The Nature of Limbs* where Owen cautiously suggests considering "the existence of such ministers" for the explanation of evolution:

> „To what natural laws or secondary causes the orderly succession and progression of such organic phenomena may have been committed we as yet are ignorant. But if, without derogation of the Divine power, we may conceive the existence of such ministers, and personify them by the term 'Nature'[342], we learn from the past history of our globe that she has advanced with slow and stately steps, guided by the archetypal light, amidst the wreck of worlds, from the first embodiment of the Vertebrate idea under its old Ichthyic vestment, until it became arrayed in the glorious garb of the Human form." (Owen 2007[1849]: 86; cf. Rupke 1994: 231-2; Amundson 2007: xxx)

Thus, although Owen aimed for "the same realm of predictability that physics and chemistry enjoy[ed]". (Padian 2007: lxxxiv; Richards 1987a: 151), he "couched his evolutionary ideas as being compatible with a natural law theology" (Cosans 2009: 43), thus preserving the teleological nature of his evolutionary account.

After his transitional retreat, Owen reaffirmed this view in the Fullerian lectures, where he employed the design implications to delineate himself from the Darwin-Wallace paper. Owen stressed that a mere mechanistic explanation could not produce evolution. Instead,

> "the highest generalizations in the science of organic bodies, like the Newtonian laws of universal matter, lead to the unequivocal conviction of a great First Cause, which is certainly not mechanical." (Owen 1859c: 63)

Thus, Owen insisted that laws were secondary causes, i.e. divine means; God acted through them. (MacLeod 1965: 270) This allowed him to bestow an air of purpose and design even on extinction and death; they were means to achieving a higher goal

> "Palaentology further teaches, that not only the individual, but the species perishes; that as death is balanced by generation, so extinction has been concomitant with the

341 Owen embeds the adaptive, i.e. Cuvierian forcie in a clear divine narrative; the passage continues: "With regard to the 'adaptive force,' whatever may be the expressions by which its nature and relations, when better understood, may be attempted to be explained, its effects must ever impress the rightly constituted mind with the conviction, that in every species co ends are obtained and the interests of the animal promoted, in a way that indicates superior design, intelligence and foresight; but a design, intelligence and foresight in which the judgement and reflection of the animal never were concerned; and which, therefore, with Virgil, and with other studious observers of nature, we must ascribe to the Sovereign of the universe, in whom we live, and move, and have our being." (Owen 1848a: 172)

342 Note that Darwin drew on this very personification in the joint paper and the Origin (sections 3.3.4, 3.4.4). Geoffroy had also employed it. (See section 2.3 ix)

> creative power which has continued to provide a succession of species; and furthermore, that, as regards the various forms of life which this planet has supported, there has been 'an advance and progress in the main'." (Owen 1860a: 3)

The point is repeated in the memoir on the Aye-aye, extending it to Darwin's "injurious" variations:

> "So neither would the phenomena of the long succession of organized species justify the notion, nor do I believe they would suggest, that they were the result of blind chance, if it should be demonstrated that they, too, are the result of secondary influences operating through long ages. It may be true that many of the aims of derivative tendencies miss their end : but myriads of germs never reach perfection ; and the proportion of such short-coming is much greater in the phenomena of human life. These serve to exemplify abundantly in how small a degree the doings of the highest created agent here square with the ideal of the aim and end of his existence : yet he is not, therefore, argued to be a thing of chance. The succession of species by continuously operating law is not necessarily a "blind operation." Such law, however dimly discerned in the properties and successions of natural objects, intimates, nevertheless, a preconceived progress. Organisms may be evolved in orderly succession stage after stage, towards a foreseen goal; and the broad features of the course may still show the unmistakeable impress of divine volition." (Owen 1866a [1862]: 91)

In the Anatomy of Vertebrates, finally, Owen explicitly opposed the two alternatives: evolution with design or without it, positioning himself as the design alternative to Darwin:

> "'Natural Selection' leaves the subsequent origin and succession of species to the fortuitous concurrence of outward conditions: 'Derivation' recognises a purpose in the defined and preordained course, due to innate capacity or power of change, by which nomogenously[343]-created protozoa have risen to the higher forms of plants and animals." (Owen 1868: 809)[344]

Moreover, the construction of laws as divine means of intervention allowed Owen to preserve the idea of divine providence: although God does not interfere directly in the course of organic things his laws keep him in touch:

> "Thus we learn, that the creative force has not deserted the earth during any of the epochs of geological time that have succeeded to the first manifestation of such force; and that, in respect to no one class of animals, has the operation of creative force been limited to one geological epoch; and perhaps the most important and significant result of paleontological research has been the establishment of the axiom of the continuous operation of the ordained becoming of living things." (Owen 1860a: 3)

[343] The term 'nomogeny' is a synonym for spontaneous generation.

[344] Note how the dualism here presented by Owen still reflects the fundamental divide of the debates between Cuvier and Geoffroy: structure versus environment.

iii. Scene: A pre-ordained universe

As with Chambers, the Scene in which evolution occurred did not play much of a role in Owen's narrative and the reasons are the same: If God is almighty, everything is subject to him, he rules the domains of the material world (physics, chemistry, geology) as well as the world of the living (biology). Thus, in Owen's teleological narrative, all features of the world bear God's mark; everything is lawful and intended change, everything displays harmony and design, the world suits its components. This becomes very clear in a passage from the Aye-aye memoir:

> "So, also, conditions of existence have a creative cause, as well as the animals related to those conditions. Constructed as we find them, animals are necessarily so related, and must be affected by every change in such conditions. But if we can conceive such conditions to change agreeably with the laws of their being,—the crust of the earth, e. g., having been created to move up and down, affecting its relations to water, air, temperature, and other circumstances influencing living beings, —these beings and their dwelling-place having been created as they are, with such interdependencies, the changes are necessary, may be called fatalistic, and yet are not the less a preordained result of the Creator of the arrangements, foreseeing the consequences of a long-continued series of operations and influences, educing new adjustments and developments out of efforts and exercises of organs stimulated by surrounding changes, or out of slight departures from parental form; which change of organs by change of exercise, and which congenital deviations or varieties, were equally a foreordained property of the living species." (Owen 1866a [1862]: 90)

In sum, despite his constant tinkering with his model, Owen's texts convey a constant and straightforward narrative. From the Archetype (1848) to his *Anatomy of Vertebrates* (1868), all accounts of evolution are embedded in a religious narrative in which God (Agent) takes center stage in a world which is subject to his will (Scene). He acts through various laws (Agency) according to his plan or will (Purpose/Reason) to achieve the kind of evolution Owen championed (Act).

3.2.5 Implications: What did Owen's explanation imply about the world?

Owen first hesitated to publicly join Chambers but later never went beyond the narrative already popularized and established by Chambers. Thus, over time, the possible ontological implications of Owen's narrative did not exceed those of Chambers. Thus, Owen's narrative settled somewhere between Paley and Darwin, clearly surpassing the theism of the former but stopping short of the materialism of the latter.

On Owen's account, Man remains in a class of his own, unified in his many races, and atop of creation – despite some anatomical resemblances to the apes. He maintains his special relationship to God and enjoys divine providence. God remains the central and dominant Agent in the world, acting in foresight and benevolence. With respect to society and politics, Owen propagated a world of limited and pre-ordained changes, of controlled dynamics, thus championing the utmost stability still compatible with the paleontological and biogeographical record. Thus, "Owen's archetypal theory resolved the teleological problem of the explanation of structural similarities between organs and organism which do not serve the similar functions, and his 'conserving reforms' came to the aid of natural theology and the social order in a period when they were both under considerable stress. " (Richards 1987a: 157)

3.3 Alfred Russel Wallace: two papers from 1855 and 1858

Alfred Russel Wallace is most famous as the co-author of Evolution theory and natural selection; this, however, was but a short episode of his life – and a rather early one. Wallace was born in 1823 in the county Monmouthshire in south east Wales. He came from a humble background. He had to leave school early, at fourteen, and briefly worked in a carpenter shop in London and, from 1837 on, as land surveyor during the railway boom. Walking the countryside, he developed an interest in natural history and began to study and identify plants. In stark opposition to Owen, he would remain a field researcher throughout his career, never witnessing an anatomical dissection until he was fifty. (Pantin 1959: 66-8; Ruse 1979: 155-6)

Wallace read Chamber's *Vestiges* and by 1845 he considered himself an evolutionist although he was not satisfied with the explanation Chambers provided. In 1848, at the age of 25, he ventured on his first great field trip to the Amazonas. He was accompanied by the Henry Bates, two years his junior and from a similar background.[345] Bates and Wallace spent nearly four years collecting specimen in South America. Unfortunately, on the return trip in 1852, Wallace's ship caught fire. He lost all his possessions and collections and barely survived. (Pantin 1959: 68; Ruse 1979: 156-7)

After two years in London, he left for another, even longer field trip: the next eight years he would spend on the Malay Archipelago (modern Indonesia) and there he would make the discoveries that eventually led to his two evolutionary papers of 1855 and 1858. When Wallace returned to England in 1862, he was well-known, respected and had acquired some financial reserves through the sale of rare specimen. (Pantin 1959: 68; Himmelfarb 1959: 202-3; Ruse 1979: 158-9)

Unfortunately, bad investments would lead to financial troubles in the late 1860s and 1870s. Wallace had to earn a living through publications, lectures and editing work. In the 1870s, he engaged in social movements and published on social topics. Still, he continued his biological work, publishing for instance T*he Geographical Distribution of Animals* in 1876, a seminal work in biogeography. In 1881, Wallace was granted a pension. He publishes a collection of his contributions to evolution theory in the book 1889 *Darwinism*. Wallace died in 1913 and a commemorative plaque was installed near Darwin' grave in Westminster Abbey.

Wallace published his pre-Origin position on evolution in two papers. In September 1855, *On the Law Which Has Regulated the Introduction of New Species* appeared in the *Annals and Magazine of the Natural History*. (Wallace 1870a [1855]) Nearly three years later, *On the Tendency of Varieties to depart indefinitely from the Original Type* was part of the famous joint Darwin-Wallace paper in the *Proceedings of the Linnean Society for Zoology*. (Wallace 1858) [346]

In the first paper, Wallace discussed the problem of geographical distribution and presented a new taxonomy, a branching tree, and thus a new account of what evolution was. In this first paper, however, Wallace would not attempt to explain his taxonomy or the process which had produced it.[347] This paper was brought to Darwin's notice by Lyell in April 1856. Darwin recognized how close

345 Bates would later give the first account of mimicry as an instance of adaption in animals and, thus, support natural selection.

346 It is unclear how much Darwin was motivated by the wish to secure priority for work.

347 I would like to emphasize how much Wallace's two papers of 1855 and 1858 are complementary. In the Darwin literature the former is usually considered a first step of Wallace towards Darwin's model,

Wallace came to his own thoughts, as documented in his Sketch of 1842 and his Essay of 1844, the latter of which had, at the time, been read by the geologist Charles Lyell and the botanist John Dalton Hooker. (Beddall 1988)

In May 1856 and on Lyell's advice, Darwin began his voluminous *Natural Selection*, a book intended to provide a comprehensive and empirically founded presentation of his views on the "species problem". By the end of March 1857 Darwin received a first letter by Wallace. In his response in May, he expressed his agreement with Wallace's views and encouraged him to go further. In early September 1857, however, Darwin wrote a letter to the American botanist Asa Gray in which he summarized and updated his views and producing a third independent witness for his priority. (Beddall 1988)

Wallace, in the meantime, had his very own Malthus moment. Lying down with fever, Wallace reflected about the checks which keep populations from expanding and, just like Darwin, remembered Malthus's essay which he had read a couple of years earlier. This finally led him to an explanation for evolution. Wallace wrote it down in a short paper and sent it Darwin with the request to publish it, if Darwin deemed it worthy. (Beddall 1988; Himmelfarb 1959)

On June 18 1858, Darwin received this paper and, noticing the obvious similarities between Wallace's and his explanation, consulted with Hooker and Lyell on what to do.[348] Lyell suggested to submit a joint paper to the Linnean Society thus acknowledging both Wallace's and Darwin's independent originality but reserve priority for Darwin. The 1858 joint paper included extracts from Darwin's Essay of 1844, which had been read by Lyell and Hooker, as well as his 1857 letter to Asa Gray providing an updated version of Darwin's argument but also displaying the continuity of his thoughts. The 18-page joint paper contains a two-page introduction, seven-and-a-half pages of Darwin's two contributions and eight-and-a-half pages for Wallace's part.

In the following analysis, I will compare Darwin's and Wallace's parts of the paper. I will focus on Wallace, however, as a Darwin's part is already very close to the Origin which I will address in the next section.

3.3.1 Description: What evidence did Wallace and Darwin present and how?

In comparing the Wallace's two papers with Darwin's contributions to the joint paper according to my framework, Wallace's papers are much more empirical, mainly due to the 1855 paper. Darwin does not provide but two explanatory sketches.[349] Wallace's first paper begins with a description of

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something of an immature idea of his model to come. This is inadequate, however. In the first paper Wallace presents the static model which his 1858 paper aims to explain by a dynamic model, the former is the empirical basis to the second, its point of reference. My four-level model makes this connection much clearer and my analysis will show how much both papers are linked. I believe that historical and philosophical analysis should take these links into consideration and regard the second paper in context with the first.

348 For an excellent and precise historical account of the events between Wallace's 1855 paper and the publication of the 1858 joint paper, see (Beddall 1988).

349 18 month later, in the Origin Darwin would supply some of these empirics. However, he never presented an amount of empirical material comparable to Owen, not even in the Origin. He seemed to have planned this in his unpublished "big book" *Natural Selection* but he never came to deliver the specification of his sketch.

geological findings and proceeds with a presentation of nine empirical regularities which link geography and geology to biology, the condensed shared empirical knowledge of biogeography (1-4) and paleontology (5-9):

> "1. Large groups, such as classes and orders, are generally spread over the whole earth, while smaller ones, such as families and genera, are frequently confined to one portion, often to a very limited district.
> 2. In widely distributed families the genera are often limited in range; in widely distributed genera, well-marked groups of species are peculiar to each geographical district.
> 3. When a group is confined to one district, and is rich in species, it is almost invariably the case that the most closely allied species are found in the same locality or in closely adjoining localities, and that therefore the natural sequence of the species by affinity is also geographical.
> 4. In countries of a similar climate, but separated by a wide sea or lofty mountains, the families, genera and species of the one are often represented by closely allied families, genera and species peculiar to the other.
> 5. The distribution of the organic world in time is very similar to its present distribution in space.
> 6. Most of the larger and some small groups extend through several geological periods.
> 7. In each period, however, there are peculiar groups, found nowhere else, and extending through one or several formations.
> 8. Species of one genus, or genera of one family occurring in the same geological time are more closely allied than those separated in time.
> 9. As generally in geography no species or genus occurs in two very distant localities without being also found in intermediate places, so in geology the life of a species or genus has not been interrupted. In other words, no group or species has come into existence twice." (Wallace 1870a [1855]: 4-5)

These nine regularities[350] Wallace summarizes by a "law" which he covers them: "Every species has come into existence coincident both in space and time with a pre-existing closely allied species." (Wallace 1870a [1855]: 5) Thus, Wallace, formulates a general statement which set fossils and living organisms in relation to each other in function of the geographical area (space) and geological layer (time) in which they were observed as well as the anatomical features by which species were classified in the first place. To Wallace, this "law" "agrees with, explains and illustrates all the facts connected with" the natural affinities (similarities) among organisms, the distribution of plants and animals in space and time as well as rudimentary organs. (Wallace 1870a [1855]: 6) Wallace then demonstrates how his law covers such facts on several generic and specific examples.

In comparison, the joint paper of 1858 contains very little empirics. This is not surprising if one considers its restricted length; these are three explanatory sketches, not more. Darwin, in the excerpt from his 1844 Essay, explicitly mentions two empirical regularities. First, he notes that animal populations remain constant despite the "enormous multiplying power inherent and annually in action in all animals [… and] the countless seeds scattered" each year by plants. (Darwin 1858a

[350] (Ruse 1979: 158) calls these regularities, „in the philosopher's terminology", 'phenomenal laws'.

[1844]: 48) Thus, organisms produce much more progeny than can possibly survive. Second, in his letter to Gray, Darwin explains that the “same spot will support more life if occupied by very diverse forms.” (Darwin 1858a [1844]: 52)

In his part of the joint paper, Wallace (1858: 57) takes up Darwin’s first regularity: “Even the least prolific of animals would increase rapidly if unchecked, whereas it is evident that the animal population of the globe must be stationary, or perhaps, through the influence of man, decreasing.” (Wallace 1858: 54) Second, he mentions that “Domestic varieties, when turned wild, must return to something near the type of the original wild stock, or become altogether extinct.” (Wallace 1858: 60) Third, Wallace refers to his law from the 1855 by claiming that there is “progression and continued divergence” among organisms such that “there is a tendency in nature to the continued progression of certain classes of varieties further and further from the original type there appears no reason to assign any definite limits” (Wallace 1858: 59, 62)

3.3.2 Classification: How did Wallace & Darwin denote and aggregate evidence?

Based on his law that “[e]very species has come into existence coincident both in space and time with a pre-existing closely allied species”, Wallace discusses a true system of Classification. He explicitly denies a “direct succession in a straight line”[351] but also “all those systems of classification which arrange species or groups in circles, as well as those which fix a definite number for the divisions of each group” as the quinary system Chambers had fancied; such system simply do not hold empirically. (Wallace 1870a [1855]: 6, 8) Therefore, Wallace suggests a novel type of taxonomy, a classification “as intricate as the twigs of a gnarled oak or the vascular system of the human body. “Wallace 1870a [1855]: 7-8)[352]

When Darwin read Wallace’s 1855 paper he wrote on the margin “uses my simile of a tree”, recognizing a representation which he had been pondering for years[353] (Beddall 1988: 19; cf. 17), and which he presented anew in his letter to Gray: “… organic beings always seem to branch and sub-branch like the limbs of a tree from a common trunk, the flourishing and diverging twigs destroying the less vigorous —the dead and lost branches rudely representing extinct genera and families.” (Darwin 1858b [1857]: 53)

Neither author provided a diagram of that taxonomic tree. Nevertheless, compared to Chambers’ or Owen’s taxonomy, it is much less orderly and systematic. There are no boundaries between orders, classes, species nor orderly steps in which organisms proceed from lower to higher forms. Particularly, it is not clear how Man relates to the animals; he is simply not mentioned in the paper.

[351] This can be read as a reference to Lamarck’s static model. (See section 2.3 vii)

[352] For an overview over static models of evolution prior to Darwin and Wallace, see (Voss 2007: 95-163).

[353] As Darwin did not mention the ‘tree’ concept in his Essay of 1844 but only in the 1857 letter to Gray, one might wonder if he took it from Wallace. Yet, Darwin clearly sketched his tree diagram in 1837 in his first transmutation notebook.

In Darwin's part of the joint paper I see no explicit justification for the classificatory tree, Darwin focuses on justifying his explanation.[354] Wallace does address the question in his 1858 paper in the same way Darwin would in the Origin (section 3.4.2):

> "Which is the variety and which the original species, there is generally no means of determining, except in those rare cases in which the one race has been known to produce an offspring unlike itself and resembling the other. This, however, would seem quite incompatible with the "permanent invariability of species," but the difficulty is overcome by assuming that such varieties have strict limits, and can never again vary further from the original type, although they may return to it…" (Wallace 1858: 53)

This justification aims at the exact point, where Wallace's and Darwin's aggregation deviates from many former classifications; it denies that the branches of the tree are neatly separated, or that the forks come in regular intervals. Both champion evolution without boundaries and argue against sharp distinctions between species and varieties, just like Lamarck nearly fifty years earlier.[355] Their argument eases taxonomy from a theoretical burden like Owen's, however, it allowed for less powerful statements about future variations or fossils. The days of Cuvier claiming he could describe an animal from a single bone were certainly coming to an end.

3.3.3 Logical explanation: How did Wallace and Darwin model evolution?

In his 1855 paper, Wallace does not explain his taxonomy, he merely describes it. The text does give a little hint in what direction to think when Wallace cites "the modified physical conditions" and "altered conditions" as a possible reason why old species replace new ones but it provides nothing close to an explanation, not even a sketch of how evolution is produced. (Wallace 1870a [1855]:14-6) I will therefore ignore it in the following section.

The three parts of the joint paper, however, provide detailed and explicit dynamic models of evolution; they satisfy four to five elements of my framework.

i. Situation Type: Growth with Reproduction & Struggle for Life

A straightforward case is the Situation in which their models apply. It constitutes the first paragraph of Darwin's 1844 essay which begins such:

> "De Candolle, in an eloquent passage, has declared that all nature is at war, one organism with another, or with external nature. Seeing the contented face of nature, this may at first well be doubted; but reflection will inevitably prove it to be true. The war, however, is not constant, but recurrent in a slight degree at short periods, and more severely at occasional more distant periods; and hence its effects are easily

[354] From Darwin's use of the Object Class of his dynamic model, however, it becomes clear that Darwin shared Wallace's position on this point. Darwin's concentration on intra-species variation can be traced back to his 1836 research diary and the article on the Galapagos finches which appeared in the New York Times in 1837. (cf. Repcheck 2007: 218)

[355] Remember how Lamarck relativized both the notion of varieties and species in favor of individuals and argued that varieties and species are somewhat arbitrary sets over individuals. (Lamarck 1873a [1809]: 73)

> overlooked. It is the doctrine of Malthus applied in most cases with tenfold force." (Darwin 1858a [1844]: 46-7)

This struggle, Darwin says, occurs between species but also between individuals. (Darwin 1858a [1844]: 48) Besides, he defines what 'struggle' denotes: the fact that organic populations are largely constant in number although they produce so much progeny each year that their numbers should grow very quickly if all these progeny would reproduce.

> "But for animals without artificial means, the amount of food for each species must, on an average, be constant, whereas the increase of all organisms tends to be geometrical, and in a vast majority of cases at an enormous ratio. Suppose in a certain spot there are eight pairs of birds, and that only four pairs of them annually (including double hatches) rear only four young, and that these go on rearing their young at the same rate, then at the end of seven years (a short life, excluding violent deaths, for any bird) there will be 2048 birds, instead of the original sixteen. As this increase is quite impossible, we must conclude either that birds do not rear nearly half their young, or that the average life of a bird is, from accident, not nearly seven years. Both checks probably concur. The same kind of calculation applied to all plants and animals affords results more or less striking…" (Darwin 1858a [1844]: 47)

In the joint paper, Darwin repeats:

> "The elder De Candolle, W. Herbert, and Lyell have written excellently on the struggle for life; but even they have not written strongly enough. […] Only a few of those annually born can live to propagate their kind." (Darwin 1858b [1857]: 51)

Thus, the term 'struggle' denotes a conditional statement, namely a sequence of two observations: (i) Growth with reproduction (overproduction): On average, organisms produce a number of offspring which surpasses the number of their parent generation, and (ii) Constancy of Populations: Despite the Growth with Reproduction, populations do not grow over the long term.

Wallace concurs with Darwin in all these points. He mentions the struggle, both between species and individuals:

> "The life of wild animals is a struggle for existence. The full exertion of all their faculties and all their energies is required to preserve their own existence and provide for that of their infant offspring. The possibility of procuring food during the least favourable seasons, and of escaping the attacks of their most dangerous enemies, are the primary conditions which determine the existence both of individuals and of entire species." (Wallace 1858: 54)

> "Now it is clear that what takes place among the individuals of a species must also occur among the several allied species of a group,—viz. that those which are best adapted to obtain a regular supply of food, and to defend themselves against the attacks of their enemies and the vicissitudes of the seasons, must necessarily obtain and preserve a superiority in population…" (Wallace 1858: 57)

and provides the same operationalization for it as Darwin, denoting the same conditional statement of Growth with Reproduction (overproduction) and a constancy of populations:

> "The greater or less fecundity of an animal is often considered to be one of the chief causes of its abundance or scarcity; but a consideration of the facts will show us that it really has little or nothing to do with the matter. Even the least prolific of animals would increase rapidly if unchecked, whereas it is evident that the animal population of the globe must be stationary, or perhaps, through the influence of man, decreasing. Fluctuations there may be; but permanent increase, except in restricted localities, is almost impossible." (Wallace 1858: 55)

In sum, both Darwin and Wallace describe the Situation by the predicate 'struggle' which has the same connotation and denotes the same observable phenomena for both of them.[356]

ii. Object Class: Species, Varieties – and Individuals?

Through their classifications, Wallace[357] and Darwin claim that evolution transcends the boundaries of species and even Owen's archetype. Their first challenge is thus to reconstruct the Object Class and to demonstrate (i) that Natural Selection applies to individuals, varieties and species alike, and (ii) that it is potentially unlimited, unrestricted by boundaries. Thus, within their understanding of evolution, it made no sense for Darwin or Wallace, to uphold the sharp distinctions between species or individuals.

Darwin, unlike in the Origin, does not address the problem explicitly in his parts of the joint paper. Yet, he does imply his position by mention both varieties and species as equals when speaking of evolutionary change. (Darwin 1858b [1857]: 53) Moreover, Darwin blurs the distinction of individuals, varieties and species by referring to all three in a single argument:

> "I cannot doubt that during millions of generations individuals of a species will be occasionally born with some slight variation, profitable to some part of their economy. Such individuals will have a better chance of surviving, and of propagating their new and slightly different structure ; and the modification may be slowly increased by the accumulative action of natural selection to any profitable extent. The variety thus formed will either coexist with, or, more commonly, will exterminate its parent form." (Darwin 1858b [1857]: 52)

Wallace addresses this problem right at the beginning of his paper:

> "Which is the variety and which the original species, there is generally no means of determining, except in those rare cases in which the one race has been known to produce an offspring unlike itself and resembling the other." (Wallace 1858: 53)

Despite these obvious equivalences, there is some debate on whether Darwin's and Wallace's models are really equivalent. Most of these objections concern the Object Class:

[356] Kutschera claims that Wallace did not mention the importance of time for his argument. (Kutschera 2003: 351) It is true, that Wallace makes no explicit point about it in the 1858 paper, but he does in his earlier paper, discussing geological time throughout the text. (Wallace 1870a [1855]) Besides, it seems somewhat obvious that somebody speaking of palaentology and the origin of species is aware of the timescales in which such change occurs. Hence, I do not consider this a relevant difference.

[357] In his first paper, Wallace mentioned varieties only twice, and never variation. He does not discuss the distinction between varieties and species or the operationalization of either topic, albeit this would be his Archimedean point in 1858. (Wallace 1870a [1855]: 18)

First, Wallace does not mention them explicitly here and generally emphasizes struggle within and selection upon varieties and species, it is sometimes asked whether Wallace implies individuals. (cf. Ruse 1979: 159, Lynch 2001: xxvi-xxvi; Bowler 1990; Bowler 1992 [1988]: 43-46; Kutschera 2003: 351) Had he not, he could not have spoken about a struggle between individuals of the same variety or species nor could he have applied natural selection to individuals. A close reading brings me to the conclusion that such claims are unjustified. On one hand, Wallace infers all claims about natural selection acting on different species from its action on individuals of the same species. (Wallace 1858: 57; cf. Ruse 1979: 159) Thus, he must assume a struggle for life within species. On the other hand, before speaking about varieties, Wallace states clearly that individuals which have undergone variation may become variations, later he mixes both expressions. (Wallace 1858: 57, 59) Thus, I see no reason to assume that Wallace's Object Class excludes individuals.

A second claim is made by Kutschera who points out that, in 1858, Wallace speaks only of animals not of plants, while Darwin mentions both. (Kutschera 2003: 351) To me this seems to witness more of carelessness than a difference in their arguments. First, Wallace spoke of both, animals and plants, in his 1855 article. Second, he makes no explicit statement that he would exclude plants from his argument and naturalists of the time addressed the "species question" on either, animals and plants. Third, the introduction of the joint paper claims that both explanations by Wallace and Darwin are supposed to be equivalent; this should include the scope of their models. As I am unaware of any reference to this difference in the reception, I suggest to ignore it and assume that Wallace included all types of organisms.

A third argument focuses on the fact that Wallace explicitly denies that domesticated animals are informative for evolution in the wild:

> "We see, then, that no inferences as to varieties in a state of nature can be deduced from the observation of those occurring among domestic animals. The two are so much opposed to each other in every circumstance of their existence, that what applies to the one is almost sure not to apply to the other." (Wallace 1858: 61; cf. Kutschera 2003: 347, 350)

Darwin, on the other hand, draws the analogy of breeders and artificial selection to introduce the concept of natural selection in both his letter to Asa Gray and, later in the *Origin*. (Darwin 1858b [1857]: 501; section 3.4.4) However, his analogy is no part of Darwin's model but a rhetorical device, namely a suggestive category shift (metábasis). Therefore, this difference between Wallace and Darwin does not constitute a difference between their models but a difference in the manner in which they introduce them.

In sum, I consider the Object Classes of both models equivalent; they include individuals, varieties and species. And there is a final, virtually invisible common feature. Neither author attempts define the term 'species'.[358]

[358] While Darwin would continue this practice in the *Origin* and never attempt a theoretical definition, Wallace provided at least three theoretical definitions, one of which comes quite close to modern definitions of populations. (Kutschera 2003: 352)

iii. Output: survival of individual variations, rise and fall of varieties, emergence and extinction of species

Both yearn to explain the Output of previous models of evolution: the emergence and extinction of species and varieties, the fact that species “come into existence coincident both in space and time with a pre-existing closely allied species” (Wallace 1870a [1855]: 5) – whatever one wants to call these moves on the taxonomic trees. It occurs on all three levels of objects, on which the Struggle for Life is fought, i.e. individuals, varieties and species. All three parts of the joint paper are very clear on this, Darwin’s *Essay of 1844*:

> “Each new variety or species, when formed, will generally take the place of, and thus exterminate its less well-fitted parent. This I believe to be the origin of the classification and affinities of organic beings at all times; for organic beings always seem to branch and sub-branch like the limbs of a tree from a common trunk, the flourishing and diverging twigs destroying the less vigorous—the dead and lost branches rudely representing extinct genera and families.“ (Darwin 1858a [1844]: 53)

Darwin’s letter to Asa Gray:

> “…during millions of generations individuals of a species will be occasionally born with some slight variation, profitable to some part of their economy. Such individuals will have a better chance of surviving, and of propagating their new and slightly different structure; and the modification may be slowly increased by the accumulative action of natural selection to any profitable extent. The variety thus formed will either coexist with, or, more commonly, will exterminate its parent form. An organic being, like the woodpecker or misseltoe, may thus come to be adapted to a score of contingences—natural selection accumulating those slight variations in all parts of its structure, which are in any way useful to it during any part of its life.” Darwin 1858b [1857]: 52)

and Wallace’s part of the paper in which an individual variation is preserved to grow into a variety and this variety replaces

> “the species, of which it would be a more perfectly developed and more highly organized form. It would be in all respects better adapted to secure its safety, and to prolong its individual existence and that of the race. Such a variety could not return to the original form; for that form is an inferior one, and could never compete with it for existence.” (Wallace 1858: 58)

This process never stops for

> “this new, improved, and populous race might itself, in course of time, give rise to new varieties, exhibiting several diverging modifications of form, any of which, tending to increase the facilities for preserving existence, must, by the same general law, in their turn become predominant. Here, then, we have *progression and continued divergence*[359] deduced from the general laws which regulate the existence

359 This seems to be a reference to the law specified in Wallace’s 1855 paper although he does not use the exact same terms.

> of animals in a state of nature, and from the undisputed fact that varieties do frequently occur." (Wallace 1858: 59)

In sum, there are six basic cases: an individual variation might survive and reproduce itself, a variety may rise or fall in frequency with respect to its parent species and a species might emerge or become extinct. And these three cases are sufficient to explain the intricate branching of the taxonomic tree:

> "We believe we have now shown that there is a tendency in nature to the continued progression of certain classes of varieties further and further from the original type—a progression to which there appears no reason to assign any definite limits—and that the same principle which produces this result in a state of nature will also explain why domestic varieties have a tendency to revert to the original type. This progression, by minute steps, in various directions, but always checked and balanced by the necessary conditions, subject to which alone existence can be preserved, may, it is believed, be followed out so as to agree with all the phenomena presented by organized beings, their extinction and succession in past ages, and all the extraordinary modifications of form, instinct, and habits which they exhibit." (Wallace 1858: 62; cf. Darwin 1858b [1857]: 53)

iv. Input: physical changes and changes of other organisms

Previous models already included physical changes as triggers of evolution; Wallace and Darwin concur. (Wallace 1870a [1855]: 14-16; Wallace 1858: 58; Darwin 1858a [1844]: 48-49; Darwin 1858b [1857]: 51-52) Yet, both go beyond their predecessors by developing their argument from individual variations as the germs of varieties.[360] If one organism varies and gains an advantage in the struggle for life, he changes the conditions of life of other organisms. This follows directly from the struggle for life within the same species and is described by both.[361]

360 In doing so, Wallace explicitly denies any relation to Lamarckian explanations: "The hypothesis of Lamarck—that progressive changes in species have been produced by the attempts of animals to increase the development of their own organs, and thus modify their structure and habits—has been repeatedly and easily refuted […]; but the view here developed renders such an hypothesis quite unnecessary, by showing that similar results must be produced by the action of principles constantly at work in nature. […] Neither did the giraffe acquire its long neck by desiring to reach the foliage of the more lofty shrubs, and constantly stretching its neck for the purpose, but because any varieties which occurred among its antitypes with a longer neck than usual at once secured a fresh range of pasture over the same ground as their shorter-necked companions, and on the first scarcity of food were thereby enabled to outlive them." (Wallace 1858: 61) – Darwin does not dissociate himself from Lamarck in the joint paper. (He used Lamarck as a reference in his notebooks but dismissed Lamarck's work in private letters. (Grinnell 1985: 51-5)

361 (Bowler 1992 [1988]: 43) cites Nicholson to argue that Wallace does put less emphasis on the variations of other organisms than Darwin, claiming that Darwin's organisms struggle against both other organisms and their physical environment while Wallace's organisms struggle mostly against the environment. (Lynch 2001) and (Kutschera 2003) make similar points. In my opinion, a close reading of the joint paper does not support such a claim. Considering how both authors emphasize the struggle within the same species, I cannot imagine how one can understand the cited passages from Wallace differently. Moreover, in the joint paper, Darwin is not more explicit than Wallace; he never explicitly states that the variations of organism X may trigger the evolution of some other organism Y. Therefore, either one grants the point to both authors or to none. I consider the former more adequate, as both authors definitely go beyond their predecessors in the type of Input they consider to trigger evolution.

Wallace considers as triggers of evolution “any change in fact tending to render existence more difficult to the species in question, and tasking its utmost powers to avoid complete extermination”. (Wallace 1858: 58) As instances he cites changes of colour, greater or less development of hair, increases in the power or dimensions of the limbs or any external organs, the mode of procuring food or the range of their Lebensraum (Wallace 1858: 57-8), and argues that such variations might lead to advantages in the struggle with other species but also with members of the same species, namely when a variety obtains and keeps “a numerical superiority” to its parent species. (Wallace 1858: 58)

Darwin expresses the same point, arguing that “any minute variation in structure, habits, or instincts” might lead to “a better chance of surviving; and those of its offspring which inherited the variation, be it ever so slight, would also have a better chance”. (Darwin 1858a [1844]: 49) Such, “the smallest grain in the balance, in the long run, must tell on which death shall fall, and which shall survive”. (Darwin 1858a [1844]: 49) This holds between species but also within species:

> “Considering the infinitely various methods which living beings follow to obtain food by struggling with other organisms, to escape danger at various times of life, to have their eggs or seeds disseminated, &c. &c., I cannot doubt that during millions of generations individuals of a species will be occasionally born with some slight variation, profitable to some part of their economy. Such individuals will have a better chance of surviving, and of propagating their new and slightly different structure; and the modification may be slowly increased by the accumulative action of natural selection to any profitable extent. The variety thus formed will either coexist with, or, more commonly, will exterminate its parent form.” (Darwin 1858b [1857]: 52)[362]

Thus, both authors go beyond previous attempts to model evolution; they introduce a whole new kind of trigger in the environment: variations of other organisms. They do not provide an operationalization for this Input, however.

v. Connector: Natural Selection and – a blank

What links the Input to the Output is a Connector which Darwin famously called “natural selection”. In both parts of the joint paper he introduces it via an analogy to the artificial selection carried out by a breeder. He borrows the term from the domain in which it was originally termed, domestic races and their breeders, and applies it to a new domain, the wild life, thus transferring parts of the connotation of the term ‘selection’ upon natural phenomena. This category shift (metábasis) is very transparent in his Essay of 1844, where speaks twice of ‘selection’ but in the two different uses:

> “Yearly more are bred than can survive; the smallest grain in the balance in the long run, must tell on which death shall fall, and which shall survive. Let this work of [natural] selection on the one hand, and death on the other, go on for a thousand generations, who will pretend to affirm that it would produce no effect, when we

[362] Actually, Darwin’s expression ‘parent form’ is intuitive but misleading, for the biological parent is already dead, it does not struggle against its descendant of a couple of generations later (when selection has accumulated variations). The variety will exterminate members of the same species which have not undergone the same variation.

> remember what, in a few years, Bakewell effected in cattle, and Western in sheep, by this identical principle of [artificial] selection ?" (Darwin 1858a [1844]: 49)

In the letter to Asa Gray he spends his first paragraph speaking about artificial selection. Then he carries out the very same category shift as in his earlier paper[363]:

> "Now suppose there were a being who did not judge by mere external appearances, but who could study the whole internal organization, who was never capricious, and should go on selecting for one object during millions of generations; who will say what he might not effect? [… Indeed] there is such an unerring power at work in Natural Selection … which selects exclusively for the good of each organic being." (Darwin 1858b [1857]: 51)

'Natural Selection' is thus the term (or name) Darwin employs to denote the succession of (1) a variation or a change of physical conditions and (2) evolution in its different expressions for individuals and varieties and, ultimately, the emergence of new species.

One of the interesting points about the joint paper is the fact that Wallace describes the same sequence of Input and Output in his model, but does not provide a name for it:

> "If, on the other hand, any species should produce a variety having slightly increased powers of preserving existence, that variety must inevitably in time acquire a superiority in numbers. These results must follow as surely as old age, intemperance, or scarcity of food produce an increased mortality. In both cases there may be many individual exceptions; but on the average the rule will invariably be found to hold good." (Wallace 1858: 58)

and, in more detail:

> "Now, let some alteration of physical conditions occur in the district—a long period of drought, a destruction of vegetation by locusts, the irruption of some new carnivorous animal seeking 'pastures new' —any change in fact tending to render existence more difficult to the species in question, and tasking its utmost powers to avoid complete extermination; it is evident that, of all the individuals composing the species, those forming the least numerous and most feebly organized variety would suffer first, and, were the pressure severe, must soon become extinct. The same causes continuing in action, the parent species would next suffer, would gradually diminish in numbers, and with a recurrence of similar unfavourable conditions might also become extinct. The superior variety would then alone remain, and on a return to favourable circumstances would rapidly increase in numbers and occupy the place of the extinct species and variety." (Wallace 1858: 58)

Besides Natural Selection, Darwin mentions Sexual Selection once as "the struggle of the males for the females" and refers to it as a "second agency" [364] (Darwin 1858a [1844]: 50) In my analysis of the *Origin*, I will argue that Sexual Selection is a sub-case of Natural Selection in Darwin's model, that the

[363] He would do the same in the *Origin*. (See section 3.4.4)

[364] It is not implied in narrative terms because the selecting organisms become supplementary Agents in the narrative. (See section 3.4.4)

latter implies the former logically. (See section 3.4.2) In the joint paper, however, this does not become clear. Actually, Darwin's introducing it as a second agency suggests that it is an independent Connector. Wallace does not mention sexual selection. (cf. Kutschera 2003: 351)

In sum, Wallace's model lacks a conditional predicate or a Connector; he does not interpret what leads from the Input to the Output of his model. Beyond, however, Situation Type, Object Class, Input and Output are clearly defined. Figure 17 provides an overview.

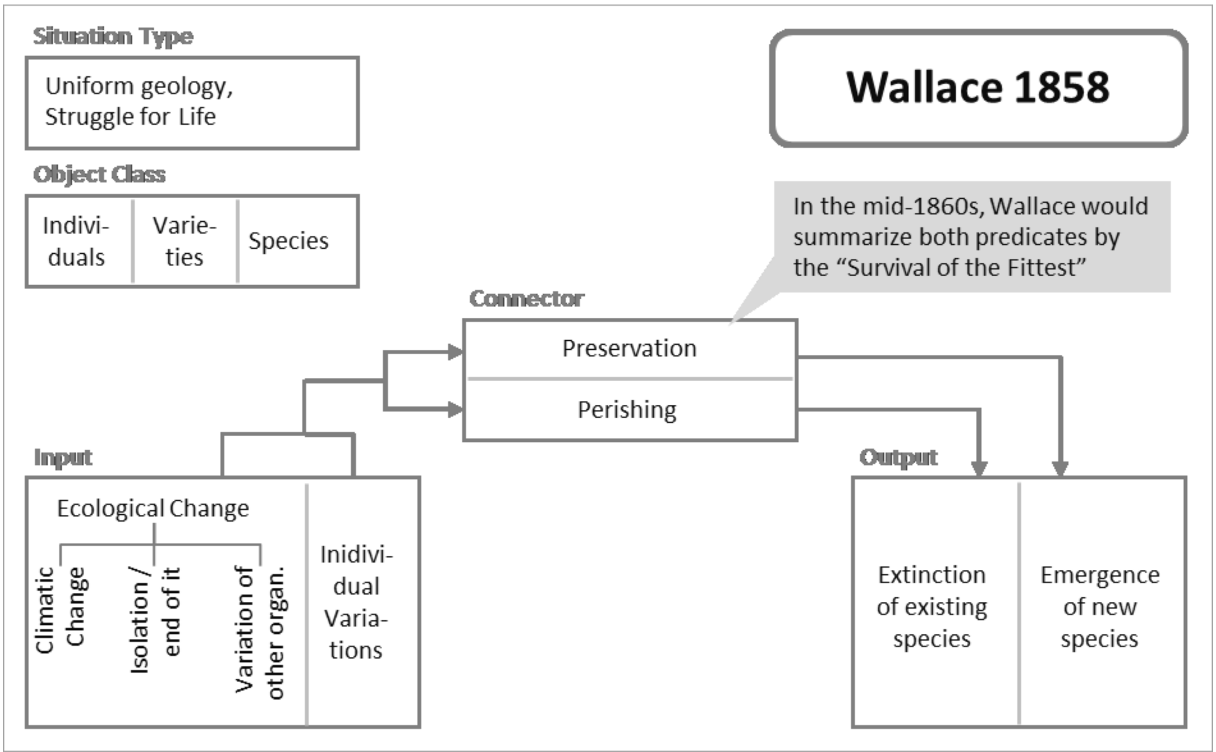

Figure 17: Wallace's dynamic model of evolution

Darwin, goes one step further and presents an explicit Connector by introducing a conditional predicate to denote the sequence of Input and Output: natural selection. This conditional predicate connotes its original use in the domain of breeders and breeding, i.e. artificial selection, and suggests that there exists an agency which selects organisms according to certain criteria. This suggestion is the basis for his narrative.

3.3.4 Narrative explanation: How did Wallace and Darwin tell evolution?

Just as it misses a Connector, Wallace's 1858 text contains single metaphors, as the Struggle for Life, which might serve as narrative elements, but it conveys nothing close to a complete narrative. Rather, Wallace attempts to sidestep narrative implications by employing verbs and verb forms which require no specification of an Agent. Thus, he speaks of the "perishing" of species instead of their elimination or of "preserving existence" without specifying who or what may preserve it. His 1855 text displays some narrative hints; it contained a language "sufficiently ambiguous that one could almost read it in a creationist sense". (Ruse 1979: 158) For instance, he speaks rather neutrally of species "coming into existence coincident … with closely-allied species" (Wallace 1870a [1855]: 5) but also of species being "created" (Wallace 1870a [1855]: 6). I do not consider his text to convey an autonomous narrative but it may be understood as alluding to the dominant narrative of the time: continued creation. Thus, I do not consider Wallace to suggest a new narrative, i.e. an alternative to the existing ones.

In the excerpt of Darwin's *Essay of 1844* I find no complete narrative either, it lacks a specification of Purpose and Agent. The letter to Asa Gray is a different case. As his Connector and the category shift from artificial selection suggest, it contained passages which can fill both elements. As I said above, Darwin's letter begins with a description of artificial selection by breeders and continues with an explicit category shift from the breeder to a different kind of Agent: "Now suppose there were a being who did not judge by mere external appearances, but who could study the whole internal organization, who was never capricious, and should go on selecting for one object during millions of generations; who will say what he might not effect?" (Darwin 1858b [1857]: 51) He then answers his own rhetorical question in the affirmative: "there is such an unerring power at work in Natural Selection". (Darwin 1858b [1857]: 51) Its Purpose is also specified, it is the betterment of the organisms for Natural Selection "selects exclusively for the good of each organic being." (Darwin 1858b [1857]: 51)[365]

Given Agent and Purpose, it is easy to fill the Agency and the Scene. The struggle for life makes for a perfect Scene and Darwin's Connector, Natural Selection, is clearly the means by which his Agent acts; it is the Agency.[366] The Narrative is thus complete: Organisms live in a ferocious Struggle for Life (Scene) but there is a power or being (Agent) which selects (Agency) for the good of each organism (Purpose) and produces evolution/transmutation (Act). - Darwin explains evolution by telling a story about it.

In comparison to previous narratives (or narratives skeletons), two points are remarkable: First, Darwin does not explicitly name God as its agent, leaving the Agent in his narrative rather obscure and vague. The terms 'power' or 'being' might be understood to refer to God but this is no necessary conclusion, particularly as Darwin does not employ the typical capitals as in 'His Actions'. Second, Darwin's narrative draws much of its narrative power from the model's Situation Type, the Struggle for Life, and its Connector, Natural Selection. This insofar remarkable, as both Chambers and Owen drew mainly upon the connotation of 'god' and the Input of their models for their explanation. (see sections 3.1.4 i, 3.2.4 i) The explanation for this may be that Darwin had not many other possibilities to create a strong narrative; he and Wallace described variations as random and Darwin does not draw upon God.[367]

In contrast to the Origin, however, Darwin's narrative still appears somewhat sub-threshold. Darwin mentions the Agent two or three times and the Purpose maybe once or twice and he addresses none of the ontological implications this narrative was determined to raise. Moreover, the one part of the

365 One might therefore wonder whether Darwin meant to imply a teleological view of evolution. However, as I have stated in the beginning, I am not analyzing what opinions Darwin held privately but what his published texts convey and the statement is very straightforward in this sense. Moreover, the other four elements of a narrative being specified, I suppose a reader of his text to look for some kind of Purpose. Therefore, it is safe to assume that Darwin's text could be thus read and the reception analysis will show that it was indeed read like this. (See sections 4.1.1, 4.1.2, 4.2.1 v)

366 It is, moreover, the only means; there are no indications in the text that the Variations can be understood as part of the Agency – the "power" or "being" – is never mentioned to act through Variation. Thus, there is no indication that the organism could be Agents here.

367 This does not imply that Darwin held no religious views at the time; he became an agnostic only after the publication of the Origin.

joint paper which did convey a narrative was sandwiched by two parts which did not. Hence, it could still be overlooked or ignored as some misplaced choice of words. Thus, Richard England is generally right when he claims that

> "…the natural selection of the Darwin-Wallace papers was not the natural selection of Darwin's best-known work. Certainly the basic process described is the same, but in the *Origin* natural selection was the driving mechanism behind a radical, evolutionary revision of the phenomena of life. In the Linnean Society papers, it was a process that principally described the relationship between varieties and species; the larger evolutionary implications were only hinted at." (England 1997: 268)[368]

3.3.5 Implications: What did Wallace's & Darwin's explanation imply about the world?

Consequently, the joint paper, as it was, conveyed no important ontological implications. Neither Man nor God was mentioned by either of the authors. Two parts of the paper contained no narrative at all and, in the third, Darwin did not even hint at whether he intended to include either in his model or narrative.

The same seems true for its social and political implications. While one could wonder how the image of a "struggle for life" related to established conceptions of divine providence and social stability. Did God not provide for all of his creatures? However, Wallace and Darwin did not introduce a completely new idea in the debate, here; Darwin's references explicit trace the concept of a struggle back to de Candolle and Malthus, other sources may have been known by the recipients. Moreover, if Darwin's narrative did not even apply to Man, what implications should it have for human culture?

In sum, the possible ontological implications of the joint paper were neither obvious nor explicated.

[368] England remarks that, when Darwin worked on the Origin, "he expressed no surprise that the Linnean Society papers had caused so little stir." (England 1997: 279) With respect to Wallace, Bowler stressed that „Even if we accept that Wallace's 1858 paper had the potential to be worked up into a comprehensive theory of evolution by natural selection, it would have taken Wallace years to develop that potential on his own." (Bowler 1992 [1988]: 45)
This also explains why Thomas Bell, the then-president of the Linnean Society did not deem the joint paper worthy for consideration when he looked back at 1858 and claimed that "it has not, indeed, been marked by any of the striking discoveries which at once revolutionize, so to speak, the department of science on which they bear; it is only at remote intervals that we can reasonably expect any sudden and brilliant innovation which shall produce a marked and permanent impress on the character of any branch of knowledge, or confer a lasting and important service to mankind." (Bell 1860 [1859]: viii-ix)

3.4 Charles Darwin: The Origin of Species by Means of Natural Selection

Charles Robert Darwin was born in Shrewsbury, England, in 1809, the year in which Lamarck published his *Philosophie Zoologique*. His family was of independent means and Darwin would have a much smoother path into science than his English competitors Owen or Wallace. In 1825, Darwin enrolled in Edinburgh for medicine but Darwin showed little passion and skill and soon turned to more general studies of nature. Upon pressure from his father, he switched to Cambridge obtaining his bachelor in theology in 1831. In Cambridge, Darwin was much under the influence of traditional British natural theology. He studied Paley's *Natural Theology* and listened geologist Adam Sedgwick (1785-1873) and botanist John Steven Henslow (1796-1861), among others.[369] With the latter, he would undertake long walks in the countryside and learn the specifics of fieldwork.

It was on Henslow's initiative too that Darwin embarked on his famous voyage on the Beatle, the fundament of his scientific career. The Beagle expedition would lead Darwin from South America to Australia to Southern Asia and South Africa; it lasted from 1831 to 1836. Darwin collected innumerable botanical and zoological specimen, but also studied geology and biogeography, occasionally also paleontological evidence. On the side, he read Lyell's Principles of Geology, making himself familiar with uniformitarianism. Throughout the expedition, Darwin sent geological papers to England which Henslow forwarded to other naturalists. Thus, upon his return, Darwin was already well-known and held in high esteem by scientists. Moreover, his father and later the fortune of his wife provided the means for a life as a self-funded scientist.

Darwin quickly connected to the scientific circles in London and Oxbridge and was introduced to Richard Owen, among others. With Lyell's backing, he became elected to the council of the *Geological Society* and to the Royal Society and he began working on his travel journals, which would appear as *Journal and Remarks* (1839) and as two volumes of the multi-volume *Zoology of the Voyage of H.M.S. Beagle* (1838-1843). In early 1837, Darwin had his influential encounter with the ornithologist John Gould who classified a group of birds from the Galapagos Islands as a series of closely related finches and mockingbirds. Still in the spring 1837, he began his famous notebooks on transmutation, speculating that one species might change into another. In mid-July he drew the first evolutionary tree and, in October 1838, Darwin Malthus' Essay on the Principle of Population, which would take a fundamental place in his theory. The public, however, would have to wait for Darwins ideas; he would not publish them but twenty years later. (see below)

In the meantime, Darwin published three books on geology (1844-1849) and four large empirical studies on barnacles (1851-1854), seeking the evidence to support his theoretical speculations. The work on barnacles contributed to his receiving the Royal Medal of the Royal Society in 1853. In his private life, he married (1839) and moved to London in the same year. In 1842 he settled in Down, where he would spend the rest of his life. From the 1830s on, Darwin suffered from a chronic illness which significantly restricted his lifestyle and ability to work.

Darwin was fifty when the *Origin of Species* finally appeared, bringing Darwin not only scientific but public fame. In the years after its initial publication, Darwin worked on orchids, climbing plants and domesticated animals and plants (1862-68), hardly intervening in the public debate on evolution but

[369] Darwin also studied Lamarck and the works of his grandfather, Erasmus Darwin, yet, neither impressed him much.

concentrating on its empirical foundation.[370] He published on the *Descent of Man* (1871) and on emotions in Man and animals (1872) only when the public debate had already quieted. His last scientific publications would be on botanical questions of relevance to evolution. Darwin died in 1882 in Down. He was honored by a ceremonial burial in Westminister Abbey, close to philosopher John Herschel and physicist Isaac Newton.

The publication of the *Origin of Species,* in 1859, was the culmination of a two-decade process. Darwin had begun his work on evolution after his return from the Beagle, in 1837. In 1842, he had summed up his thoughts in a first *Sketch*. (Darwin 1958a [1842]) Two years later, months before the publication of *Vestiges*, he had expanded them to a 230 page *Essay*. (Darwin 1958b [1844]) By the mid-1850s he was working on his voluminous *Natural Selection*, a book intended to provide a comprehensive and empirically founded presentation of his views on the "species problem" – a book Darwin would never finish.[371]

After Wallace's independent work rushed Darwin into the publication of the joint paper in 1858, Darwin set out to write an abstract of the supposedly upcoming *Natural Selection* which Darwin intended to call *An abstract of an Essay on the Origin of Species and Varieties through natural selection*.[372] His editor, John Murray, convinced him of dropping the essay- and the abstract-part and in November 1859 the book appeared under its now-famous title: *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*. As the *Origin* immediately sold out its first edition of 1.250 copies, a second edition of 3.000 copies followed in January 1860, a third one in 1861. Overall, Darwin would see six British editions[373] in his lifetime:

edition	**Publication Date**	**copies**
1st	November 1859	1.250
2nd	January 1860	3.000
3rd	April 1861	2.000
4th	June 1866	1.500
5th	February 1869	2.000
6th	February 1872	3.000

Table 9: Editions of the Origin of Species during Darwin's lifetime

The first two editions are virtually identical with only editorial changes and minor changes in content.[374] From the 3rd one on (1861), however, each edition knew considerable changes which

370 In his 1868 *The Variation of Animals and Plants under Domestication*, Darwin unsuccessfully attempted to explain heredity by pangenesis, a Connector which, again, implied the inheritance of acquired characteristics as it had been championed by Lamarck at the beginning of the century. (Darwin 1868)

371 *The Variation of Animals and Plants under Domestication* from 1868 constitutes the first part of the intended volume.

372 All dates are from the Darwin Online Project. For a more detailed bibliographical account, see http://darwin-online.org.uk/EditorialIntroductions/Freeman_OntheOriginofSpecies.html

373 A 1876 printing of the 6th edition displays some minor changes but is usually not considered an autonomous edition. For the different editions, see (Darwin 1859; Darwin 1860; Darwin 1861; Darwin 1866; Darwin 1869; Darwin 1872a; Darwin 1876

374 For instance, after the first reviews, Darwin diluted the story of the bear becoming a whale, which had been received in misleading fashion. (Darwin 1859: 184; Darwin 1860: 184)

were tracked in a table of differences. Also in the 3rd edition, Darwin inserted a historical sketch in which he mentions important predecessors and competitors who had an impact on the emergence of the book. Darwin mentions Lamarck, Geoffroy, Chambers, Owen and Wallace, among many others. (Darwin 1861: xiii-xix) In the 5th edition, the lengthy title of the book was reduced to “On the Origin of Species”, in the 6th edition even to “The Origin of Species”.

3.4.1 Description: What evidence did Darwin present and how?

Darwin’s text is stacked with reference and with examples; he cites biological authorities and numerous single studies. Moreover, Darwin complements the body of scientific knowledge by practitioners, frequently citing the expertise of breeders, horticulturalists and gardeners for instance on cattle, pigeons, gooseberries, or pears. (Darwin 1860: 8-44)[375]

Most of his descriptions of observations are embedded in explanatory sketches. Therefore, they are often partly formulated in the terminology of his model, a particularity which seems due to the pyramidal structure of Darwin’s text. As opposed to typical scientific articles but also monographs like Owen’s, the *Origin* begins with the introduction of – what I will below demonstrate to be – his model. In the very short introductory section, Darwin mentions his core concepts and sketches how these concepts are linked in the explanation of evolution (Darwin 1860: 4-5): He describes that all organisms are in a constant *Struggle for Existence*. In this struggle, the *Variation* of organisms or an *Ecological Change*[376] might lead to a slight advantage for certain organisms. Consequently, *Natural Selection* sets in, preserves these fitter organisms and, in the long run, leads to a *Divergence of Character* in the original species. Conversely, the now less fit organisms face the danger of *Extinction*.

Thus, most observations mentioned in the text are put in relation to the previously introduced theoretical concepts (or their sub-concepts) and/or presented in particular chapters as evidence for particular aspects of his model. This allows Darwin, while not presenting much novel empirics to relate his theory to large areas of the contemporary body of biological knowledge.

3.4.2 Classification: How did Darwin denote and aggregate evidence?

With respect to the aggregation and classification of organisms, Darwin stresses one major point which he and Wallace had already made in the joint paper:

> „No one can draw any clear distinction between individual differences and slight varieties; or between more plainly marked varieties and sub-species, and species.“ (Darwin 1860: 469)

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375 James A. Secord provides an interesting overview over this relation. He reveals how Darwin systematically approached breeders in order to complement the methodologically gathered knowledge of scientists by the practical knowledge of practitioners. Hans-Jörg Rheinberger and Peter McLaughlin discuss the role of this relation for the development of Darwin’s theory. (Secord 1985; Rheinberger and McLaughlin 1984)

376 Darwin does not use the expression ‘ecological change’. Instead, he speaks, for instance, of the adaption of organic beings to „physical conditions of life“ which presume either that these physical conditions have recently changed or that the organisms concerned have entered into a new territory. (Darwin 1860: 4, 44, 63, 80, 109, 175, 466, 477)

This is a point to which Darwin stresses throughout the Origin, but particularly in the first pages of the chapter II, Variation under Nature (Darwin 1860: 44-52), where he emphasized the continuous relations between the main distinctions of species, sub-species, varieties and individuals:

> “No one supposes that all the individuals of the same species are cast in the very same mould. These individual differences are highly important for us, as they afford the materials for natural selection to accumulate...“ (Darwin 1860: 45)

> “The term ’variety’ is almost equally difficult to define; but here community of descent is almost universally implied, though it can rarely be proved. We have also what are called monstrosities; but they graduate into varieties. By a monstrosity I presume is meant some considerable deviation of structure in one part, either injurious to or not useful to the species, and not generally propagated. Some authors use the term Variation’ in a technical sense, as implying a modification directly due to the physical conditions of life; and ‘variations’ in this sense are supposed not to be inherited: but who can say that the dwarfed condition of shells in the brackish waters of the Baltic, or dwarfed plants on Alpine summits, or the thicker fur of an animal from far northwards, would not in some cases be inherited for at least some few generations? And in this case I presume that the form would be called a variety.” (Darwin 1860: 44-45)

> “But cases of great difficulty, which I will not here enumerate, sometimes occur in deciding whether or not to rank one form as a variety of another, even when they are closely connected by intermediate links; nor will the commonly-assumed hybrid nature of the intermediate links always remove the difficulty. In very many cases, however, one form is ranked as a variety of another, not because the intermediate links have actually been found, but because analogy leads the observer to suppose either that they do now somewhere exist, or may formerly have existed; and here a wide door for the entry of doubt and conjecture is opened .
> Hence, in determining whether a form should be ranked as a species or a variety, the opinion of naturalists having sound judgment and wide experience seems the only guide to follow. We must, however, in many cases, decide by a majority of naturalists, for few well-marked and well-known varieties can be named which have not been ranked as species by at least some competent judges.” (Darwin 1860: 47)

> “Certainly no clear line of demarcation has as yet been drawn between species and sub-species —that is, the forms which in the opinion of some naturalists come very near to, but do not quite arrive at the rank of species; or, again, between sub-species and well-marked varieties, or between lesser varieties and individual differences. These differences blend into each other in an insensible series…” (Darwin 1860: 51)

> “From these remarks it will be seen that I look at the term species as one arbitrarily given for the sake of convenience to a set of individuals closely resembling each other, and that it does not essentially differ from the term variety, which is given to less distinct and more fluctuating forms. The term variety, again, in comparison with mere individual differences, is also applied arbitrarily, and for mere convenience’s sake.” (Darwin 1860: 52)

As in the joint paper, this disenchantment of the elements of taxonomic schemes leads to a disenchantment of the taxonomy itself. Darwin reduces the common patterns of taxonomic classifications from a divine blueprint of development to mere inherited structural patterns; turning Owen's archetype in a mere progenitor and *en passant* appropriating Owen's concept:

> "If we suppose that the ancient progenitor, the archetype as it may be called, of all mammals, had its limbs constructed on the existing general pattern, for whatever purpose they served, we can at once perceive the plain signification of the homologous construction of the limbs throughout the whole class. So with the mouths of insects, we have only to suppose that their common progenitor had an upper lip, mandibles, and two pair of maxillæ, these parts being perhaps very simple in form; and then natural selection will account for the infinite diversity in structure and function of the mouths of insects." (Darwin 1860: 435; Darwin 1859: 435-6; Darwin 1861: 467, cf. xvi; Darwin 1866: 514, cf. xvii; Darwin 1869: 517, cf. xix; Darwin 1872a: 383, cf. xvii)

The taxonomy itself is than introduced as a diagram – Darwin does not speak of a tree[377] – which depicts an irregularly branching scheme but according to Darwin is still much too regular and simple. (Darwin 1860: 118, 331) the interval between its horizontal lines "may represent each a thousand generations" or even "a million or hundred million generations". (Darwin 1860: 117, 124) Thus, the diagram really is a scheme for the interpretation of taxonomic relations, not an actual depiction of taxonomic classifications – and, contrarily to ideas of a scala naturae or Owen's archetype, it brings little[378] metaphysical import only. Hence, Darwin's stressing that

> "The terms used by naturalists of affinity, relationship, community of type, paternity, morphology, adaptive characters, rudimentary and aborted organs, etc., will cease to be metaphorical, and will have plain significance. (Darwin 1860: 486)

only highlights how much less philosophically sophisticated the concept of common descent is, compared to the scala or the archetype. Figure 18 displays Darwin's static model.

[377] Darwin does neither speak of a coral which Horst Bredekamp saw in Darwin's scheme. (Bredekamp 2005) For a comprehensive overview of the culture of visualization in 19th century biology, see (Voss 2007).

[378] Gillian Beer nonetheless emphasizes the interpretative power of the tree metaphor and stresses how it serves both as a classificatory device and an interpretative scheme for Darwin, bringing into line its denotative and its connotative meaning: "The polysemism of metaphor means that it is hard to control its implications: it may be argued, for example, that Darwin's metaphor of the tree is a formal analogy whose function is purely diagrammatic, describing a shape not an experience. Its initial value for Darwin lay undoubtedly in the fact that the diagram declared itself as tree, rather than being foreknowingly designed to represent a tree-like shape for descent. On the page, however, it could as well be interpreted by the eye as shrub, branching coral, or seaweed. But Darwin saw not only the explanatory but the mythic potentiality of this diagram, its congruity with past orders of descent, and extended these in a form which is experimental rather than formal at the conclusion of the same chapter 'Natural Selection'. The tree discovered in the diagram is not only Arbor Vitae but the Arbor Scientiae. Darwin establishes so close a connection between representation and actuality that he can claim 'truth' for it. The prose succession imitates the order it describes, branching out into further and further similitudes…" (Beer 2009: 85-6) – This private perspective, however, was not available to contemporary recipients.

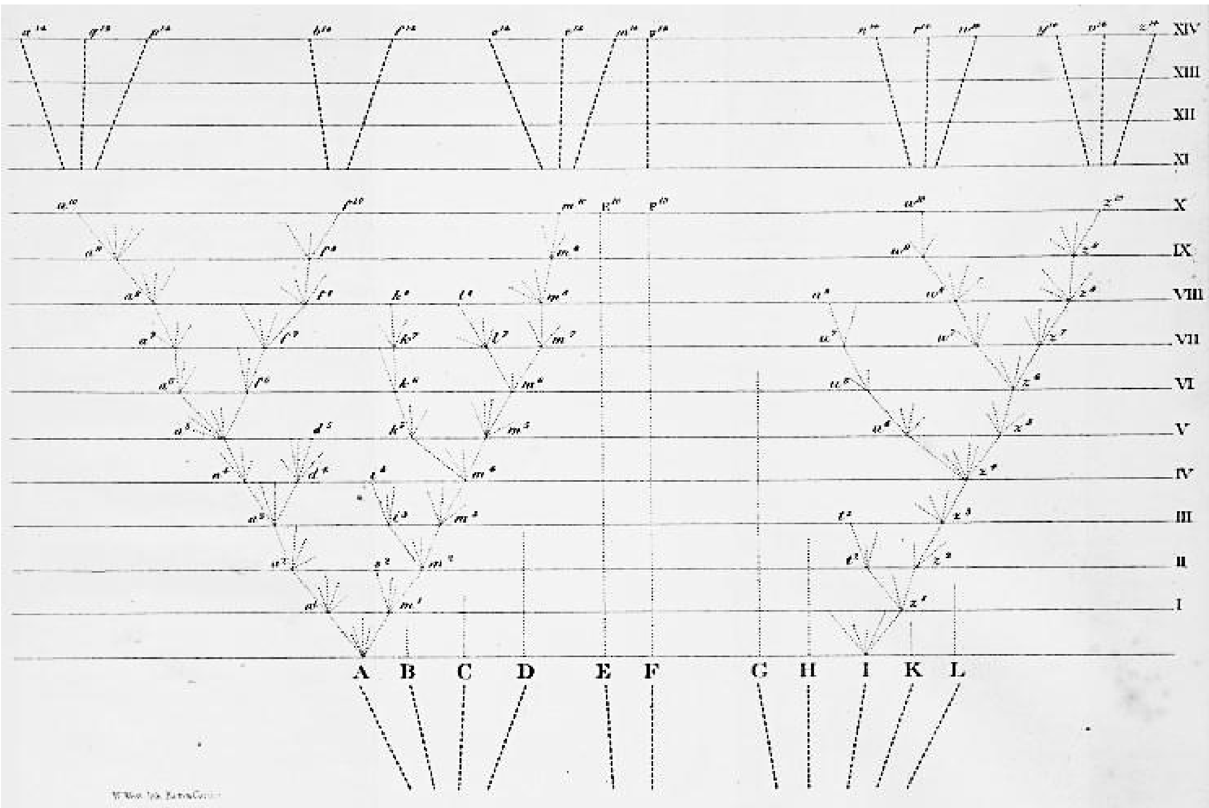

Figure 18: Darwin's static model: the tree (Darwin 1860: 117)

3.4.3 Logical explanation: How did Darwin model evolution?

i. Object Class: Individuals, Varieties, Species

The Object Class of Darwin’s dynamic model comprises living specimen or fossils of organisms. They include both plants and animals, with the exception of humans. He refers to a broad range of species from domestic cattle (Darwin 1860: 13-4), to wolves (Darwin 1860: 90-1) and squirrels (Darwin 1860: 180-1) to rare species as the Apteryx or Ornithorhynchus (Darwin 1860: 182, 416). Also, the number of organisms in his examples varies; he refers to single individuals, entire species or sub-groups of these species, namely varieties.[379] However, in several of his examples the distinctions between these different reference groups are blurred, for instance in the following passage:

> “Now, if any slight innate change of habit or of structure benefited an individual wolf, it would have the best chance of surviving and of leaving offspring. Some of its young would probably inherit the same habits or structure, and by the repetition of this process, a new variety might be formed which would either supplant or coexist with the parent form of wolf. Or, again, the wolves inhabiting a mountainous district, and those frequenting the lowlands, would naturally be forced to hunt different prey; and from the continued preservation of the individuals best fitted for the two

379 Darwin distinguishes at least two types of sub-groups to species: sub-species and varieties. (e.g. Darwin 1860: 23, 25, 27, 51, 52, 60, 166, 469) For simplification and in order to better compare his dynamic model to those of his predecessors, I will only speak of varieties as a sub-group. This should not pose a problem because Darwin refers to sub-species much less than to varieties and did not develop an independent argument for sub-species as opposed to varieties.

> sites. Two varieties might slowly be formed. […] I may add, that, according to Mr Pierce, there are two varieties of the wolf inhabiting the Catskill Mountains in the United States, one with a light greyhound-like form, which pursues deer, and the other more bulky, with shorter legs, which more frequently attacks the shepherd's flocks." (Darwin 1860: 91)

This blurring[380] complies with Darwin's main argument on species and the one that framed his static model: the differences between species and varieties as well as between individual differences and varieties are fluid.[381] Moreover, this blurring leads to an interesting consequence in Darwin's dynamic model: the same empirical regularity can be described as an Input-Output sequence for two or even three of the members of his Object Class. Thus, the survival of a single individual may also be part of the conservation of a species or variety and the growth and spread of a variety may be part of the emergence of a new species. As species, varieties and individuals overlap in the individuals, the event sequences which touch individuals, do also concern varieties and species – though in decreasing magnitude.[382]

ii. Situation Type: Uniformitarianism and the Struggle for Life

Like most of his predecessors, Darwin clearly subscribed to Lyell's uniformitarianism, i.e. a slowly and steadily changing surrounding world and, thus, an equally slow and steady development of life on earth. (Darwin 1860: 269; Darwin 1869: 110) The innovative and remarkably more spectacular part, however, was the Struggle for Life or Struggle for Existence. The metaphor of a struggle itself is no

380 Gillian Beer claims that "The blurring of the distinction between ontogeny – individual development – and phylogeny – species development – in the single term 'evolution' proved to be one of the most fruitful disturbances of meaning in the literature of the ensuing hundred years, and is a striking example of the multivalency of evolutionary concepts." (Beer 2009: 12) For its emergence with respect to struggle, see (Herbert 1971; Sober 1985).

381 This view of species was heavily criticized in the 20th century, notably by Theodosius Dobzhansky and Ernst Mayr. (See Mallet 2010; Mayr 1996; Beatty 1982; Wilson 2007) The main difference between the Darwinian notion of species and modern accounts may be described, in my model, as a shift from an analytic concept to a synthetic one: For Darwin, a species was a set over objects and their outward (phenotypic) features and as such it figured in his dynamic model. The empirical criterion for evolution was an observable change in these very features, i.e. in the features used for determining the species.
Many modern biologists, however, uncoupled the species concept from these phenotypic features. They defined species as "reproductively isolated populations" and operationalized the term 'reproductive isolation' either via separated gene pools and/or via geographically isolated of existence (Lebensräume). (see Mayr 1996: 268-75) Thus, in the modern terminology, a change in the outwards (phenotypic) features is an evolutionary change only if it happened within a population which displays an isolated gene pool or lives in geographical isolation from similar populations. (In my model, the first criterion would figure in the Object Class, the second in the Situation Type (with the Struggle for Life). Therefore, a modern dynamic model of evolution would further specify the Object Class and the Situation Type, i.e. it would restrict both sets and, consequently, the set of empirical regularities covered by the model.)
Darwin had no access to genetics but to geographical isolation, which he discussed at length in the Origin. One might thus ask why he did not employ the criterion of geographical isolation for the definition of 'species'. I wonder, however, whether this additional criterion would have made an empirical difference for him, i.e. whether adding geographical isolation to the Situation Type of his model would have led to a substantial restriction of the set of empirical regularities. I suppose that this was not the case and that, therefore, it made no sense (there was no empirical reason) for Darwin to switch from an analytic concept of species to a synthetic one.

382 This overlap is the case for Darwin's concept of species, at least.

novel idea[383], yet Darwin provided an operationalization for it and did thus transform it into the name of a background regularity:

> „A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction during some period of its life, and during some season or occasional year, otherwise, on the principle of geometrical increase its numbers would quickly become so inordinately great that no country could support the product. Hence, as more individuals are produced than can possibly [better: do] survive, there must in every case be a struggle for existence, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. It is the doctrine of Malthus applied with manifold force to the whole animal and vegetable kingdoms; for in this case there can be no artificial increase of food, and no prudential restraint from marriage." (Darwin 1860: 63)

Darwin provides several examples of how quickly populations can grow in exceptional circumstances: of cattle and horses in South America and America, of introduced plants in India (Darwin 1860: 64-5) and concludes that

> „There is no exception to the rule that every organic being naturally increases at so high a rate, that if not destroyed, the earth would soon be covered by the progeny of a single pair. Even slow-breeding man has doubled in twenty-five years, and at this rate, in a few thousand years, there would literally not be standing room for his progeny. Linnaeus has calculated that if an annual plant produced only two seeds—and there is no plant so unproductive as this—and their seedlings next year produced two, and so on, then in twenty years there would be a million plants. […] (Darwin 1860: 64)

As this geometrical increase does not occur and populations remain constant increase, there must be a fierce struggle for life. Hence, Darwin's term 'struggle for life' sums up two simultaneous observations: (i) organisms reproduce at a rate which would allow them to grow exponentially ("Growth with Reproduction") and (ii) populations remain constant.

Darwin specifies several modes of the struggle, i.e. manners in which populations are checked despite the Growth with Reproduction (overproduction). First, organisms may be destroyed due to changes in their ecology:

> "Two canine animals in a time of dearth, may be truly said to struggle with each other which shall get food and live. But a plant on the edge of a desert is said to struggle for life against the drought, though more properly it should be said to be dependent on the moisture. A plant which annually produces a thousand seeds, of which on an average only one comes to maturity, may be more truly said to struggle with the plants of the same and other kinds which already clothe the ground. The mistletoe is dependent on the apple and a few other trees, but can only in a far-fetched sense be said to struggle with these trees, for if too many of these parasites

[383] It can be found with many biologists prior to Darwin but also with Wallace. (See sections 2.3 x, 3.4.4)

> grow on the same tree, it will languish and die. But several seedling mistletoes, growing close together on the same branch, may more truly be said to struggle with each other. As the mistletoe is disseminated by birds, its existence depends on birds; and it may metaphorically be said to struggle with other fruit-bearing plants, in order to tempt birds to devour and thus disseminate its seeds rather than those of other plants. In these several senses, which pass into each other, I use for convenience' sake the general term of struggle for existence." (Darwin 1860: 62-3)

This is especially true early in life because

> "Eggs or very young animals seem generally to suffer most, but this is not invariably the case. With plants there is a vast destruction of seeds, but, from some observations which I have made, I believe that it is the seedlings which suffer most from germinating in ground already thickly stocked with other plants. Seedlings, also, are destroyed in vast numbers by various enemies; for instance, on a piece of ground three feet long and two wide, dug and cleared, and where there could be no choking from other plants, I marked all the seedlings of our native weeds as they came up, and out of the 357 no less than 295 were destroyed, chiefly by slugs and insects. If turf which has long been mown, and the case would be the same with turf closely browsed by quadrupeds, be let to grow, the more vigorous plants gradually kill the less vigorous, though fully grown, plants: thus out of twenty species growing on a little plot of turf (three feet by four) nine species perished from the other species being allowed to grow up freely." (Darwin 1860: 67-8)

Second, organisms may fall prey to other organisms, notably animals to other animals:

> "The amount of food for each species; of course gives the extreme limit to which each can increase; but very frequently it is not the obtaining food, but the serving as prey to other animals, which determines the average numbers of a species." (Darwin 1860: 68)

Third, Darwin specifies that the struggle consists not only in shortening of life but also in hindering organisms to reproduce:

> „I should premise that I use the term Struggle for Existence in a large and metaphorical sense, including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny." (Darwin 1860: 62)

Albeit in the beginning of the relevant chapter, Darwin mentions the "success in leaving progeny" only once as explicitly. Therefore, Michael Ruse is right in pointing out that, connotation-wise, it would have been more fitting to speak of 'the struggle for reproduction' because the struggle for existence is basically a struggle to survive long enough to reproduce, that is, to leave offspring. (Ruse 1971: 316-7)

iii. Input: individual variations, climate, isolation and variations of other organisms

Of all theories of evolution here analyzed, Darwin distinguishes the most expressions of Input. In his dynamic model, evolution may be triggered by ecological change but also by inheritable variations of individual organisms. Although Darwin openly admits that he is ignorant of the "laws" of inheritance[384], he stresses that he only considers inheritable variations, for only those can be passed on to the next generation.

> „Any variation which is not inherited is unimportant for us. But the number and diversity of inheritable deviations of structure, both those of slight and those of considerable physiological importance, is endless." (Darwin 1860: 13)

> „A large amount of inheritable and diversified variability is favourable [for the production of new species], but I believe mere individual differences suffice for the work.[385] A large number of individuals, by giving a better chance for the appearance within any given period of profitable variations, will compensate for a lesser amount of variability in each individual, and is, I believe, an extremely important element of success.“ (Darwin 1860: 102)

Such inheritable individual variations may consist in changes of habit, including mental qualities[386]:

> „Habit is hereditary with plants, as in the period of flowering, in the amount of rain requisite for seeds to germinate, in the time of sleep, etc., and this leads me to say a few words on acclimatisation. As it is extremely common for species of the same genus to inhabit very hot and very cold countries, and as I believe that all the species of the same genus have descended from a single parent, if this view be correct, acclimatisation must be readily effected during long continued descent. […] But the degree of adaptation of species to the climates under which they live is often overrated. We may infer this from our frequent inability to predict whether or not an

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384 Darwin does, however, discuss the conditions of variability: „… plants low in the scale of organisation are generally much more widely diffused than plants higher in the scale; and here again there is no close relation to the size of the genera. […]From looking at species as only strongly-marked and well-defined varieties, I was led to anticipate that the species of the larger genera in each country would oftener present varieties, than the species of the smaller genera […] To test the truth of this anticipation I have arranged the plants of twelve countries, and the coleopterous insects of two districts, into two nearly equal masses, the species of the larger genera on one side, and those of the smaller genera on the other side, and it has invariably proved to be the case that a larger proportion of the species on the side of the larger genera present varieties, than on the side of the smaller genera. Moreover, the species of the large genera which present any varieties, invariably present a larger average number of varieties than do the species of the small genera. Both these results follow when another division is made, and when all the smallest genera, with from only one to four species, are absolutely excluded from the tables. These facts are of plain signification on the view that species are only strongly-marked and permanent varieties…"(Darwin 1860: 55-5)
"We have, also, seen that it is the most flourishing or dominant species of the larger genera which on an average vary most; and varieties, as we shall hereafter see, tend to become converted into new and distinct species of the larger genera thus tend to become larger; and throughout nature the forms of life which are now dominant end to become still more dominant by leaving many modified and dominant descendants." (Darwin 1860: 59)
"…rare species will be less quickly modified or improved within any given period, and they will consequently be beaten in the race for life by the modified descendants of the commoner species. From these several considerations I think it inevitably follows, that as new species in the course of time are formed through natural l selection, others will become rarer and rarer, and finally extinct." (Darwin 1860: 110)

385 In this, Darwin follows Lamarck's early focus on individual differences for the explanation of evolution. (Lamarck 1873a[1809]: 73)

386 The question of mental qualities would be a key topic in the reception as the mental qualities of Man were supposed not to be producible by Natural Selection. (See sections 4.1.2, v)

> imported plant will endure our climate, and from the number of plants and animals brought from warmer countries which here enjoy good health. We have reason to believe that species in a state of nature are limited in their ranges by the competition of other organic beings quite as much as, or more than, by adaptation to particular climates.“ (Darwin 1860: 139-40)

> „…the mental qualities of our domestic animals vary, and that the variations are inherited. Still more briefly I have attempted to show that instincts vary slightly in a state of nature. No one will dispute that instincts are of the highest importance to each animal. Therefore I can see no difficulty, under changing conditions of life, in natural selection accumulating slight modifications of instinct to any extent in any useful direction.” (Darwin 1860: 242-3)

Alternatively[387], individual variation may consist in – as Darwin calls it – “deviations of structure” – a concept he describes metaphorically because he is ignorant of the “laws of inheritance”, and can only speculate on its workings:

> “The laws governing inheritance are quite unknown; no one can say why a peculiarity in different individuals of the same species, or in individuals of different species, is sometimes inherited and sometimes not so; why the child often reverts in certain characters to its grandfather or grandmother or other more remote ancestor; why a peculiarity is often transmitted from one sex to both sexes, or to one sex alone, more commonly but not exclusively to the like sex.“ (Darwin 1860: 13)

> “Some authors believe it to be as much the function of the reproductive system to produce individual differences [sic!], or very slight deviations of structure, as to make the child like its parents. But the much greater variability, as well as the greater frequency of monstrosities, under domestication or cultivation, than under nature, leads me to believe that deviations of structure are in some way due to the nature of the conditions of life, to which the parents and their more remote ancestors have been exposed during several generations. […] But why, because the reproductive system is disturbed, this or that part should vary more or less, we are profoundly ignorant. Nevertheless, we can here and there dimly catch a faint ray of light, and we may feel sure that there must be some cause for each deviation of structure, however slight.“ (Darwin 1860: 131-2)

> „Our ignorance of the laws of variation is profound. Not in one case-out of a hundred can we pretend to assign any reason why this or that part differs, more or less, from the same part in the parents. But whenever we have the means of instituting a comparison, the same laws appear to have acted in producing the lesser differences

387 Whether these are true alternatives, Darwin is unsure of: „How much of the acclimatisation of species to any peculiar climate is due to mere habit, and how much to the natural selection of varieties having different innate constitutions [sic!], and how much to both means combined, is a very obscure question. That habit or custom has some influence I must believe, both from analogy, and from the incessant advice given in agricultural works… On the other hand, I can see no reason to doubt that natural selection will continually tend to preserve those individuals which are born with constitutions best adapted to their native countries.“ (Darwin 1860: 141-2) - „…it is difficult to tell and immaterial for us, whether habits generally change first and structure afterwards; or whether slight modifications of structure lead to changed habits; both probably often change almost simultaneously.“ (Darwin 1860: 183)

> between varieties of the same species, and the greater differences between species of the same genus." (Darwin 1860: 167-8)

However, he stresses that while he sometimes refers to inheritable variations as being accidental (Darwin 1860: 93, 94, 142, 144, 189, 209, 213, 242), this does not imply that they need be the result of chance processes:

> „I have hitherto sometimes spoken as if the variations – so common and multiform in organic beings under domestication, and in a lesser degree in those in a state of nature – had been due to chance. This, of course, is a wholly incorrect expression, but it serves to acknowledge plainly our ignorance of the cause of each particular variation." (Darwin 1860: 131)

The second major trigger of evolution in Darwin's dynamic model is ecological change. It may consist in climate change:

> "Climate plays an important part in determining the average numbers of a species, and periodical seasons of extreme cold or drought; I believe it to be the most effective of all checks. I estimated that the winter of 1854-55 destroyed four-fifths of the birds in my own grounds; and this is a tremendous destruction …. The action of climate seems at first sight to be quite independent of the struggle for existence; but in so far as climate chiefly acts in reducing food, it brings on the most severe struggle between the individuals, whether of the same or of distinct species, which subsist on the same kind of food." (Darwin 1860: 68)

> "When we reach the Arctic regions, or snow-capped summits, or absolute deserts, the struggle for life is almost exclusively with the elements. That climate acts in main part indirectly by favouring other species, we may clearly see in the prodigious number of plants in our gardens which can perfectly well endure our climate, but which never become naturalized, for they cannot compete with our native plants nor resist destruction by our native animals." (Darwin 1860: 69)

> "We shall best understand the probable course of natural selection by taking the case of a country undergoing some physical change, for instance, of climate. The proportional numbers of its inhabitants would almost immediately undergo a change, and some species might become extinct. We may conclude, from what we have seen of the intimate and complex manner in which the inhabitants of each country are bound together, that any change in the numerical proportions of some of the inhabitants, independently of the change of climate itself, would seriously affect many of the others." (Darwin 1860: 81)

in isolation or the end of isolation:

> „Isolation, also, is an important element in the process of natural selection. In a confined or isolated area, if not very large, the organic and inorganic conditions of life will generally be in a great degree uniform; so that natural selection will tend to modify all the individuals of a varying species throughout the area in the same manner in relation to the same conditions. Intercrosses, also, with the individuals of the same species, which otherwise would have inhabited the surrounding and

> differently circumstanced districts, will be prevented. But isolation probably acts more efficiently in checking the immigration of better adapted organisms, after any physical change, such as of climate or elevation of the land, etc.; and thus new places in the natural economy of the country are left open for the old inhabitants to struggle for, and become adapted to, through modifications in their structure [sic!] and constitution. Lastly isolation, by checking immigration and consequently competition, will give time or any new variety to be slowly improved; and this may sometimes be of importance in the production of new species. If, however, an isolated area be very small, either from being surrounded by barriers or from having very peculiar physical conditions, the total number of the individuals supported on it will necessarily be very small; and fewness of individuals will greatly retard the production of new species through natural selection, by decreasing the chance of the appearance of favourable variations.“ (Darwin 1860: 105-6)

> “Many cases are on record showing how complex and unexpected are the checks and relations between organic beings which have to struggle together in the same country. I will give only a single instance, which, though a simple one, has interested me. In Staffordshire, on the estate of a relation, where I had ample means of investigation, there was a large and extremely barren heath, which had never been touched by the band of man; but several hundred acres of exactly the same nature had been enclosed twenty-five years previously and planted with Scotch fir. The change in the native vegetation of the planted part of the heath was most remarkable, more than is generally seen in passing from one quite different soil to another: not only lie proportional numbers of the heath-plants were wholly changed. But twelve species of plants (not counting grasses and carices) flourished in the plantations, which could not be found on the heath.” (Darwin 1860: 71)

or in inheritable variations of other organisms, notably closely allied ones with which the organisms in question compete for resources in the Struggle for Life:

> “Let it also be borne in mind how infinitely complex and close-fitting are the mutual relations of all organic beings to each other and to their physical conditions of life; and consequently what infinitely varied diversities of structure might be of use to each being under changing conditions of life.” (Darwin 1860: 62)

> “…variations, however slight, and from whatever cause proceeding, if they be in any degree profitable to the individuals of a species, in their infinitely complex relations to other organic beings and to their physical conditions of life, will tend to the preservation of such individuals, and will generally be inherited by the offspring.” (Darwin 1860: 49, cf. 137)

> “…the conditions of life are infinitely complex from the large number of already existing species; and if some of these many species become modified and improved, others will have to be improved in a corresponding degree or they will be exterminated.” (Darwin 1860: 83)

Of these three kinds of ecological change – climate change, isolation or the end of isolation and inheritable variations of other organisms – only the latter is a novel kind of Input. Both climate change and isolation (or the end of it) had been employed as Input before: Climate change had been an explaining phenomenon of evolution since Lamarck; Owen and Wallace had already mentioned isolation. Isolation had been established fact of biogeography before 1830s, for instance due to the work of Christian Leopold von Buch (1744-1853).

Aside from distinguishing types of ecological change and separating it from inheritable variations, Darwin classifies variations as either favorable (useful) or injurious; these labels can be found throughout the Origin. Their introduction is one of the most important innovations in Darwin's explanation and matters for both his dynamic model and his narrative. (see below)

Moreover, Darwin also mentions variations[388] which are neither injurious nor favorable and to which I will refer as 'irrelevant' as in irrelevant for Natural Selection. Darwin identifies such variations in polymorphic species:

> "There is one point connected with individual differences which seems to me extremely perplexing: I refer to those genera which have sometimes been called 'protean' or 'polymorphic,' in which the species present an inordinate amount of variation; and hardly two naturalists can agree which forms to rank as species and which as varieties. […] These facts seem to be very perplexing, for they seem to show that this kind of variability is independent of the conditions of life. I am inclined to suspect that we see in these polymorphic genera variations in points of structure which are of no service or disservice to the species, and which consequently have not been seized on and rendered definite by natural selection, as hereafter will be explained." (Darwin 1860: 46)

In sum, the Input to Darwin's dynamic model can be described by a simple matrix which opposes three types of ecological change and two types of individual variations to the three labels 'favorable', 'injurious' and 'irrelevant'. Thus, all kinds of variations and all kinds of ecological change[389] can be either favorable, injurious, or irrelevant for Natural Selection. (see Table 10)

	Favorable	**Injurious**	**Irrelevant**
Ecological change	Climate change Isolation or the end of isolation Individual Inheritable Variations of other organisms		
Inheritable individual variations	Deviations in structure Change in habit		

Table 10: Expressions of the Input of Darwin's dynamic model

iv. Output: Evolution, in all its expressions for Individuals, Varieties and Species as well as Fluctuations of Varieties and Conservations of Species

The basic distinction of favorable, injurious and irrelevant changes of individuals and the ecology, is also to be found in Darwin's Output – and it can be found with respect to all three types within his

388 Darwin mentions no irrelevant ecological change.

389 I assume that Darwin also implied this, although I find no such examples. If one disagrees with this belief, one can obviously restrict the matrix with respect to ecological change.

Object Classes – individuals, varieties and species. As in Darwin's Object Class, the boundaries between effects on individuals, varieties and species are often blurred; therefore short-term, medium-term and long-term evolutionary effects are blended.[390]

Thus, Darwin mentions the effects of favourable variations on individuals

> „Again, it may be asked, how is it that varieties, which I have called incipient species, become ultimately converted into good and distinct species, which in most cases obviously differ from each other far more than do the varieties of the same species? How do those groups of species, which constitute what are called distinct genera, and which differ from each other more than do the species of the same genus, arise? All these results, as we shall more fully see in the next chapter, follow from the struggle for life. Owing to this struggle for life [sic!], any variation, however slight, and from whatever cause proceeding, if it be in any degree profitable to an individual of any species, in its infinitely complex relations to other organic beings and to external nature, will tend to the preservation of that individual, and will generally be inherited by its offspring."" (Darwin 1860: 61)

> "When we see any structure highly perfected for any particular habit, as the wings of a bird for flight, we should bear in mind that animals displaying early transitional grades of the structure will seldom continue to exist to the present day, for they will have been supplanted by the very process of perfection through natural selection." (Darwin 1860: 182-3)

> „As we sometimes see individuals of a species following habit widely different from those of their own species and of the other species of the same genus, we might expect, on my theory, that such individuals would occasionally have given rise to new species, having anomalous habits, and with their structure either slightly or considerably modified from that of their proper type." (Darwin 1860: 184)

but also on varieties and species

> „It would be easy to show that within the same group carnivorous animals exist having every intermediate grade between truly aquatic and strictly terrestrial habits; and as each exists by a struggle for life, it is clear that each is well adapted in its habits to its place in nature. Look at the Mustela vison of North America, which has webbed feet and which resembles an otter in its fur, short legs, and form of tail; during summer this animal dives for and preys on fish, but during the long winter it leaves the frozen waters, and preys like other pole-cats on mice and land animals." (Darwin 1860: 179-80)

> „Look at the family of squirrels; here we have the finest gradation from animals with their tails only slightly flattened, and from others. As Sir J. Richardson has remarked, with the posterior part of their bodies rather wide and with the skin on their flanks rather full, to the so-called flying squirrels; and flying squirrels have their limbs and

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[390] Darwin does not use these terms but I assume that they provide a useful time-scale for the effects concerning individuals, varieties and species. Varieties which exist for a long period of time and are not considered species sometime within this period might, however, blur this distinction.

> even the base of the tail united by a broad expanse of skin, which serves as a parachute and allows them to glide through the air to an astonishing distance from tree to tree. We cannot doubt that each structure is of use to each kind of squirrel in its own country, by enabling it to escape birds or beasts of prey, or to collect food more quickly, or, as there is reason to believe, by lessening the danger from occasional falls. But does not follow from this fact that the structure of each squirrel is the best that it is possible to conceive under all natural conditions? Let the climate and vegetation change, let other competing rodents or new beasts of prey immigrate, or old ones become modified, and all analogy would lead us to believe that some at least of the squirrels would decrease in numbers or become exterminated. Unless they also became modified and improved in structure in a corresponding manner. Therefore, I can see no difficulty, more especially under changing conditions of life, in the continued preservation of individuals with fuller and fuller flank-membranes, each modification being useful, each being propagated, until by the accumulated effects of this process of natural selection, a perfect so-called flying squirrel was produced.“ (Darwin 1860: 180-1)

> He who believes in the struggle for existence and in the principle of natural selection, will acknowledge that every organic being is constantly endeavouring to increase in numbers; and that if any one being vary ever so little. Either in habits or structure, and thus gain an advantage over some Other inhabitant of the country, it will seize on the place of that inhabitant, however different it may be from its own place.“ (Darwin 1860: 186)

Injurious variations of individuals are mentioned only a few times, presumably because they produce no long-term effects:

> „Natural selection will never produce in a being anything injurious to itself, for natural selection acts solely by and for the good of each. … If a fair balance be struck between the good and evil caused by each part, each will be found on the whole advantageous. After the lapse of time, under changing conditions of life, if any part comes to be injurious, it will be modified; or if it be not so, the being will become extinct, as myriads have become extinct.“ (Darwin 1860: 201)

For varieties and species, i.e. large groups of organisms, such effects are both visible and well-marked, and Darwin discusses them extensively:

> „… the intermediate varieties will be liable to accidental extermination; and during the process of further modification through natural selection, they will almost certainly be beaten and supplanted by the forms which they connect; for these from existing in greater numbers will, in the aggregate, present more variation, and thus be further improved through natural selection and gain further advantages.“ (Darwin 1860: 179)

> „The whole subject of the extinction of species has been involved in the most gratuitous mystery. Some authors have even supposed that is the individual has a definite length of life, so have species a definite duration. No one I think can have marveled more at the extinction of species, than I have done. When I found in La

> Plata the tooth of a horse embedded with the remains of Mastodon, Megatherium, Toxodon, and other extinct monsters, which all co-existed with still Toxodon, and other extinct monsters, which all co-existed with still living shells at a very late geological period, I was filled with astonishment; for seeing that the horse, since its introduction by the Spaniards into South America, has run wild over the whole country and has increased in numbers at an unparalleled rate, I asked myself what could so recently have exterminated the former horse under conditions of life apparently so favourable. But how utterly groundless was my astonishment! Professor Owen soon perceived that the tooth, though so like that of the existing horse, belonged to an extinct species. Had this horse been still living, but in some degree rare, no naturalist would have felt the least surprise at its rarity; for rarity is the attribute of a vast number of species of all classes, in all countries. [f we ask ourselves why this or that species is rare, we answer that something is unfavourable in its conditions of life; but what that something is, we can hardly ever tell. On the supposition of the fossil horse still existing as a rare species, we might have felt certain from the analogy of all other mammals, even of the slow-breeding elephant, and from the history of the naturalization of the domestic horse in South America, that under more favourable conditions it would in a very few years have stocked the whole continent. But we could not have told what the unfavourable conditions were which checked its increase, whether some one or several, contingencies, and at what period of the horse's life, and in what degree, they severally acted. If the conditions had gone on, however slowly, becoming less and less favourable, we assuredly should not have perceived the fact, yet the fossil horse would certainly have become rarer and rarer, and finally extinct;—its place being seized on by some more successful competitor." (Darwin 1860: 318-9)

However, Darwin most often describes injurious effects for one individual / variety /species as a favorable effect for another individual / variety / species which competes for the same resources. Such effects might emerge through individual variations and their preservation:

> "…varieties, in order to become in any degree permanent, necessarily have to struggle with the other inhabitants of the country, the species which are already dominant will be the most likely to yield offspring, which, though in some slight degree modified, still inherit those advantages that enabled their parents to become dominant over their compatriots.
> If the plants inhabiting a country and described in any Flora be divided into two equal masses, all those in the larger genera being placed on one side, and all those in the smaller genera on the other side, a somewhat larger number of the very common and much diffused or dominant species will be found on the side of the larger genera." (Darwin 1860: 54)

> „We have seen that in each country it is the species of the larger genera which oftenest present varieties or incipient species. This, indeed, might have been expected; for as natural selection acts through one form having some advantage over other forms in the struggle for existence, it will chiefly act on those which already have some advantage; and the largeness of any group shows that its species have inherited from a common ancestor some advantage in common. Hence, the struggle

> for the production of new and modified descendants will mainly lie between the larger groups, which are all trying to increase in number. One large group will slowly conquer another large group, reduce its numbers, and thus lessen its chance of further variation and improvement. Within the same large group, the later and more highly perfected sub-groups from branching out and seizing on many new places in the polity of Nature, will constantly tend to supplant and destroy the earlier and less improved sub-groups. Small and broken groups and sub-groups will finally disappear. Looking to the future, we can predict that the groups of organic beings which are now large and triumphant, and which are least broken up, that is, which as yet have suffered least extinction, will for a long period continue to increase. But which groups will ultimately prevail, no man can predict; for we well know that many groups, formerly most extensively developed, have now become extinct. Looking still more remotely to the future, we may predict that, owing to the continued and steady increase of the larger groups, a multitude of smaller groups will become utterly extinct, and leave no modified descendants; and consequently that of the species living at any one period, extremely few will transmit descendants to a remote futurity. … I may add that on this view of extremely few of the more ancient species having transmitted descendants, and on the view of all the descendants of the same species making a class, we can understand how it is that there exist but very few classes in each main division of the animal and vegetable kingdoms. Although extremely few of the most ancient species may now have living and modified descendants, yet at the most remote now have living and modified descendants, yet at the most remote many species of many genera, families, orders, and classes, as at the present day.“ (Darwin 1860: 126-7)

> „As natural selection acts solely by the preservation of profitable modifications, each new form will tend in a fully-stocked country to take the place of, and finally to exterminate, its own less improved parent or other less-favoured forms with which it comes into competition. Thus extinction and natural selection will, as we have seen, go hand in land. Hence, if we look at each species as descended from some other unknown form, both the parent and all the transitional varieties will generally have been exterminated by the very process of formation and perfection of the new form.“ (Darwin 1860: 172)

Yet, they are often described as the result of both preserved variations and ecological factors combined:

> „By my theory these allied species have descended from a common parent; and during the process of modification, each has become adapted to the conditions of life of its own region, and has supplanted and exterminated its original parent and all the transitional varieties between its past and present states. Hence we ought not to expect at the present time to meet with numerous transitional varieties in each region, though they must have existed there, and may be embedded there in a fossil condition. […] the neutral territory between two representative species is generally narrow in comparison with the territory proper to each. We see the same fact in ascending mountains. And sometimes it is quite remarkable how abruptly, as Alph. De Candolle has observed, a common alpine species disappears. The same fact has

> been noticed by E. Forbes in sounding the depths of the sea with the dredge.“ (Darwin 1860: 173-4)

> „To those who look at climate and the physical conditions of life as the all-important elements of distribution, these facts ought to cause surprise, as climate and height or depth graduate away insensibly. But when we bear in mind that almost every species, even in its metropolis, would increase immensely in numbers, were it not for other competing species; that nearly all either prey on or serve as prey for others; in short, that each organic being is either directly or indirectly related in the most important manner to other organic beings, we must see that the range of the inhabitants of any country by no means exclusively depends on insensibly changing physical conditions, but in large part on the presence of other species, on which it depends, or by which is destroyed, or with which it comes into competition; and as these species are already defined objects (however they may have become so), not blending one into another by insensible gradations, the range of any one species, depending as it does on the range of others, will tend to be sharply defined. Moreover, each species on the confines of its range, where it exists in lessened numbers, will, during fluctuations in the number of its enemies or of its prey, or in the seasons, be extremely liable to utter extermination; and thus its geographical range will come to be still more sharply defined.“ (Darwin 1860: 175)

> „… the intermediate varieties will be liable to accidental extermination; and during the process of further modification through natural selection, they will almost certainly be beaten and supplanted by the forms which they connect; for these from existing in greater numbers will, in the aggregate, present more variation, and thus be further improved through natural selection and gain further advantages.“ (Darwin 1860: 179)

Finally, Darwin describes the effects of variations which are irrelevant for Natural Selection. Within species they lead to fluctuations of varieties:

> „…we occasionally see an animal like the Ornithorhynchus or Lepidosiren, which in some small degree connects by its affinities two large branches [of the Tree] of life, and which has apparently been saved from fatal competition by having inhabited a protected station. “ (Darwin 1860: 130)

> „Organs now of trifling importance have probably in some cases been of high importance to an early progenitor, and, after having been slowly perfected at a former period, have been transmitted in nearly the same state, although now become of very slight use; and any actually injurious deviations in their structure will always have been checked by natural selection. Seeing how important an organ of locomotion the tail is in most aquatic animals, its general presence and use for many purposes in so many land animals, which in their lungs or modified swimbladders betray their aquatic origin, may perhaps be thus accounted for. A well-developed tail having been formed in an aquatic animal, it might subsequently come to be worked in for all sorts of purposes, as a fly-flapper, an organ of prehension, or as an aid in turning, as with the dog…“ (Darwin 1860: 195-6)

> „Natural selection will never produce in a being anything injurious to itself, for natural selection acts solely by and for the good of each. … If a fair balance be struck between the good and evil caused by each part, each will be found on the whole advantageous. After the lapse of time, under changing conditions of life, if any part comes to be injurious, it will be modified; or if it be not so, the being will become extinct, as myriads have become extinct.“ (Darwin 1860: 201)

In the long-term and with respect to species they lead to the conservation of species in what, today, we would describe as ecological niches, i.e. isolated areas with a less severe struggle for life:

> „… in the case of an island, or of a country partly surrounded by barriers, into which new and better adapted forms could not freely enter, we should then have places in the economy of nature which would assuredly be better filled up, if some of the original inhabitants were in some manner modified; for, had the area been open to immigration, these same places would have been seized on by intruders. In such case, every slight modification, which in the course of ages chanced to arise, and which in any way favoured the individuals of any of the species, by better adapting them to their altered conditions, would tend to be preserved; and natural selection would thus have free scope for the work of improvement.“ (Darwin 1860: 81)

> „On a small island, the race for life will have been less severe. And there will have been less modification and less extermination. Hence, perhaps, it comes that the flora of Madeira … resembles the extinct tertiary flora of Europe. All fresh-water basins, taken together, make a small area compared with that of the sea or of the land; and, consequently, the competition between fresh-water productions will have been less severe than elsewhere; new forms will have been more slowly formed, and old forms more slowly exterminated. And it is in fresh water that we find seven genera of Ganoid fishes, remnants of a once preponderant order, and in fresh water we find some of the most anomalous forms now known in the world, as the Ornithorhynchus and Lepidosiren, which, like fossils, connect to a certain extent orders now widely separated in the natural scale. These anomalous forms may almost be called living fossils [sic!], they have endured to the present day, from having inhabited a confined area, and from having thus been exposed to less severe competition.“ (Darwin 1860: 106-7)

These different cases of Output can be presented in a simple matrix, by opposing Individuals, varieties and species as the bearers of evolution (and the Object Class) to favourable, injurious and irrelevant effects as Darwin distinguishes them in the Input. (See Table 11)

	Individuals (short-term)	**Varieties (medium-term)**	**Species (long-term)**
Favourable variation or favourable ecological change	Reproduction	Geographical expansion & Increase in frequency	Divergence & Emergence of New Species
Injurious variation or injurious ecological change	No Reproduction	Geographical contraction & Decrease in Frequency	Convergence, Extinction

Irrelevant variations or irrelevant ecological change	? (Reproduction or No Reproduction)	Fluctuation	Conservation

Table 11: Expressions of the Output of Darwin's dynamic model

Favorable variations or favorable ecological change allows for the reproduction of an individual, the increase in frequency and geographical expansion of a variety and the divergence of species and, finally, the emergence of new species. In this, favorable ecological change may consist in isolation or climatic change but not in the change of other organisms for these cannot survive a change in a direction injurious to themselves and favorable to their ecology. Injurious variations[391] or injurious ecological change leads to the individual's failure to reproduce, the decrease in frequency of a variety and its geographical contraction as well as the convergence, and, finally, the extinction of a species. The effects of irrelevant variations on individuals are not specified by Darwin; these organisms may either reproduce or fail to do so. In varieties, irrelevant changes lead to fluctuation, in species to the conservation.[392]

According to Darwin, these different Outputs cover all relevant phenomena of long-term change in groups of organisms. It allows to explain the geological record i.e. the geological-paleontological regularities[393]:

> „Passing from these difficulties, all the other great leading facts in palaeontology seem to me simply to follow on the theory of descent with modification through natural selection. We can thus understand how it is that new species come in slowly

391 Injurious variations occur in individuals only; they are not preserved in varieties or species because they diminish the bearing individual's capacity to reproduce: "Natural selection will never produce in a being anything injurious to itself, for natural selection acts solely by and for the good of each. … If a fair balance be struck between the good and evil caused by each part, each will be found on the whole advantageous. After the lapse of time, under changing conditions of life, if any part comes to be injurious, it will be modified; or if it be not so, the being will become extinct, as myriads have become extinct." (Darwin 1860: 201)

392 Theoretically, conservation would also be the result of an absence of change but this would not be covered by Darwin's model. Moreover, as nature is constantly changing, it seems hard to describe any period in the history of life as free of change. Rather, the change is constant but may or may not be relevant for an organism in question.

393 Darwin, however, stressed how imperfect remained the contemporary knowledge of these regularities: „I have attempted to show that the geological record is extremely imperfect; that only a small portion of the globe has been geologically explored with care; that only certain classes of organic beings have been largely preserved in a fossil state; that the number both of specimens and of species, preserved in our museums, is absolutely as nothing compared with the incalculable number of generations which must have passed away even during a single formation; that, owing to subsidence being necessary for the accumulation of fossiliferous deposits thick enough to resist future degradation, enormous intervals of time have elapsed between the successive formations; that there has probably been more extinction during the periods of subsidence, and note variation during the periods of elevation, and during the latter the record will have been least perfectly kept; that each single formation has not been continuously deposited; that the duration of each formation is, perhaps, short compared with the average duration of specific forms; that migration has played an important part in the first appearance of new forms in any one area and formation; that widely ranging species are those which have varied most, and have oftenest given rise to new species; and that varieties have at first often been local. All these causes taken conjointly, must have tended to make the geological record extremely imperfect, and will to a large extent explain why we do not find interminable varieties, connecting together all the extinct and existing forms of life by the finest graduated steps." (Darwin 1860: 370-1)

and successively; how species of different classes do not necessarily change together, or at the same rate, or in the same degree; yet in the long run that all undergo modification to some extent. The extinction of old forms is the almost inevitable consequence of the production of new forms. We can understand why when a species has once disappeared it never reappears. Groups of species increase in numbers slowly, and endure for unequal periods of time; for the process of modification is necessarily slow, and depends on many complex contingencies. The dominant species of the larger dominant groups tend have many modified descendants, and thus new sub-groups and groups are formed. As these are formed, the species of the less vigorous groups, from their inferiority inherited from a common progenitor, tend to become extinct together, and to leave no modified offspring on the face of the earth. But the utter extinction of a whole group of species may often be a very slow process, from the survival of a few descendants, lingering in protected and isolated situations. When a group has once wholly disappeared, it does not reappear; for the link of generation has been broken.

We can understand how the spreading of the dominant forms of life, which are those that oftenest vary, will in the long run tend to people the world with allied, but modified, descendants; and these will generally succeed in taking the places of those groups of species which are their inferiors in the struggle for existence. Hence, after long intervals of time, the productions of the world will appear to have changed simultaneously.

We can understand how it is that all the forms of life, ancient and recent, make together one grand system; for all are connected by generation. We can understand, from the continued tendency to divergence of character, why the more ancient a form is, the more it generally differs from those now living. Why ancient and extinct forms often tend to fill up gaps between existing forms, sometimes mending two groups previously classed as distinct into one; but more commonly only bringing them a little closer together. The more ancient a form is, the more often, apparently, it displays characters in some degree intermediate between groups now distinct; for the more ancient a form is, the more nearly it will be related to, and consequently resemble, the common progenitor of groups, since become widely divergent. Extinct forms are seldom directly intermediate between existing forms; but are intermediate only by a long and circuitous course through many extinct and very different forms. We can clearly see why the organic remains of closely consecutive formations are more closely allied to each other, than are those of remote formations; for the forms are more closely linked together by generation: we can clearly see why the remains of an intermediate formation are intermediate in character.

The inhabitants of each successive period in the world's history have beaten their predecessors in the race for life, and are, in so far. Higher in the scale of nature; and this may account for that vague yet ill-defined sentiment, felt by many palaeontologists, that organisation on the whole has progressed. If it should hereafter be proved that ancient animals resemble to a certain extent the embryos of more recent animals of the same class, the fact will be intelligible. The succession of the same types of structure within the same areas during the later geological periods ceases to be mysterious, and is simply explained by inheritance.

If then the geological record be as imperfect as I believe it to be, and it may at least

> be asserted that the record cannot be proved to be much more perfect, the main objections to the theory of natural selection are greatly diminished or disappear. On the other hand, all the chief laws of palaeontology plainly proclaim, as it seems to me. That species have been produced by ordinary generation: old forms having been supplanted by new and improved forms of life, produced by the laws of variation still acting around us, and preserved by Natural Selection.“ (Darwin 1860: 343-5)

but also the regularities of biogeography:

> „If the difficulties be not insuperable in admitting that in the long course of time the individuals of the same species, and likewise of allied species, have proceeded from some one source; then I think all the grand leading facts of geographical distribution are explicable on the theory of migration (generally of the more dominant forms of life), together with subsequent modification and the multiplication of new forms. We can thus understand the high importance of barriers, whether of land or water, which separate our several zoological and botanical provinces. We can thus understand the localisation of sub-genera, genera, and families; and how it is that under different attitudes, for instance in South America, the inhabitants of the plains and mountains, of the forests, marshes, and deserts, are in so mysterious a manner linked together by affinity, and are likewise linked to the extinct beings which formerly inhabited the same continent. Bearing in mind that the mutual relation of organism to organism is of the highest importance, we can see why two areas having nearly the same physical conditions should often be inhabited by very different forms of life; for according to the length of time which has elapsed since new inhabitants entered one region; according to the nature of the communication which allowed certain forms and not others to enter, either in greater or lesser numbers; according or not. As those which entered happened to come in more or less direct competition with each other and with the aborigines; and according as the immigrants were capable of varying more or less rapidly, there would ensue in different regions, independently of their physical conditions, infinitely diversified conditions of life,—there would be an almost endless amount of organic action and reaction,—and we should find, as we do find, some groups of beings greatly, and some only slightly modified,—some developed in great force, some existing in scanty numbers—in the different great geographical provinces of the world.
>
> On these same principles, we can understand, as I have endeavoured to show, why oceanic islands should have few inhabitants, but if these a great number should be endemic or peculiar; and why, in relation to the means of migration, one group of beings, even within the same class, should have all its species endemic, and another group should have all its species common to other quarters of the world. We can see why whole groups of organisms, as batrachians and terrestrial mammals, should be absent from oceanic islands, whilst the Host isolated islands possess their own peculiar species of aerial mammals or bats. We can see why there should be some relation between the presence of mammals, in a more or less modified condition, and the depth of the sea between an island and the mainland. We can clearly see why all the inhabitants of an archipelago, though specifically distinct on the several islets, should be closely related to each other, and likewise be related, but less closely, to those of the nearest continent or other source whence immigrants were

> probably derived. We can see why in two areas, however distant from each other, there should be a regularity, in the presence of identical species, of varieties, of doubtful species, and of distinct but representative species.“ (Darwin 1860: 408-10)

and, finally, an important class of regularities in anatomy and morphology: useless, rudimentary or nascent organs and the overall similarity of organisms of different taxonomic classes[394]:

> „Organs or parts in this strange [i.e. rudimentary, atrophied, or aborted] condition, bearing the stamp of inutility, are extremely common throughout nature. For instance, rudimentary mammae are very general in the males of mammals: I presume that the ‘bastard-wing’ in birds may be safely considered as a digit in a rudimentary State: in very many snakes one lobe of the lungs is rudimentary; in other snakes there are rudiments of the pelvis and hind limbs. Some of the cases of rudimentary organs are extremely curious; for instance, he presence of teeth in foetal whales, which when grown up have no tooth in their heads; and the presence of teeth, which never cut through the gums, in the upper jaws of our unborn calves. It has even been stated on good authority that rudiments of teeth can be detected in the beaks of certain embryonic birds. Nothing can be plainer than hat wings are formed for flight, yet in how many insects do we see wings so reduced in size as to be utterly incapable of flight, and not rarely lying under wing-cases, firmly soldered together!“ (Darwin 1860: 450)

> „An organ serving for two purposes, may become rudimentary or utterly aborted for one, even the more important purpose; and remain perfectly efficient for the other. Thus in plants, the office of the pistil is to allow the pollen-tubes to reach the ovules protected in the ovarium at its base. The pistil consists of a stigma supported on the style; but in some Compositae, the male florets, which of course cannot be fecundated, have a pistil, which is in a rudimentary state, for it is not crowned with a stigma; but the style remains well developed, and is clothed with hairs as in other Compositae, for the purpose of brushing the pollen out of the surrounding anthers. Again, an organ may become rudimentary for its proper purpose, and be used for a distinct object: in certain fish he swim-bladder seems to be nearly rudimentary for its proper function of giving buoyancy, but has become converted into a nascent wreathing organ or lung. Other similar instances could be given.“ (Darwin 1860: 451-2)

394 To explain these regularities was Owen’s project and before, Cuvier’s and Geoffroy’s. And, indeed, Darwin does link his work to theirs: „It is generally acknowledged that all organic beings have been formed on two great laws — Unity of Type, and the conditions of Existence. By unity of type is meant that fundamental agreement in structure, which we see in organic beings of the same class, and which is quite independent of their habits of life. On my theory, unity of type is explained by unity of decent. The expression of conditions of existence, so often insisted on by the illustrious Cuvier, is fully embraced by the principle of natural selection for natural selection acts by either now adapting the varying parts of each being to its organic and inorganic conditions of life; or by having adapted them during long-past periods of time: the adaptations being aided in some cases by use and disuse, being slightly affected by the direct action of the external conditions of life, and being in all cases subjected to the several laws of growth. Hence, in fact, the law of the Conditions of Existence is the higher law; as it includes, through the inheritance of former adaptations, that of Unity of Type.“ (Darwin 1860: 206)

> „Organs, however little developed, if of use, should not be called rudimentary; they cannot properly be said to be in an atrophied condition; they may be called nascent, and may hereafter be developed to any extent by natural selection. Rudimentary organs, on the other hand, are essentially useless, as teeth which never cut through the gums; in a still less developed condition, they would be of still less use. They cannot, therefore, under their present condition, have been formed by natural selection, which acts solely by the preservation of useful modifications; they have been retained, as we shall see, by inheritance, and relate to a former condition of their possessor. It is difficult to know what are nascent organs; looking to the future, we cannot of course tell how any part will be developed, and whether it is now nascent; looking to the past, creatures with an organ in a nascent condition will generally have been supplanted and exterminated by their successors with the organ in a more perfect and developed condition. The wing of the penguin is of high service, and acts as a fin; it may, therefore, represent the nascent state of the wings of birds; not that I believe this to be the case, it is more probably a reduced organ, modified for a new function: the wing of the Apteryx is useless, and is truly rudimentary. The mammary glands of the Ornithorhynchus may, perhaps, be considered, in comparison with the udder of a cow, as in a nascent state. The ovigerous frena of certain cirripedes, which are only slightly developed and which have ceased to give attachment to the ova, are nascent branchiae." (Darwin 1860: 452)

v. Connector: Natural Selection, Drift, Use & Disuse,

Darwin employs four different terms for the Connectors which link the Input and Output of his dynamic model: Natural Selection, Sexual Selection, Preservation and Elimination.[395] Furthermore, he describes an assignment of a subset of the Input to a subset of the Output which he does not name, namely the fluctuation of certain features as the result of irrelevant variations. For lack of a fixed term, I will refer to this assignment as 'Drift', a term which anticipates the modern denotation.

Natural Selection is the most general of these terms and logically implies Preservation – as Darwin states explicitly:

> "This preservation of favourable variations and the rejection of injurious variations, I call Natural Selection." (Darwin 1860: 81)

Moreover, Darwin clearly explains how he operationalizes this trio of terms. In an early reaction to the reception, in the 3rd edition of 1861, he further clarifies his use of the term and its denotative meaning. In accordance with my model, these terms summarize sets of empirical regularities:

> "…it is difficult to avoid personifying the word Nature; but I mean by Nature, only the aggregate action and product of many natural laws, and by laws the sequence of

395 In the later editions of the Origin, Darwin replaced 'Natural Selection' by 'Survival of the Fittest' and 'Elimination' by 'Destruction'. (Ruse 1971: 331) Extensionally, this does not change his dynamic model, but intensionally it attenuates the intentionality of his language. ('Survival of the Fittest' is first mentioned in the fourth edition, where it appears in the title of chapter and with explicit mention of the inventor of the expression, Herbert Spencer, on page 72. (Darwin 1869: 72, 92, 95, 103, 105, 125, 145, 149, 160, 168, 226, 239, 421, 556) In the fifth and sixth edition can be found a similar number of references.

> events[396] as ascertained by us. [sic!] With a little familiarity such superficial objections will be forgotten." (Darwin 1861: 81-2; Darwin 1866: 91-2; Darwin 1869: 92-3; Darwin 1872a: 63-4)[397]

He provides examples of the workings of both expressions of Natural Selection, Elimination and Preservation. In these, he no longer links extinction or emergence exclusively to one type of Input, like Ecological Change or Individual Variations. With Darwin, all kinds of Inputs may lead to all kinds of Output, it depends simply whether they are favorable, injurious or irrelevant.

> "…the struggle almost invariably will be most severe between the individuals of the same species, for they frequent the same districts, require the same food, and are exposed to the same dangers. In the case of varieties of the same species, the struggle will generally be almost equally severe, and we sometimes see the contest soon decided: for instance, if several varieties of wheat be sown together, and the mixed seed be resown, some of the varieties which best suit the soil or climate, or are naturally the most fertile, will beat the others and so yield more seed, and consequently in a few years quite supplant the other varieties." (Darwin 1860: 75)

> „Take the case of a carnivorous quadruped, of which the number that can be supported in any country has long ago arrived at its full average. If its natural powers of increase be allowed to act, it can succeed in increasing (the country not undergoing any change in its conditions) only by its varying descendants seizing on places at present occupied by other animals… The more diversified in habits and structure the descendants of our carnivorous animal became, the more places they would be enabled to occupy. What applies to one animal will apply throughout all time to all animals – that is, if they vary – for otherwise natural selection can do nothing." (Darwin 1860: 113)

> „It has been experimentally proved, that if a plot of ground - be sown with one species of grass, and a similar plot be sown with several distinct genera of grasses, a greater number of plants and a greater weight of dry herbage can thus be raised. The same has been found to hold good when first one variety and then several mixed varieties of wheat have been sown on equal spaces of ground. Hence, if any one species of grass were to go on varying, and those varieties were continually selected which differed from each other in at all the same manner is distinct species and genera of grasses differ from each other, greater number of individual plants of this species of grass, including its modified descendants, would succeed in living on the same piece of ground. And we well know that each species and each variety of grass is annually sowing almost countless seeds; and thus, as it may be said, is striving its utmost to increase its numbers. Consequently, I cannot doubt that in the course of many thousands of generations, the most distinct varieties of any one species of grass would always have the best chance of succeeding and of increasing in numbers,

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396 Darwin is a imprecise when he speaks of "sequences of events" for he applies his model to paleontological evidence, too. While paleontological evidence may stem from events, these events have not been observed.

397 The number of pages decreases significantly from the 4th to the 5th and 6th edition. Therefore, the citation moves to lower pages.

> and thus of supplanting the less distinct varieties; and varieties, when rendered very distinct from each other, take the rank of species.
> The truth of the principle, that the greatest amount of life can be supported by great diversification of structure, is seen under many natural circumstances." (Darwin 1860: 113-114)
>
> „Only those variations which are in some way profitable will be preserved or naturally selected." (Darwin 1860: 117)
>
> „But during the process of modification, … another of our principles, namely that of extinction, will have played an important part. As in each fully stocked country natural selection necessarily acts by the selected from having some advantage in the struggle for life over other forms, there will be a constant tendency in the improved descendants of any one species to supplant and exterminate in each stage of descent their predecessors and their original parent. For it should be remembered that the competition will generally be most severe between those forms which are most nearly related to each other in habits, constitution, and structure. hence all the intermediate forms between the earlier and later states, that is between the less and more improved state of a species, as well as the original parent-species itself, will generally tend to become extinct. So it probably will be with many whole collateral lines of descent, which will be conquered by later and improved lines of descent. If, however, the modified offspring of a species get into some distinct country, or become quickly adapted to some quite new station, in which child and parent do not come into competition. Both may continue to exist." (Darwin 1860: 121-2)
>
> „In some cases we might easily put down to disuse modifications of structure which are wholly, or mainly, due to natural selection. Mr Wollaston has discovered the remarkable fact that 200 beetles, out of the 550 species inhabiting Madeira, are so far deficient in wings that they cannot fly; and that of the twenty-nine endemic genera, no less than twenty-three genera have all their species in this condition! Several facts, namely, that beetles in many parts of the world are frequently blown to sea and perish; that the beetles in Madeira, as observed by Mr Wollaston, lie much concealed, until the wind lulls and the sun shines; that the proportion of wingless beetles is larger on the exposed Desertas than in Madeira itself; and especially the extraordinary fact, so strongly insisted on by Mr Wollaston, of the almost entire absence of certain large groups of beetles, elsewhere excessively numerous, and which groups have habits of life almost necessitating frequent flight;—these several considerations have made me believe that the wingless condition of so many Madeira beetles is mainly due to the action of natural selection, but combined probably with disuse " (Darwin 1860: 135-6)

The fourth term for the Connector is sexual selection, a more complicated case. In the joint paper, Darwin had referred to it as a "second agency" (Darwin 1858 [1844]: 50) and does so again in the *Origin* (Darwin 1860: 90). (I will discuss its meaning with respect to the narrative below.) Whether one understands it as a second Connector, independent of Natural Selections, seems to depend on two factors. First, it depends on how one interprets the Struggle for Life: as a struggle for survival or a struggle for reproduction, i.e. a struggle for leaving most progeny. (see above) To me, Darwin's text suggests the latter and therefore, leaving more progeny implies more success in the struggle for life and, in the longer term, to the emergence of varieties and species. Therefore, I would argue that natural selection implies sexual selection because success in terms of sexual selection is also success in terms of natural selection[398] – although his text sometimes opposes both:

> „…natural selection will be able to modify one sex in its functional relations to the other sex, or in relation to wholly different habits of life in the two sexes, as is sometimes the case with insects. […] This depends, not on a struggle for existence, but on a struggle between the males for possession of the females; the result is not death to the unsuccessful competitor but few or no offspring. Sexual selection is, therefore, less rigorous than natural selection. Generally, the most vigorous males, those which are best fitted for their places in nature, will leave most progeny. But in many cases, victory depends not on general vigour, but on having special weapons, confined to the male sex." (Darwin 1860: 87-88)

The ensuing examples, however, rather support my claim because, second, whether one understands natural selection as implying sexual selection or not, depends on whether Darwin provides a criterion to empirically distinguish between both. [399] He does no such thing; rather he equates the results of both types of selection:

> "A hornless stag or spurless cock would have a poor chance of leaving offspring. Sexual selection by always allowing the victor to breed might surely give indomitable courage, length to the spur, and strength to the wing to strike in the spurred leg, as well as the brutal cock-fighter, who knows well that he can improve his breed by careful selection of the best cocks. How low in the scale of nature the law of battle descends, I know not; male alligators have been described as fighting, bellowing, and whirling round, like Indians in a war-dance, for the possession of the females; male salmons have been seen fighting all day long; male stag-beetles often bear wounds from the huge mandibles of other males. The war is, perhaps, severest between the males of polygamous animals, and these seem oftenest provided with special weapons. The males of carnivorous animals are already well armed; though to them and to others, special means of defence may be given through means of sexual selection, as the mane to the lion, the shoulder-pad to the boar, and the hooked jaw to the male salmon; for the shield may be as important for victory, as the sword or spear." (Darwin 1860: 88)

> "Amongst birds, the contest is often of a more peaceful character. All those who have attended to the subject, believe that there is the severest rivalry between the males of many species to attract by singing the females. The rock-thrush of Guiana, birds of Paradise, and some others, congregate; and successive males display their gorgeous plumage and perform strange antics before the females, which, standing by as spectators, at last choose the most attractive partner. Those who have closely attended to birds in confinement well know that they often take individual

[398] In modern terminology one would speak of natural selection implying both sexual and ecological (non-sexual) selection.

[399] Himmelfarb argues for 'sexual selection' denoting a second connector without providing empirical support for her position. (Himmelfarb 1959: 257)

> preferences and dislikes: thus Sir R. Heron has described how one pied peacock was eminently attractive to all his hen birds. …[thus] if man can in a short time give elegant carriage and beauty to his bantams, according to his standard of beauty, I can see no good reason to doubt that female birds, by selecting, during thousands of generations, the most melodious or beautiful males, according to their standard of beauty, might produce a marked effect.“ (Darwin 1860: 89)

Beyond, the preservation of favourable variations and the elimination of injurious ones, Darwin assigns long-term changes of groups of organisms to variations which he considers neither injurious nor favourable: irrelevant variations. For this assignment, Darwin introduces no predicate, he does not denote it by any term as 'natural selection' or 'sexual selection'. In order to refer to this assignment, I will speak of 'drift', the modern term by which are named changes which are not considered evolution.[400]

The Origin contains several references to such drift and Darwin does clearly oppose it to the sequence of variation – selection – evolution, i.e. the core of his dynamic model:

> "This preservation of favourable variations and the rejection of injurious variations, I call Natural Selection. Variations neither useful nor injurious would not be affected by natural selection, and would be left a fluctuating element, as perhaps we see in the species called polymorphic." (Darwin 1860: 81)

> „I have sometimes felt much difficulty in understanding the origin of simple parts, of which the importance does not seem sufficient to cause the preservation of successively varying individuals.“ (Darwin 1860: 194-5)

> „The foregoing remarks lead me to say a few words on the protest lately made by some naturalists, against the utilitarian doctrine that every detail of structure has been produced for the good of its possessor. They believe that very many structures have been created for beauty in the eyes of man, or for mere variety. This doctrine, if true, would be absolutely fatal to my theory. Yet I fully admit that many structures are of no direct use to their possessors. […] Thus, we can hardly believe that the webbed feet of the upland goose or of the frigate-bird are of special use to these birds; we cannot believe that the same bones in the arm of the monkey, in the fore-leg of the horse, in the wing of the bat, and in the flipper of the seal, are of special use to these animals. We may safely attribute these structures to inheritance. But to the progenitor of the upland goose and of the frigate-bird, webbed feet no doubt were as useful as they now are to the most aquatic of existing birds. " (Darwin 1860: 199)

[400] Thus, Darwin not foresaw a concept equivalent of Genetic Drift in his Theory. He did not name it, yet, he clearly discusses examples which fall under such a concept, namely Variations which do not lead to sustainable evolution. As Ellegård put it, Darwin, over time, "was becoming increasingly willing to ascribe same variations to mere chance fluctuations, or to what he called 'correlation of growth': the fact that, in many cases, variations in one organ may be automatically accompanied by a variation in a different part of the organism. One of these variations might be useful, and thus naturally selected, the other, concomitant one, might be wholly useless, or even slightly injurious. The selection depended on the total effect." (Ellegård 1958: 252)

Darwin does not preclude, however, that such irrelevant variations may latter become useful, namely after some favorable ecological change:

> „We are far too ignorant, in almost every case, to be enabled to assert that any part or organ is so unimportant for the welfare of a species, that modifications in its structure could not have been slowly accumulated by means of natural selection. But we may confidently believe that many modifications, wholly due to the laws of growth, and at first in no way advantageous to a species, have been subsequently taken advantage of by the still further modified descendants of this species. We may, also, believe that a part formerly of high importance has often been retained (as the tail of an aquatic animal by its terrestrial descendants), though it has become of such small importance that it could not, in its present state, have been acquired by natural selection, — a power which acts solely by the preservation of profitable variations in the struggle for life.“ (Darwin 1860: 205)

In sum, Darwin explains the features of plants and organisms not by their particular use but by the fact that they have not been injurious to their bearer.

Finally, Darwin mentions a fourth Connector – albeit mostly as a subordinate complement to Natural Selection. This fourth Connector is the Lamarckian use and disuse and is mentioned throughout the text, usually as part of the explanation of rudimentary organs:

> "…the wingless condition of so many Madeira beetles is mainly due to the action of natural selection, but combined probably with disuse. For during thousands of successive generations each individual beetle which flew least, either from its wings having been ever so little less perfectly developed or from indolent habit, will have had the best chance of surviving from not being blown out to sea; and, on the other hand, those beetles which most readily took to flight would oftenest have been blown to sea and thus have been destroyed.“ (Darwin 1860: 135-6)

> „On the whole, I think we may conclude that habit, use, and disuse have, in some cases, played a considerable part in the modification of the constitution, and of the structure of various organs; but that the effects of use and disuse have often been largely combined with, and sometimes overmastered by the natural selection of innate variations.“ (Darwin 1860: 142-3)

> "In some cases habit or use and disuse have probably come into play. I do not pretend that the facts given in this chapter strengthen in any great degree my theory; but none of the cases of difficulty, to the best of my judgment, annihilate it.“ (Darwin 1860: 242-3)

> „On my view of descent with modification, the origin of rudimentary organs is simple. […] We often see rudiments of various parts in monsters. But I doubt whether any of these cases throw light on the origin of rudimentary organs in a state of nature, further than by showing that rudiments can be produced; for I doubt whether species under nature ever undergo abrupt changes. I believe that disuse has been the main agency; that it has led in successive generations to the gradual reduction of various organs, until they have become rudimentary,—as in the case of the eyes of

> animals inhabiting dark caverns, and of the wings of birds inhabiting oceanic islands. Which have seldom been forced to take flight, and have ultimately lost the power of flying.“ (Darwin 1860: 454-5)
>
> „Disuse, aided sometimes by natural selection, will often tend to reduce an organ, when it has become useless by changed habits or under changed conditions of life; and we can clearly understand on this view the meaning of rudimentary organs. But disuse and selection will generally act on each creature, when it has come to maturity and has to play its full part in the struggle for existence, and will thus have little power of acting on an organ during early life; hence the organ will not be much reduced or rendered rudimentary at this early age. “ (Darwin 1860: 479-80)

vi. Synthesis

Figure 19 and Figure 20 provide an overview over Darwin’s dynamic model and specify its different elements as I have identified then in the *Origin*. Figure 19 is the more detailed and focusses on the assignments of Inputs to Outputs. It is thus oriented primarily on the distinctions between favorable, injurious and irrelevant Inputs and between individuals, varieties and species as subsets of the Object Class. Figure 20 is more oriented towards the kinds of events which count as Input and Output of Darwin’s model, i.e. the kinds of ecological change and variations he considers triggers of evolution. Thus, Figure 20 is more simplified but allows for a better comparison of Darwin to his predecessors and competitors analyzed above. Also, it focuses on the main Connectors of evolution and leaves Drift aside. In this sense, Figure 20 is a normalized version of Figure 19.

In the literature, there are several other representations of Darwin’s dynamic model. (Himmelfarb 1959: 256-76; Vorzimmer 1972: 3-20; Ruse 1971: Ruse 1979: 188-201; Beatty 1980; Bowler 1985. 114-125; Oldroyd 1986; Lloyd 1988; Thompson 1989; Griffiths 1997; Thompson 2007) I consider my representation as both more precise and more detailed than any of them. Let me illustrate what I mean by this on one prominent representation of Darwin’s model by Ernst Mayr (Mayr 1991: 72; cf. Mayr 1985), which also seems to be the best-known among biologists. (see Figure 21) Mayr presents Darwin’s model as complex of three inferences, based on five facts. Of these five facts, four can be found in my model: Facts 1 and 2, are covered by my Situation Type, Fact 4 by the individuals in the Object Class, Fact 5 in Input 2 of my presentation. Fact 3, the limitation of resources, is no autonomous observation in my reading of Darwin; he observes only the Growth with Reproduction (overproduction) (Fact 1) and the stability of populations (Fact 2). One might read that Darwin interprets Facts 1 and 2 as suggesting Fact 3 but this takes no systematic position in his argument in my reading. As for the inferences, the first is the name for Facts 1 and 2 as displayed in my Situation Type. Inference 3 of Mayr’s scheme corresponds to my long-term Output for species and is, in his wording, a fact rather than an inference. His Inference 2 is my Connector, i.e. the name of the assignment of Inputs to Outputs in my model. In sum, I believe that my model covers all elements of Mayr’s model and is even more detailed. Also, it represents Darwin’s model in a more precise framework, separating its logical and empirical elements more neatly.

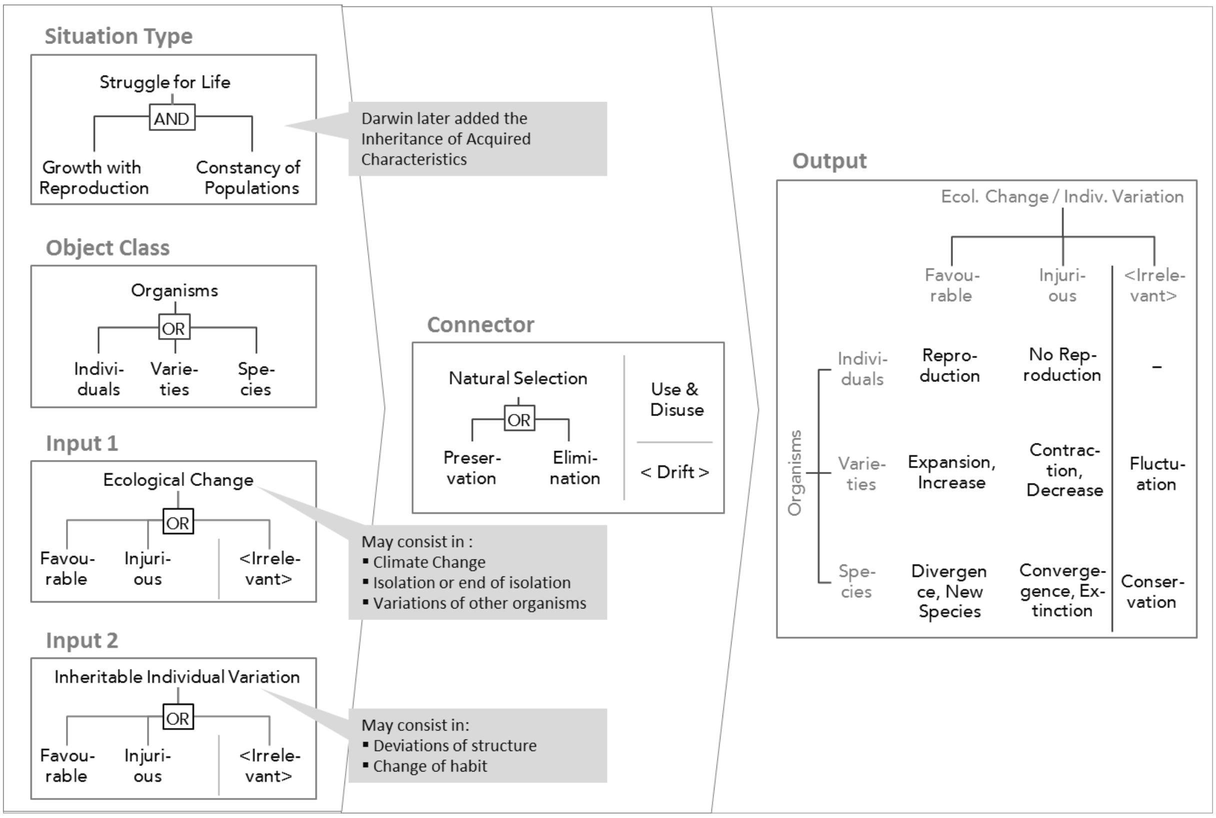

Figure 19: Darwin's dynamic model – full version, focus on the distinction favorable – injurious – irrelevant

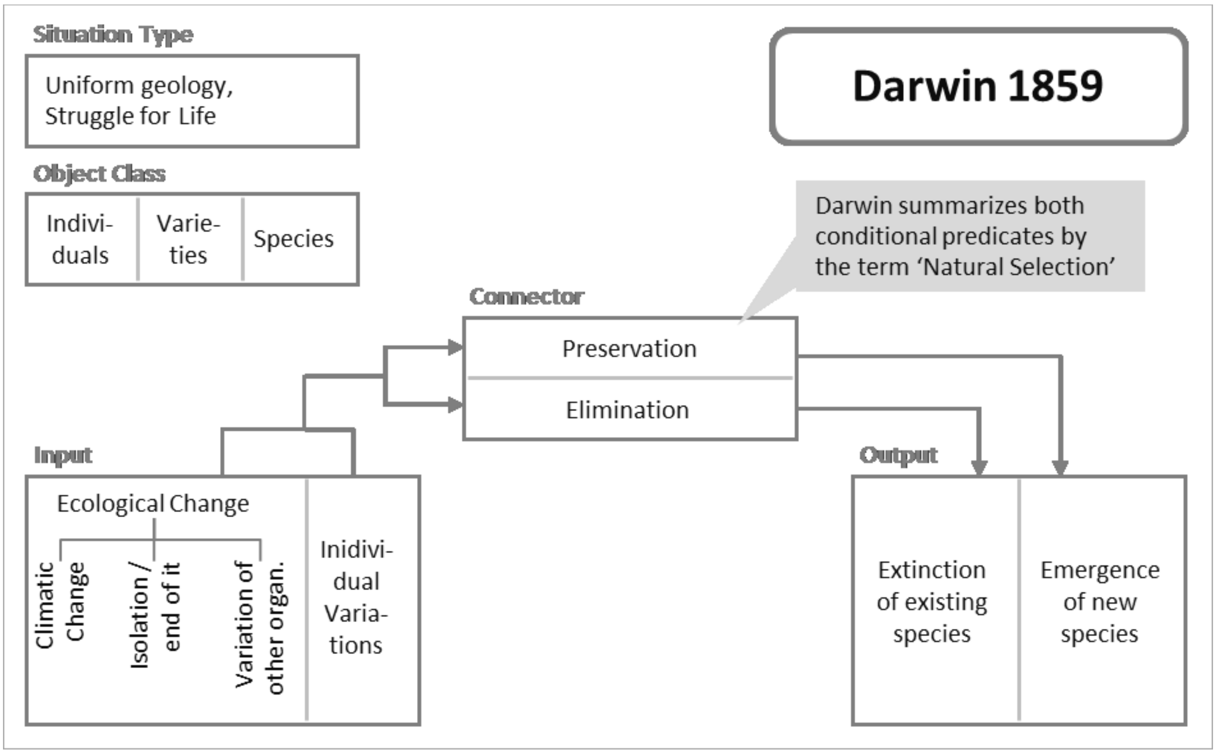

Figure 20: Darwin's dynamic model – simplified and normalized version

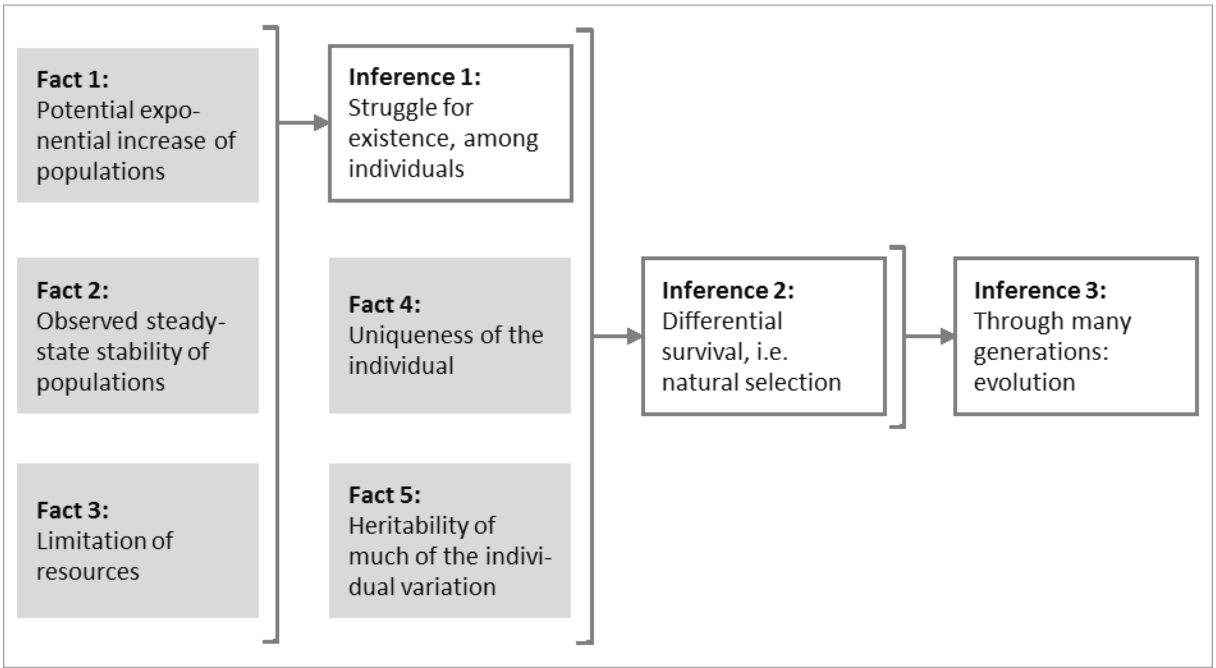

Figure 21: "Darwin's Explanatory Model of Evolution through Natural Selection" taken from (Mayr 1991: 72)

3.4.4 Narrative explanation: How did Darwin tell evolution?

Already in the *Origin*'s short introduction (Darwin 1860: 4-5), Darwin outlines the blue-print for his narrative: All organisms are in a constant Struggle for Existence (or Struggle for Life), in which Variation or an Ecological Change[401] leads to a slight advantage for certain organisms. Natural Selection then preserves the organisms with this advantage and, in the long run, produces a Divergence of Character in the original species. At the same time, the now less fit Organisms face the danger of Extinction. This basic narrative form is developed and applied throughout the Origin; elements of it can be found in empirical examples and theoretical discussions but also in prototypical imaginative stories, a particular feature of Darwin's text. Let me address these little stories before I dissect Darwin's general narrative.

Darwin begins to tell his prototypical stories in Chapter 4 of the *Origin*, the chapter on *Natural Selection* in which Darwin assembles the components of his argument and first applies the blue-print from the introduction in complete explanations.[402] These stories display the same blurring of the members of the Object Class as Darwin's dynamic model; they evolve from incidents around individual organisms to tales about large groups of organisms, for instance in this story about wolves in which:

> „... a [wolf] cub [sic!] might be born with an innate tendency to pursue certain kinds of prey. Nor can this be thought to be very improbable; for [with cats the] tendency to catch rats rather than mice is known to be inherited. Now, if any slight innate change of habit or of structure benefited an individual wolf [sic!], it would have the

401 Remember that Darwin does not use the expression 'ecological change'. Instead, speaks of the adaptation of organic beings to „physical conditions of life" which presume either that these physical conditions have recently changed or that the organisms concerned have entered into a new territory.

402 Rhetorically, Chapter 4 resolves a tension which Darwin built up from the introduction throughout the first three chapters.

> best chance of surviving and of leaving offspring. Some of its young [sic!] would probably inherit the same habits or structure, and by the repetition of this process, a new variety [sic!] might be formed which would either supplant or coexist with the parent form of wolf. Or, again, the wolves inhabiting a mountainous district, and those frequenting the lowlands, would naturally be forced to hunt different prey; and from the continued preservation of the individuals best fitted for the two sites. Two varieties might slowly be formed. […] I may add, that, according to Mr Pierce, there are two varieties of the wolf inhabiting the Catskill Mountains in the United States, one with a light greyhound-like form, which pursues deer, and the other more bulky, with shorter legs, which more frequently attacks the shepherd's flocks." (Darwin 1860: 91)

The organisms in this story change their form four times: from a cub, to an adult wolf, to a couple of young to a variety. Darwin's narration does thus bend the laws of time. While his "vehicle of change" are individuals (Eliot 2009), his story does not stay with them:

> "Whereas a simple developmental narrative still using the model of the single life span might have placed the embryo at the beginning, and a narrative preoccupied with origins and cosmogony might have started with the geological record, Darwin places the initiating emphasis in his narrative on the profusion of individuals, their variability, the diversity of species. Only gradually do the laws emerge from the welter of particularity." (Beer 2009: 59-60)

This rhetorical trick allowed for accelerating the course of time throughout the story and, hence, telling processes which are much too slow for humans to observe.[403]

Another powerful example of both effects is be the following fictive example of a species of plants excreting sweet juice:

> „Let us now take a more complex case. Certain plants excrete a sweet juice, apparently for the sake of eliminating something injurious from their sap: this is effected by glands at the base of the stipules in some Leguminosae, and at the back of the leaf of the common laurel. This juice, though small in quantity, is greedily sought by insects. Let us now suppose a little sweet juice or nectar to be excreted by the inner bases of the petals of a flower. In this case insects in seeking the nectar would get dusted with pollen, and would certainly often transport the pollen from one flower to the stigma of another flower. The flowers of two distinct individuals of the same species would thus get crossed; and the act of crossing, we have good reason to believe (as will hereafter be more fully alluded to), would produce very vigorous seedlings, which consequently would have the best chance of flourishing and surviving. Some of these seedlings would probably inherit the nectar-excreting power. Those individual flowers which had the largest glands or nectarines, and which excreted most nectar, would be oftenest visited by insects, and would be

[403] Gillian Beer remarks that "The rapidity of Darwin's narrative made it difficult for him to render accurately the extreme slowness of the processes he was describing, Ontogeny and phylogeny might therefore be confused in the reader's mind - and even in the syntax of the text." (Beer 2009: 98)

> oftenest crossed; and so in the long-run would gain the upper hand.“ (Darwin 1860: 92)

Once these intuitive narrative patterns are established, Darwin can extend his explanation to less graphic cases like examples where the starting point of evolutionary change is a Variety not a single Individual or to the Elimination of less fit Organisms. In such cases, the Useful Variation of one Variety might represent an Injurious Environmental Change to another Variety which competes for the same resources:

> „It has been experimentally proved, that if a plot of ground - be sown with one species of grass, and a similar plot be sown with several distinct genera of grasses, a greater number of plants and a greater weight of dry herbage can thus be raised. The same has been found to hold good when first one variety and then several mixed varieties of wheat have been sown on equal spaces of ground. Hence, if any one species of grass were to go on varying, and those varieties were continually selected which differed from each other in at all the same manner is distinct species and genera of grasses differ from each other, greater number of individual plants of this species of grass, including its modified descendants, would succeed in living on the same piece of ground. And we well know that each species and each variety of grass is annually sowing almost countless seeds; and thus, as it may be said, is striving its utmost to increase its numbers. Consequently, I cannot doubt that in the course of many thousands of generations, the most distinct varieties of any one species of grass would always have the best chance of succeeding and of increasing in numbers, and thus of supplanting the less distinct varieties; and varieties, when rendered very distinct from each other, take the rank of species.
> The truth of the principle, that the greatest amount of life can be supported by great diversification of structure, is seen under many natural circumstances.“ (Darwin 1860: 113-4)

The explanatory effect in such examples ultimately stems from the same type of story as in the prototypical examples above: single Organisms benefit from a Useful Variation, are preserved by Natural Selection, survive and reproduce. In the medium and long run they will leave more progeny and form new Species. The opposite case of Death, Decrease of Frequency and Extinction is but the negative of Darwin’s story. – After this look at his prototypical stories, let me analyze Darwin’s general narrative.

i. Scene: The struggle for life

Evolution takes place within the *Scene* in which all of Darwin’s stories begin: the Struggle for Life – or Struggle for Existence. In his autobiography, Darwin has emphasized how much the concept of *Struggle* meant for the development of his theory:

> "In October 1838, that is, fifteen months after I had begun my systematic inquiry, I happened to read for amusement ‘Malthus on Population’, and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observation of the habits of animals and plants, it at once struck me that under these circumstances favourable variations would tend to be preserved, and unfavourable ones to be destroyed. The results of this would be the formation of a

> new species. Here, then I had at last got a theory by which to work". (Darwin 1958c: 120)

And, indeed, the Struggle is the key to Darwin's narrative which unfolds in the midst of an archaic competition for survival and reproduction – so archaic that Darwin "had initially … used the Hobbesian phrase 'war of nature' and had quoted Hobbes directly." (Beer 2009: 52-3)[404]

Darwin himself emphasized that he employed the term 'struggle' in a "large and metaphorical sense" (Darwin 1860: 62) covering the struggle between individual organisms for resources, for survival, and for leaving progeny, as well as the relation between predator and prey. In the end, the very ferocity of this struggle explains why Natural Selection and Sexual Selection are necessary, why only some organisms are preserved and most are eliminated: resources and mating partners are scarce. Darwin thereby transcended Malthus'[405] original notion by far[406], providing a vivid and graphic impression of the arena in which Evolution was to take place.

Moreover, employed in Darwin's large sense, the term allowed for application in a wide array of different stories; it made Darwin's Scene remarkably versatile. Hence, Darwin had succeeded in constructing a powerful and versatile Scene for his narrative, prone to be applied in numerous single explanations of evolutionary facts.

ii. Agent: Nature, God, the organisms?

The text of the Origin suggests several candidates for the Agent. The first and for modern readers most obvious is certainly Nature[407]. Throughout the book, Darwin personifies Nature[408] and describes her as an Agent:

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404 (Beer 2009: 52-3) interprets Darwin's change of words as "an attempt to move away from the human into a word which lacked the organised force of war and expressed instead the interpenetration of energies."

405 Darwin clearly borrows the idea of a geometrical increase from Malthus and felt inspired by Malthus for his idea of a struggle. Yet, as Peter J. Bowler (1976) points out, Darwin's concept of struggle differs very much from Malthus'. While Malthus described a struggle of groups for scarce resources, Darwin spoke of a struggle between individuals, which can be fiercest among individuals of the same species. (Bowler 1976: 643; Darwin 1860: 63) Thus, Darwin clearly extends the denotative meaning of Malthus' concept while preserving its connotative meaning, a category shift or metábasis. (cf. Radick 2003)
Young discusses whether Darwin's concept of struggle stems from the laissez-faire economists (cf. Gale 1972) but denies this idea for "Where the modern observer sees cutthroat struggle and exploitation, the laissez-faire school saw a natural harmony between the different sections of the economy, with competition between self-seeking individuals at each level leading to a balance in which all would benefit." (Young 1985: 643) He wonders, however, whether Darwin's image of struggle might reflect the actual experience of economic reality as the namely cutthroat struggle. An indicator for this might be the frequency in which Darwin speaks of 'competition' and 'compete' in chapter three on the Struggle for Existence (8 times) and in chapter four on Natural Selection (15 times). (Hull 2005) dismisses Young's suggestion – I hold the position that the metaphor of a struggle in nature is a basal mental model of biology, which can be found throughout the history of biology. (See sections 2.3 x, 5.1 vi) Therefore it makes no sense to identify one single source from which Darwin might have taken it.

406 Neither the development of Malthus' struggle nor the large field of application hindered the popularization of Darwin's metaphor. Instead, in 1868, 'struggle for life' had already reached the "phraseology of everyday conversation". (Ellegård 1958: 43) Moreover, its impact was to be felt for decades to come, be it in Marx's 'Struggle of the Classes' or in the Social Darwinist construction of human society.

407 Gillian Beer highlights that the "Darwinian theory takes up elements from older orders and particularly from recurrent mythic themes such as transformation and metamorphosis. It retains the idea of natura naturans, or the Great Mother, in its figuring of Nature". (Beer 2009: 7)

> "… but Natural Selection … is a power incessantly ready for action, and it is immeasurably superior to man's feeble efforts, as the works of Nature are to those of Art."(Darwin 1860: 61-2)
>
> "Man selects only for his own good; Nature only for that of the being which she tends. Every selected character is fully exercised by her; and the being is placed under well-suited conditions of life." (Darwin 1860: 84)
>
> "…we must suppose that there is a power always intently watching each slight accidental alteration in the transparent layers; and carefully selecting each alteration…" (Darwin 1860: 189)
>
> "…natural selection will pick out with unerring skill each improvement…" (Darwin 1860: 189)
>
> "Why should not Nature have taken a leap from structure to structure?" (Darwin 1860: 194)

Darwin's personifications went so far that Wallace complained to Darwin about them in a letter. (Young 1985: 100) Consequently, in later editions, Darwin tried to explicitly delimit the metaphorical (connotative) implications of his metaphor. Already in the third edition of the Origin, in April 1861, he stated very clearly:

> "It has been said that I speak of natural selection as an active power or Deity; but who objects to an author speaking of the attraction of gravity as ruling the movements of the planets? Every one knows what is meant and is implied by such metaphorical expressions; and they are almost necessary for brevity. So again it is difficult to avoid personifying the word Nature; but I mean by Nature, only the aggregate action and product of many natural laws, and by laws the sequence of events as ascertained by us." (Darwin 1861: 85, cf. Beer 2009: 62-4; Beer 2008: xxii)[409]

Such explicit denial, however, could not prevent that any reader who looked for an explanatory narrative in the Origin, would first stumble upon Darwin's Nature.

The second possible Agent behind Evolution is God. Darwin mentions God only a few times in the Origin, much less than Chambers or Owen.[410] These references, however, are placed prominently in the final chapter of the Origin. There, Darwin portrays God as having ignited the process that Darwin had modeled as evolution through natural selection:

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408 Such, Darwin frequently writes nature with a capital 'n'. (Darwin 1860: 61, 62, 66, 82, 83, 84, 126, 194, 225, 269, 293, 388) Moreover, as Gillian Beer emphasizes: "His grandfather, Erasmus Darwin, had already noted the speed and ease with which personification takes place in English. Since English is an ungendered language one need only add a 'his' or 'hers' to turn a word into personification. With personification enters intention." (Beer 2009: 62-3) For other discussions of this point, see Young 1985: 93; Mayr 1990a: 58; Ruse 1971: 329-30; Beer 2009: xviii)

409 It is revealing that Darwin compares Natural Selection to Gravity for these two Begriffe are the central conditional predicates in Darwin's and Newton's theory respectively; they fulfill the same logical role in the two theories and Darwin attempts to ascribe them the same role in the narrative as well.

410 I count eight references in the body of the text. Of these eight, five address creationist (design) arguments and only three express Darwin's own position.

> “Therefore I should infer from analogy that probably all the organic beings which have ever lived on this earth have descended from some one primordial form, into which life was first breathed by the Creator.” Darwin 1860: 484)

> “Authors of the highest eminence seem to be fully satisfied with the view that each species has been independently created. To my mind it accords better with what we know of the laws impressed on matter by the Creator that the production and extinction of the past and present inhabitants of the world should have been due to secondary causes, like those determining the birth and death of the individual.” (Darwin 1860: 489)

> “There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.“ (Darwin 1860: 490)

The image of God which Darwin conveyed in the Origin was thus clearly deist; it significantly reduced[411] his role in nature and let Nature fill “the space left by God” (Beer 2009: 64). In Victorian philosophy of science, however, this did not imply that God did not influence Nature; Nature could be understood as a secondary cause which was itself an agent of God, the First Cause. (See section2.3 xi) In any case, God clearly maintains a role in his tale of evolution; he is the Agent who created the first living beings and the laws by which evolution now proceeds.[412]

Third, Darwin might have constructed the organisms undergoing Evolution as Agents. Lamarck had experienced important criticism and ridicule for passages which allowed for such a reading and Darwin had no interest in being associated with them. (Young 1985: 96; Ruse 1971: 331; Beer 2009: 62; Hull 1973: 10) However, a couple of passages in the Origin do suggest that the organisms act, albeit in a different sense than in Lamarck’s *Philosophie Zoologique*:

> “The rock-thrush of Guiana, birds of Paradise, and some others, congregate; and successive males display their gorgeous plumage and perform strange antics before the females, which, standing by as spectators, at last choose the most attractive partner.” (Darwin 1860: 89)

> “…I can see no good reason to doubt that female birds, by selecting, during thousands of generations, the most melodious or beautiful males, according to their standard of beauty, might produce a marked effect.” (Darwin 1860: 89)

> “Yet, I would not wish to attribute all such sexual differences to this agency: for we see peculiarities arising and becoming attached to the male sex in our domestic animals (as the wattle in male carriers, horn-like protuberances in the cocks of certain fowls, &c.), which we cannot believe to be either useful to the males in battle, or attractive to the females.” (Darwin 1860: 90)

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411 His position is further affirmed by his dismissal of creationist arguments throughout the book, e.g. in (Darwin 1860: 44, 55, 133, 159, 185, 203, 315, 355-6, 372, 389-96, 406, 420, 433, 434, 436, 456, 469-489)

412 This does not imply that Darwin himself held elaborated religious beliefs. Rather, in a letter to his friend the botanist John Dalton Hooker Darwin regretted “having used expressions in the Origin which seemed to imply that he regarded the origin of life as supernatural.” (Ellegård 1958: 134).

These passages are less striking than Darwin's speaking of a "second agency" in the joint paper. (Darwin 1858a [1844]: 50) However, they allow for identifying a third possible Agent in the *Origin*: the organisms themselves.

iii. Agency: selection, the creation of life, variation?

The Agency of two of Darwin's possible Agents is selection: female organisms select males for breeding and nature selects favourable variations or organisms which encounter favourable ecological changes. Sexual Selection, the Agency of the organisms, is clearly inferior to Natural Selection[413] in that it acts but on superficial features. Like Man, it "can act only on external and visible characters" (Darwin 1860: 84); females may select[414] beautiful plumages or coats, melodious singing or the charming tail of a peacock (cf. Darwin 1860: 88-9) but no deeper, inherent features.

Conversely, Natural Selection acts on internal features and can achieve much more profound changes in organisms:

> "As man can produce and certainly has produced a great result by his methodical and unconscious means of selection, what may not Nature effect? Man can act only on external and visible characters: Nature cares nothing for appearances [sic!], except in so far as they may be useful to any being. She can act on every internal organ [sic!], on every shade of constitutional difference [sic!]. On the whole machinery of life [sic!]. Man selects only for his own good; Nature only for that of the being which she tends." (Darwin 1860: 84)

> "In the preservation of favoured individuals and races, during the constantly-recurrent Struggle for Existence, we see the most powerful and ever-acting means of selection." (Darwin 1860: 467)

Natural Selection is the core of Darwin's narrative and, together with the Struggle, his most powerful metaphor. It suggests the principal Agent of the narrative: Nature, and, through Darwin's explicit comparison to artificial selection[415], it conveys a graphic image of the Agency by which Evolution is achieved. Thus,

> „… it claimed an explanatory role before contemporaries had learnt what it meant. They puzzled, as people have puzzled since, over its individual elements: natural as

413 From the fifth edition on, Darwin employed the term 'Survival of the Fittest' which does not evoke an Agent as much as 'natural selection'. See (Darwin 1869: 72 (reference to Spencer), 92, 95, 103, 105, 125, 145, 149, 160, 168, 226, 239, 421, 556) and (Darwin 1872a: 49, 63, 65, 70, 72, 85, 98, 103, 108, 146, 156, 169, 315, 412).

414 Remember that Darwin's dynamic model comprises different Connectors: Natural Selection, Preservation, Elimination and Drift. However, most of Darwin's case studies and examples concentrate on only one of them: Preservation. Cases of Drift are completely ignored by Darwin in his stories, presumably because Drift yields no sustainable Output. Elimination yields stories, but somewhat limited ones for Injurious Variation of individual organisms will quickly lead to death without reproduction and provide little material for extensive explanation. Therefore, Darwin's stories are built around Preservation and Elimination figures but as the negative of Preservation. – Ruse emphasizes that Darwin replaced 'Elimination' by 'destruction' in the later editions – an expression which does immediately evokes an agent. (Ruse 1971: 331)

415 To support this comparison, Darwin called gardeners, pigeon-fanciers and stock-breeders to witness for the power of artificial selection for they "can all refine chosen characteristics within a few short generations from among the animals or plants under their control." (Beer 2008: xix)

> opposed to unnatural, or manmade? selected by whom or what? Part of Darwin's triumph is that the phrase, in the event, quite rapidly passed from his unruly question-raising, context-rich status into technical description. It came to seem honed, even simple." (Beer 2009: xviii)

> "Certainly, there is something extra, above and beyond the technical, in [Darwin's] insistence on the *naturalness* of natural selection. Nature authorizes and is internal at once. Whereas artificial selection implies an outside agency, natural selection brings agency inside production." (Beer 2008: xxii)

Compared to Nature and the female organisms, God's means are less immediate, albeit profound in their impact. In Darwin's narrative, he created the first organisms and set the laws according to which evolution proceeds. Hence, once life had begun on earth, he does not interfere directly. However, if one considers Nature as a secondary cause, i.e. as an agent of God, then Nature merely carries out divine law and it is God who acts through its selection.

iv. Act and Purpose: improving species for better adaption

As Gillian Beer emphasized, evolutionary change,

> "is an invisible process, registered only in retrospect. It can therefore be expressed intellectually only as narrative; it has meaning primarily in terms of its own past." (Beer 2009: 99)

To make visible the results of this invisible process, the Act of his narrative, Darwin could only point[416] to the paleontological and biogeographic record or to the variety of artificial races[417] and suggest that the most likely explanation for either was the evolution of earlier forms and their supplanting their ancestors. In his narrative, he garnished this interpretation in a teleological metaphor of gradual and steady improvement. Throughout the text he speaks of the evolved descendants as being "improved" or of natural selection as improving them. (e.g. Darwin 1860: 83, 84, 86, 102-110, 119-128, 172, 177-81, 189, 215, 279-281, 302, 314) With another nuance, Darwin spoke of Natural Selection as "better adapting" organisms to their environment. (e.g. Darwin 1860: 81, 82, 104, 144, 406, 468), thus gradually filling ecological niches with the "fittest" organisms:

> "…there will always be a fair field for natural selection to improve still further the inhabitants, and thus produce new species." (Darwin 1860: 108)

> "…if any one species does not become modified and improved in a corresponding degree with its competitors, it will soon be exterminated. […]
> within a confined area, with some place in its polity not so perfectly occupied as might be, natural selection will always tend to preserve all the individuals varying in the right direction, though in different degrees, so as better to fill up the unoccupied place." (Darwin 1860: 102)

416 Gillian Beer highlights that Darwin begins the first Chapter on Variation with the words "When we look" (Darwin 1860: 7, 15, 74, 473, 486), inviting his readers to share the moment of observation. (Beer 2009: 59)

417 In a subsection on pigeons, Darwin gave an particularly impressive account of the breeds raised in a London Pigeon Club. (Darwin 1860: 21-2)

Hence, in his narrative, Darwin gave "some considerable emphasis to the language of progress and improvement, generating an onward and upward motion" (Beer 2009: xix) and this motion provides the Purpose for the Origin's narrative. Therefore, in Darwin's narrative, evolution is no accidental development but a directed, teleological, process towards the "the betterment of the individual and its species" (Beer 2008: xix). New species produced by Nature are

> „…far ‚truer' in character than man's productions; [… they are] infinitely better adapted to the most complex conditions of life, and … plainly bear the stamp of higher workmanship". (Darwin 1860: 84, cf. 108)

v. Synthesis

In sum, Darwin provides a compelling narrative which is centered around two strong metaphors: Natural Selection and the Struggle for Life. His principal Agent is Nature, but God and, to a lesser degree, female organisms figure as well. The first and third act through selection, God acts through his initial creation of the first organisms as well as through the laws of evolution. The Purpose of evolution is the betterment of species and it achieves a gradual but continuous improvement in organisms and their better adaption to the conditions of life and, thus, an improved chance of survival and reproduction.[418]

3.4.5 Implications: What did Darwin's explanation imply about the world?

Darwin is very much aware of the ontological implication of his narrative, how it relates to the world-views of his contemporaries. He chooses, however, not to discuss these possible ontological consequences in length and merely hints at them on the last pages of the Origin. There, Darwin addresses the origins of Life and God's role in it, clearly championing a deist image of the world:

> "It is interesting to contemplate an entangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately

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[418] While not tautological (Ruse 1971), one can argue that Darwin's narrative is circular: "The 'survival of the fittest' seems at first sight one of the few single-direction stories in evolutionary thought - but its tautological structure makes of it a satire on organicism. It is (with a vengeance) as Coleridge said narrative should be a serpent with its tail in its mouth. The survival of the fittest means simply the survival of those most fitted to survive; this implies not distinction, nor fullest development, but aptness to the current demands of their environment – and these demands may be for deviousness, blueness, aggression, passivity, long arms, or some other random quality. So chance reenters the potentially deterministic organization of evolutionary narrative." (Beer 2009: 109; cf. Young 1985: 98)
Logically, this circularity can be identified in the two adjectives Darwin employs to characterize Variations and Environmental Changes: injurious & favourable. (He does not introduce a term for irrelevant ones.) Darwin provides no empirical criterion by which to distinguish both independently from the Output to which they lead. Therefore, one cannot determine a priori which Variation is favourable and which is injurious. Any variation which fails to reproduce is termed 'injurious' – even if a second organism with a similar variation could reproduce and lead to a new variety.
Similar arguments can be made for the metaphorical 'chance' of surviving or dying as a supposedly statistical statement (Ruse 1971: 328-9): We do not know which organisms had a better chance until they have survived. as well as for Spencer's Survival of the Fittest which Darwin employed from 1869 on: "'The 'survival of the fittest' implies, tautologically, that those who survive are the 'fit', the 'superior' examples. Having survived proves them fit to survive; that other signification of 'fitness' as 'aptness', also crucial to Darwin's argument, is lost." (Beer 2008: xix)

> constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting [sic!] around us. These laws, taken in the largest sense, being Growth with Reproduction; Inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the external conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less-improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life [sic!], with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity [sic!][419], from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved." (Darwin 1860: 490)

With respect to Man's position in this world, Darwin is even more cautious, merely alluding to the possibility that Man may be of lowly descent in both his physical and mental features:

> „Analogy would lead me one step further, namely, to the belief that all animals and plants have descended from some one prototype. But analogy may be a deceitful guide. Nevertheless all living things have much in common, in their chemical composition, their germinal vesicles, their cellular structure, and their laws of growth and reproduction. […] Therefore I should infer from analogy that probably all the organic, beings which have ever lived on this earth have descended from some one primordial form, into which life was first breathed by the Creator." (Darwin 1860: 490)

> "In the distant future I see open fields for far more important researches. Psychology will be based on a new foundation, that of the necessary acquirement of each mental power and capacity by gradation. Light will be thrown [sic!] on the origin of man and his history." (Darwin 1860: 488-9)

Still, coming from a well-respected scientist, Darwin's feeble allusions would provoke impressive repercussions in Victorian Britain.

[419] Apparently, Darwin here compares the laws of evolution to those of gravitation, Newton's theory.

3.5 Synthesis: Common points & differences of the theories from Lamarck to Darwin

Let me synthesize the comparative analysis within the framework of my four-level model, thus highlighting differences and common features in specific elements of the respective theories. Furthermore, to account for those elements of the British debate which recapitulated the earlier French debate, I will also compare them to the works of Lamarck and Geoffroy – albeit in limited depth.[420]

My synthesis spans a period of 60 years approximately. In France, Lamarck published his *Philosophie Zoologique* in 1809, Cuvier denied evolution until his death in 1832, Geoffroy expressed his late evolutionary ideas in his 1835 *Etudes progressives d'un naturaliste*. In Britain, Chambers published in 1844 and 1845, Wallace in 1855 and 1858 and Darwin in 1859. Owen's early works on evolution appeared in 1848 and 1849, the latest work here considered in 1868, at the end of the Darwinian revolution. Thus, the first evolutionary theories in Britain trailed the continent by at least 35 years and Geoffroy, the latest of the Parisian theoreticians, still by ten years.

Darwin had begun his transmutation notebook in 1837, still two years after Geoffroy but Darwin had not read Geoffroy's late works, missing out on the evolutionary part.[421] Darwin's early sketch and essay stem from 1842 and 1844, shortly before the publication of Chambers' Vestiges. When Darwin finally published the *Origin of Species* in 1859, 24 years had passed since Geoffroy's *Etudes*. Thus, historically speaking, Geoffroy sits right between Lamarck and Owen; he published 26 years after Lamarck and 24 before Darwin.

During this period, empirical biology displayed unprecedented dynamics, exploiting new knowledge sources in paleontology and biogeography but also in morphology and comparative anatomy. Thus, although Darwin still doubted the empirical fundament of his theory, he knew immensely more than Geoffroy, not to speak of Lamarck. This advance in sheer knowledge accounts for much of the theoretical advances – but not for all. Let me specify along the lines of my model.

3.5.1 Level 1: Description

In my historical introduction to 19th biology, I identified three types of regularities in empirical biological knowledge: regularities on and between organisms, regularities in space and regularities in time. Table 12 specifies which sub-disciplines produced these regularities.

[420] As I did not dispose of the resources to carry out the same in-detail analysis of the French theories as of the English theories, this comparison will remain limited in depth and representativeness. Still, it should reveal some major aspects of the English theories which can already be found in the works of the French theoretical biologists, particularly Lamarck and Geoffroy.

[421] Geoffroy's *Etudes progressives* appear in Darwin's brown notebook on the list for books to read, but a full-text key-word search produces no direct reference to the book in Darwin's notebooks and manuscripts. (darwin-online.org.uk/manuscripts) This lack of reception may be due to Darwin's relatively weak French. (Grinnell 1985)

	Regularities on and between organisms	**Regularities in space**	**Regularities in time**
Shared knowledge from	Anatomy, Morphology, Osteology, Physiology, Histology	Biogeography	Ontogeny (incl. embryology), Paleontology

Table 12: Biological sub-disciplines and empirical regularities around 1840

What did Chambers, Owen, Wallace, and Darwin add to these regularities, respectively? For Chambers, the answer is very short. He presented neither a new type of regularities nor any new empirics at all. His 1845 *Vestiges* and its 1846 sequel *Explanations* contain some eclectic second-hand empirics, but no novel empirical regularities.

Owen presented plentiful of new empirics. He provided anatomical analyses of many “firsts”, for instance the Archaeopteryx, the gorilla or the chimpanzee. Moreover, he did specify ontogeny[422], particularly Geoffroy’s embryology, by analyzing series of embryological development. He did not restrain his analysis to single embryo specimen of a species but compared embryos in different stages of their development, in order to describe their ontogenic development and identify regularities of growth. Yet, Owen did not tap a completely new source of knowledge in the sense in which Buffon had integrated biogeography into biology or in which Cuvier had advanced paleontology.

Wallace and Darwin, first, provided a major novel empirical fact from their field work. Both acknowledged that organisms varied not only in space and in time but independently of space and time and, thus, independently of environmental changes.[423] In other words, organisms of the same taxonomic group differ in numerous features despite living at the same moment in the same place.[424]

This empirical finding related to all three types of empirical regularities above: (i) Darwin and Wallace pointed out that, even within the smallest taxonomic groups, organism do still differ. Thus, regularities on and between organisms were always incomplete; taxonomic groups always but partial descriptions.[425] Hence, Darwin and Wallace directed the interest of biologists on individuals and individual differences.[426] (ii) Moreover, these individual differences could be traced in space and time. One could distinguish sub-groups[427] and individual features and investigate which of those

[422] Ontogeny describes the development of an organism within its life-span, i.e. from embryo to adult.

[423] In comparison to Owen and Chambers it is interesting how little attention Darwin and Wallace pay to anatomy or embryology in their descriptions, and how much they focus on individual differences instead of common features. Both trends resonate in their models, which focus on the environment as a driving force of evolution and put the Struggle at the center of their explanation. This different view point fits well with how much time both Darwin and Wallace spend in the field and how little in the dissecting room.

[424] I do not know whether they were the first to notice this, although I do not suppose it. Still, Wallace and Darwin were the first to integrate this observation in a prominent place of their respective models.

[425] I do not assume that Linnaeus or other important taxonomists perceived their taxonomic features as fully determining individual exemplars of a type. However, this point is and was regularly forgotten by philosophical minds.

[426] However, already in Lamarck’s theory, individuals had taken center stage: The transforming development occurs on individuals and “races” are formed by all those individuals which are on the same level of development. (See section 2.3 vii)

[427] In the Darwinian debate, the reference point was species such that the sub-groups would be sub-species or varieties.

disappeared, persisted or multiplied over time. Or, one could study which individual differences and which sub-groups were found in which areas.[428]

Second, Darwin and Wallace pointed out the regularity they would summarize by the term 'struggle for life', namely that all organisms reproduced at a rate which would allow for exponential growth (Growth with Reproduction), yet, populations remained constant. This regularity, a priori, applied to all regularities in time and could be assumed as a background regularity.[429]

What neither Darwin[430] nor Wallace nor Owen succeeded in was identifying the regularities which governed inheritance. This feat would be achieved by the Austrian monk Gregor Mendel (1822-1884) and his re-discoverers, the botanists Hugo de Vries (1848-1935) of the Netherlands, Carl Correns (1864-1933) of Germany and the Erich Tschermak (1871-1962) of Austria.[431]

3.5.2 Level 2: Classification

While the late 18th and early 19th century was characterized by a spectacular widening of and an important increase in biological knowledge, it saw no radical revolution of established taxonomic classifications. The same is true for the mid-19th century and the Darwinian revolution. Classifications were enlarged and specified, minor aspects were modified; yet, their basic form remained constant throughout this highly dynamic period of biology. Thus, the important differences on this level are limited to two questions: (i) Which general principles and concepts are being introduced to organize the aggregations? (ii) With respect to which principles and concepts are aggregations being justified?

Chambers, again, provided no novel aggregating scheme of organisms. Instead, he cited the idealized "quinary system" which suggested a harmonic order in nature and presented taxonomic orders in a scheme of regular branches. Thus, he associated himself with a tradition which had dominated much of the 18th century: the pursuit of an ideal and regular *scala naturae*.[432] In 1840, however, it was already obvious to biologists that such schemes did not fit the taxonomic record; the regularities on and between organisms did not comply with any regular scheme.

In Lamarck's and Cuvier's writings, one still finds references to a scale (or échelle), yet neither presents the natural orders in an idealized, i.e. a perfectly regular, scheme.[433] Particularly Cuvier had dismissed any such suggestions as empirically inadequate, denying transgression between larger classes of animals, intermediate types or progression in the geological record.[434] In the later works of

[428] To give one example, foxes with larger ears are found in warmer climate, foxes with smaller ears in colder climate.

[429] Remember though that it was not tested together with evolutionary changes.

[430] Darwin addressed this point very explicitly; he emphasized that he could only speculate on inheritance. (See section 3.4.3)

[431] Mendel carried out his experiments mainly between 1856 and 1863 and published them from 1865 on, yet, his contemporaries did not draw the link from his work to the open slots in evolution theory. Only in 1900, de Vries, Correns and Tschermak independently carried out similar experiments as Mendel and rediscovered his work. In the modern synthesis of the 1930s and 1940s, genetics was then integrated with evolution theory.

[432] The fact that his scheme had branches may have been inspired by the works of Geoffroy and Lamarck. Yet, the latter did not present idealized schemes.

[433] For an explicit denial, see also (Lamarck 1873a [1809]: 27-8)

[434] Remember that, to Cuvier, there existed independent (unrelated) types in every geological period which had each been created independently.

Geoffroy[435], references to a "scale" are rare and there is no propagation of a harmonic, ideal order in nature. Thus, the French discourse already pointed towards the irregular branching schemes which Darwin and Wallace would present in 1858.

Owen temporarily reversed this trend. In his minute descriptive and classificatory work, Owen followed Cuvier and specified established classifications, hence accounting for the many observable differences between organisms. Consequently, he also emphasized the continuity throughout taxonomic groups. Owen established three kinds of homologies as classificatory categories and systematized classifications over large taxonomic groups, allowing for systematic large-scale comparisons and the systematic description of regularities between distant taxonomic classes.

In the interpretation (static modeling) of taxonomic relations, Owen continued Geoffroy's earlier pursuit of a 'unity of type' by novel means.[436] The archetype as a general, somewhat loose concept allows for many more irregularities and deviations than Geoffroy's initial concept. By thus allowing for deviations within the boundaries of basic archetypes Owen could cope with taxonomic irregularities for some more time. The problems of his static model would only be uncovered when the 1850s and 1860s produced more and more intermediate forms, forms which could be attributed to different archetypes; fossils like the Archaeopteryx (an intermediate of birds and reptiles) clearly did not fit comply with Owen's model, unless one altered basic taxonomic groups.[437]

Wallace and Darwin allowed for even more deviations than Owen and, on this point, were closer to Cuvier than to Geoffroy. In line with their empirical finding that organisms varied independently from space and time, they denied the importance of taxonomic classifications, degrading them to mere pragmatic tools. Both sketched the taxonomic order as resembling a branching tree. Yet, neither specified this point: Wallace, in his two short papers, merely evoked the metaphor. Darwin, in the *Origin*, did provide his famous drawing but did not specify how to map the known taxonomic groups onto such a tree; his drawing is entirely generic.

Moreover, neither Darwin nor Wallace provided a static model which could compare to Owen's archetype. One may argue that the concept of common descent is the equivalent of Owen's archetype insofar as it explains how the branches and twigs relate to the trunk of the branching tree and to each other. Yet, the concept of common descent is explanatory only before the specific background of Darwin's and Wallace's dynamic model; it requires an additional layer of theory. Contrarily, Owen's archetype was and could be directly embedded in the existing narrative of divine creation and required no further modeling to be explanatory. Thus, Owen's and even Chambers' static models are both, more specified and more sophisticated than those of Darwin and Wallace; the former authors put much more emphasis on static modeling than the latter.

Figure 22 provides an overview over the development from the late 18th century to Darwin, presenting simplified figures of a *scala naturae*, Chambers' branching scheme with "stirpes", Owen's irregular branching within the boundaries of the archetype and the irregular tree of Darwin and Wallace before the background of Owen's framework. As can be seen, Chamber's ideal branching

435 Geoffroy's pursuit of a "unity of type" in the 1820s can be read as the pursuit of an idealizing static model.

436 Remember that it was Owen's ambition to provide a synthesis of Cuvier's functionalism (conditions of existence) and Geoffroy structuralism (unity of type); the archetype can clearly be read as an attempt of specifying the notion of 'type'.

437 Particularly problematic were old intermediate forms for in Owen's scheme older forms should be closer to their own type, not to a neighboring one.

scheme already goes far beyond the idea of a *scala naturae* but remains idealizing in its regularity. Owen gives up the idea of harmonic classifications but upholds some idealism in the vertical lines which separate his archetypes. These are transgressed by the tree which depicts the static model of taxonomic relations of Darwin and Wallace.

In sum, the development from the Aristotle-inspired concept of an ideal *scala naturae* to the irregular tree of Wallace and Darwin seems like one of continued disillusionment and pragmatization. The more empirical knowledge biology acquired, the less the image of a harmonic and orderly scheme could be upheld. Lamarck had already given up such ambitions, Cuvier had flat-out denied their legitimacy. Chambers clung to an idealized scheme which, at the time of its publication, had no more empirical basis. Geoffroy in his in unity of type and Owen in his archetype postulated some partial continuity but did not attempt or – in Geoffroy's case – succeed in developing this continuity into a sophisticated static model. Owen's work may be understood as a late attempt to salvage some elements of the broken *scala naturae*. Thus, his appears as the last attempt to make sense of the geological and biogeographical record based on a static model alone (embedded in a divine narrative).

Wallace and Darwin had no more such ambitions; they suggested a pragmatic scheme by which taxonomic relations could be represented. Furthermore, by highlighting how much arbitrary choices were involved in classificatory work, they called into question the very ambition of identifying a scheme of harmonic organizing principles in nature. Conversely, their interpretation of taxonomic relations as resembling a tree does not hold up to Owen's archetype in either technical sophistication or interpretative prowess. Rather, it depends on their dynamic model to bestow plausibility on this static model: the concept of common descent requires the dynamic model of Natural Selection in order to provide a compelling interpretation of the taxonomic record. Thus, Darwin and Wallace reallocated theoretical resources from the project of biological interpretation to dynamic modeling, the next level of my framework.[438]

[438] Remember that this intricate link shows also in their ambiguous use of the term 'variation'. To Darwin and Wallace, it denotes, first, an object, an organism which has diverged from its type: a variety. Second, it denotes the event in which such a variety occurs. Consciously or unconsciously, Wallace and Darwin identify both with another, thus blurring the distinction between the interpretation of analytic regularities on object features (level 2) and the explanation of synthetic regularities between object features or events (level 3).

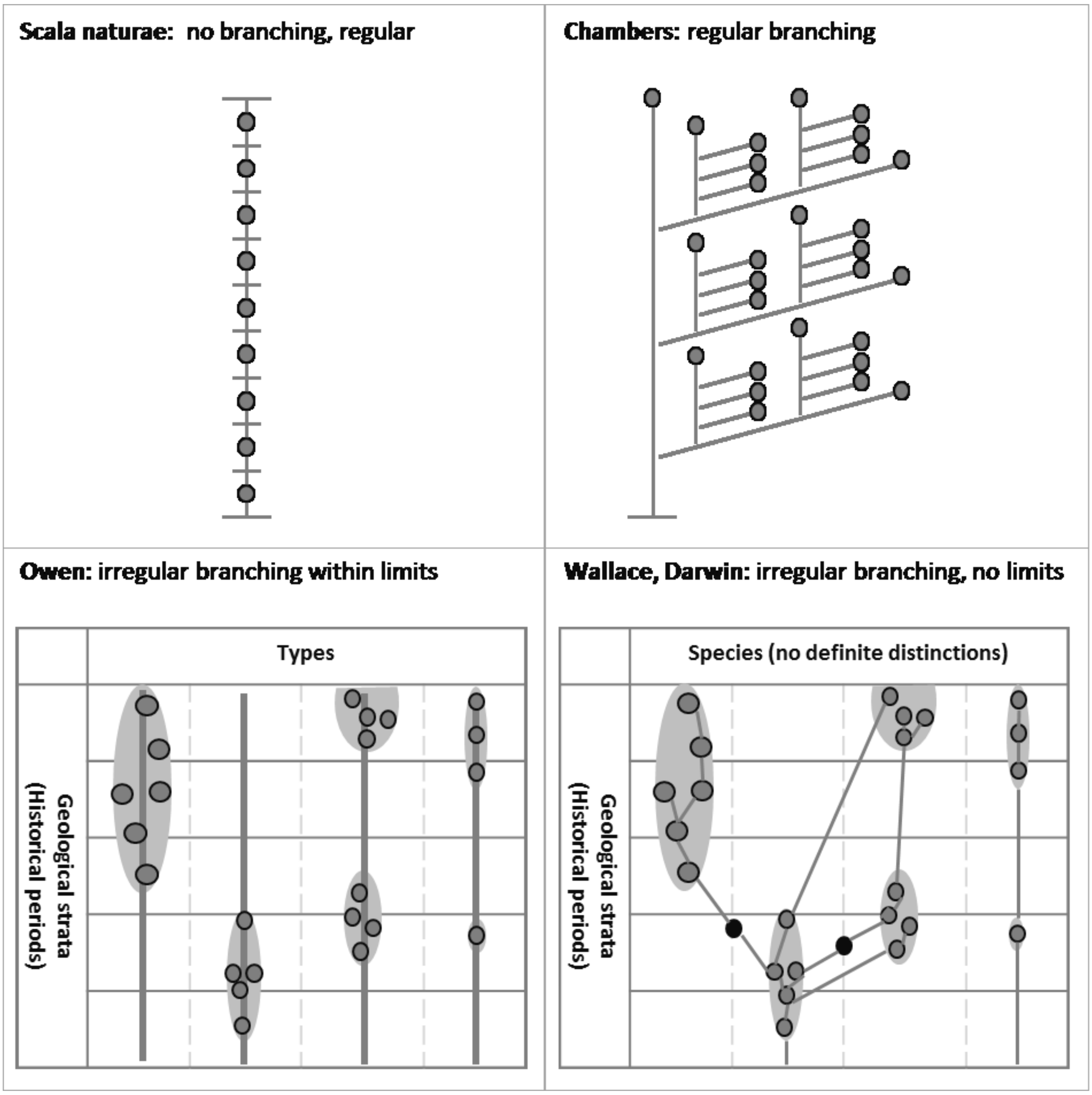

Figure 22: Static models of taxonomic relations from the scala naturae to Darwin and Wallace[439]

[439] The dots represent groups of fossils, individual fossils oliving forms on a timescale – except for the scala naturae. Recent organisms are found towards the top of the schemes; older ones towards to bottom. The lines in the Darwin-Wallace-tree represent genetic relations, the black dots intermediate forms (missing links) which were predicted by Darwin and did not comply with Owen's model. The dotted lines in the tables represent the limits of Owen's types as they were exceeded by the tree of Wallace and Darwin. The bold lines in the center of each column in Owen represent the types from which individual organisms or groups of organisms may diverge. – This is a standardized presentation which has been modified in order to allow for easier comparison. The number of species separated in a *scala naturae* is not representative of any actual scheme. Chambers does not specify how many lines and sub-lines ("stirpes") he would distinguish; thus the representation is generic. The presentation from Owen is borrowed from his representation of the mammalian class (Darwin 1860: 407) but is not supposed to represent mammalian types. Darwin provides a generic figure in the *Origin* which I have simplified and modified in order to match the simplified representation of Owen. Note however, that Darwin did never identify intermediate types in the mammalian class. Wallace provides no drawing of his evolutionary "tree" or "capillary system".

3.5.3 Level 3: Explanation – Dynamic Modeling

For Cuvier, evolution did not occur. All others presented dynamic models of evolution or at least parts of such models. Figure 23, Figure 24 and Figure 25 display the models of Lamarck, Geoffroy, Chambers, Owen, Wallace and Darwin within my framework of dynamic models, distinguishing Situation Type, Object Class, Input, Connector and Output. Let me specify the important differences and common elements between these models in order to grasp how models of evolution changed between 1809 (Lamarck) and 1859 (Darwin).

i. *Object Class: species, varieties – and individuals?*

With respect to the Object Class, the major difference is whether the models applied to features of individual objects, notably individual variations. This is the case for Lamarck, Geoffroy, Wallace and Darwin but not for Chambers and Owen. Thus, in the models of Chambers and Owen, evolution could not be triggered by individual variations.

ii. *Situation Type: catastrophes vs. uniform change, spontaneous generation vs. struggle*

Except for Chambers, who wavered on the topic, all theoreticians supported uniform changes in geology and, with them, in biology. The commitment to the uniformitarianism of Lyell and Hutton implied the interpretation of geological strata as displaying continuous and gradual changes and it provided the time-scale for dynamic models of evolution: life evolved in equally gradual and small steps as the physical conditions of life. (See section 2.3 vi)

	Geological background: uniform or catastrophic?	**Biological background: Where does the supply for evolution come from?**
Lamarck (1809)	Uniform changes	Continued spontaneous generation
Geoffroy (1835)	Uniform changes	Continued spontaneous generation
Chambers 1845/6)	Uniform changes since the last catastrophe	Continued spontaneous generation
Owen (1848-68)	Uniform changes	Continued spontaneous generation
Wallace (1855/58)	Uniform changes	Growth with Reproduction (overproduction) (as implied by the Struggle for Life)
Darwin (1859)	Uniform changes	Growth with Reproduction (overproduction) (as implied by the Struggle for Life)

Table 13: Geology and the supply for evolution in the explanations from Lamarck to Darwin

A relevant difference existed with respect to the biological background of evolution: where did the organisms come from which evolved over time? Lamarck, Geoffroy, Chambers and Owen lend their models plausibility by referring to spontaneous generation (nomogeny), claiming that new organisms were continuously created from dead matter and would then, successively and over many generations, evolve into higher forms.[440] (See section 0) Darwin and Wallace, instead, denoted their Situation Type by the famous 'Struggle for Life'[441] which implied Growth with Reproduction (overproduction) as a source for evolutionary material. (see below) This constitutes an important difference in evolutionary narratives (see below) but also in modeling. The term 'spontaneous generation' denoted effects in experimental biology, for instance the appearance of bacteria on heated chicken broth. (See section 0) 'Struggle for Life', however, denoted a regularity of two observations in the field, namely the Growth with Reproduction (overproduction) and the overall constancy of populations. (See sections 3.3.3i; 3.4.3 ii)[442] Table 13 provides an overview over the elements of the Situation Type.

iii. Output: step-wise or continuous evolution, regular or irregular branching

Everybody, Lamarck and Geoffroy, Chambers and Owen, Wallace and Darwin did put their classifications on a timeline and interpreted the geological (paleontological) record such that less complex organisms had been followed by more complex ones. All accepted extinction – except Lamarck (1809) who lacked the paleontological knowledge of it. [443]

However, even among those who integrated both the emergence of new species and extinctions in their Output, the understanding of their Output differed. Explanations differed with the different interpretations of the paleontological record. (See above) Moreover, Darwin was the only one to include polymorphic species in his model, describing an early form of genetic drift.

iv. Input: more and more diverse triggers of evolution

It was an established empirical regularity that organisms differed with climatic zones. Thus, it is not surprising to find climatic change in the Input of all six models. Owen goes a step further by including isolation or the end of isolation (for instance the immigration of enemies) as a second variant of ecological change. Wallace and Darwin add variations of neighboring organisms as a third variant, thus introducing complementing macro-ecological changes as climate and isolation by a micro-

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440 Remember that this debate had occupied biology since the 17th century. Pasteur carried out experiments to counter the claim as late as 1859. In the second half of the 19th century, after Pasteur's experiments and the Darwinian revolution, the idea would lose most of its supporters and fade eventually.

441 Owen spoke of 'struggle' and a 'contest' as well but did not specify what these terms denoted beyond the Input to his model, namely climate change and isolation. (See section 3.2.3 iii) Thus, I do not consider this a Situation Type. With respect to the Scene, these metaphors are discussed below.

442 Remember, however, the logical role of the Situation Type with respect to the modeled empirical regularities (Input-Output-regularities): the Situation Types serves for denoting sets of Input-Output-regularities but is not part of these regularities; it is not observed together with the underlying empirical regularities but independently. The electric field in Millikan's example fulfills the same function (as the homo oeconomics in the Rational Choice explanation with respect to the Object Class). For a discussion of this point, see sections 2.1.3 and 6.

443 One could argue that the inclusion or exclusion of the origin of life is another important difference, that, figuratively speaking, Wallace and Darwin explained only moves on their evolutionary tree, while the earlier theoreticians also debated discussed how the tree trunk formed. (cf. Perrier 2009 [1884]: 198)

ecological dimension. Furthermore, they introduced a fully novel Input for evolution: individual variations.[444]

v. Connector: manifold choices

	Connector (Conditional predicate)	**Input-Output-Relations (Conditional statements)**		
		Input	**Op.**	**Output**
Lamarck (1809)	Use & disuse	Ecological Change	→	Emergence of new species
Geoffroy (1835)	Modified respiration	Ecological Change	→	Emergence of new species
	No modified respiration	Ecological Change	→	Extinction of species
Chambers 1845/6)	Development	Ecological Change	→	Emergence of new species
	"Exhaustion of prolific energy"	?	→	Extinction of species
Owen (1848-68)	"laws of development"	?	→	Emergence of new species
	Disuse?	Ecological Change	→	Extinction of species
Wallace (1859)	Preservation	Favourable Individual Variation or favourable Ecological Change	→	Emergence of new species
	Perishing	Injurious Individual Variation or injurious Ecological Change	→	Extinction of species
Darwin (1859)	Preservation	Favourable Individual Variation or favourable Ecological Change	→	Emergence of new species
	Elimination	Injurious Individual Variation or injurious Ecological Change	→	Extinction of species

Table 14: Connectors and Input-Output-relations from Lamarck to Darwin

Even when the same phenomena were modeled as Inputs to the model, they might have been related to different Outputs. Thus, for Geoffroy, Wallace and Darwin, ecological change triggers both the emergence of new species and their extinction, for Lamarck and Chambers only the emergence. For Owen, ecological change could only lead to the extinction of species, not to their emergence. Chambers provides no Input which would lead to extinctions, Owen none for the emergence of new species. Having introduced a novel Input with individual variations, Darwin and Wallace could also introduce it in a novel way in their models. They linked it to both extinctions and the emergence of new species. Moreover, Wallace & Darwin do not distinguish the Input by types of Input, e.g. ecological change versus individual variations, but by a tautological classification, namely the

[444] While one finds deep and thorough reflections on "laws of development" (Owen) or a "unity of type" (Geoffroy) with previous biologists, none of them developed these insights into a trigger of long-term large-scale change in classes of organisms, i.e. a trigger of evolution.

distinction of favourable and injurious ecological changes or variations. Table 14 provides an overview of the different Connectors employed in the models from Lamarck to Darwin. (Not all of these differences are visible in Figure 23, Figure 24 and Figure 25.)

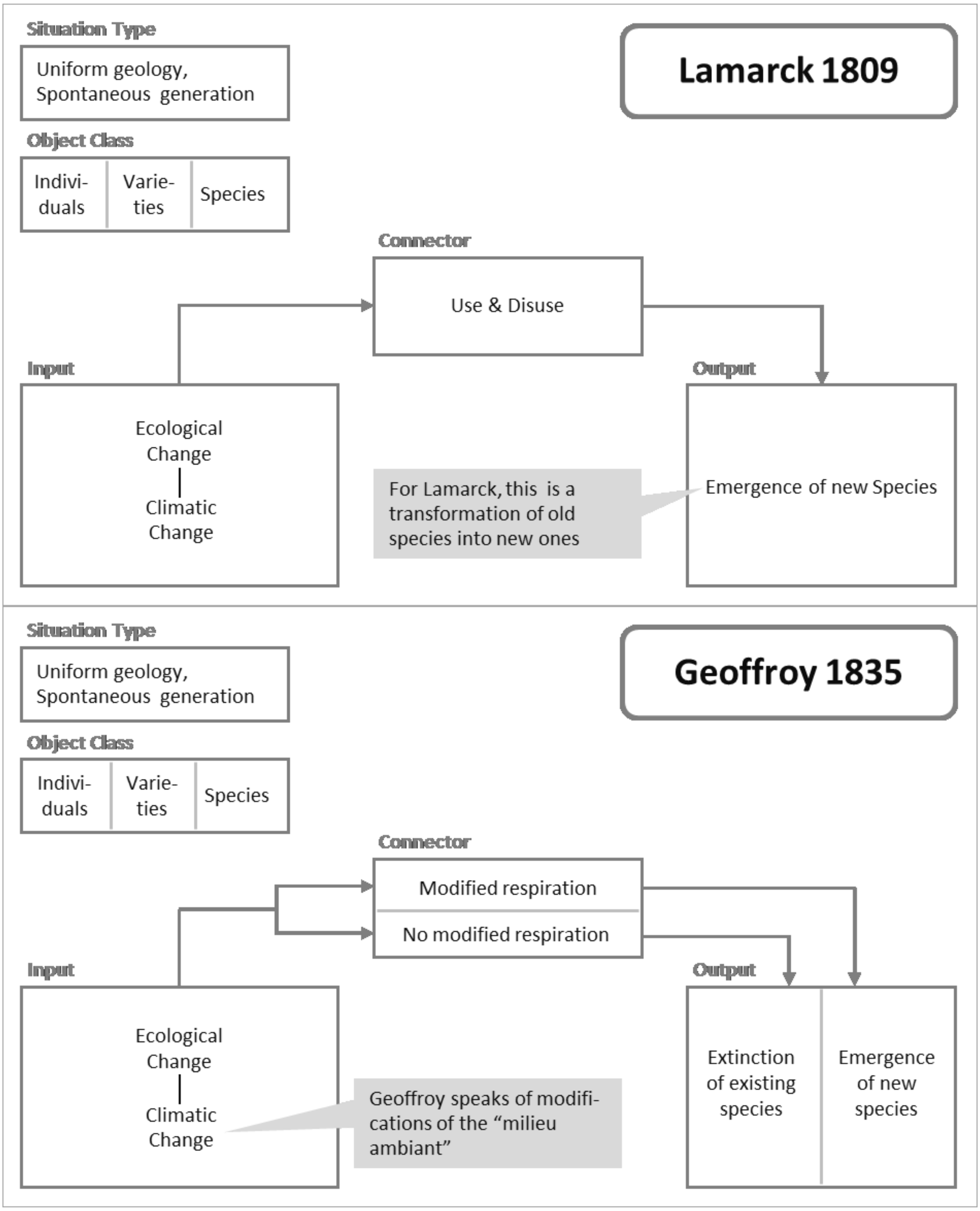

Figure 23: Lamarck's and Geoffroy's dynamic models

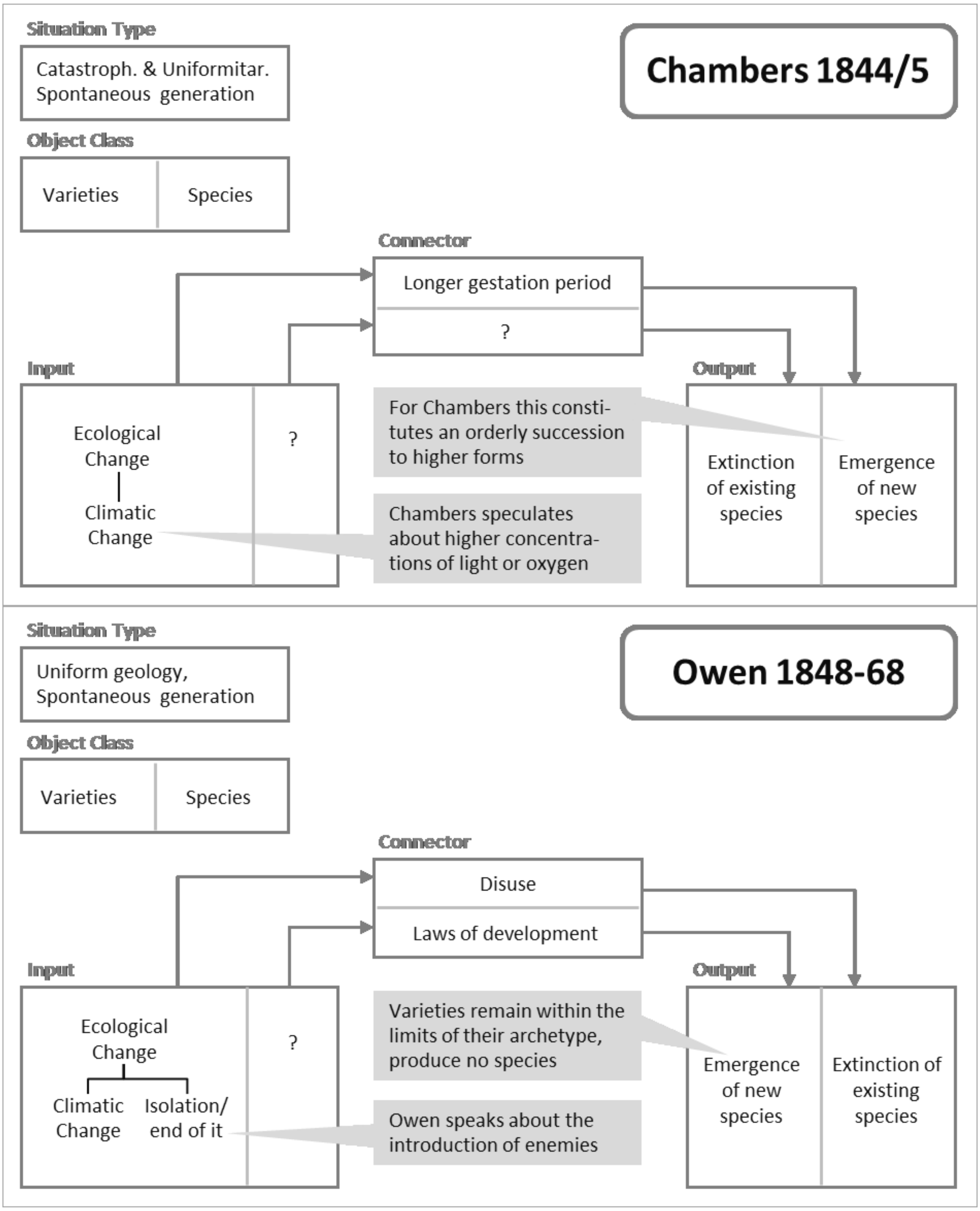

Figure 24: Chamber's and Owen's dynamic models

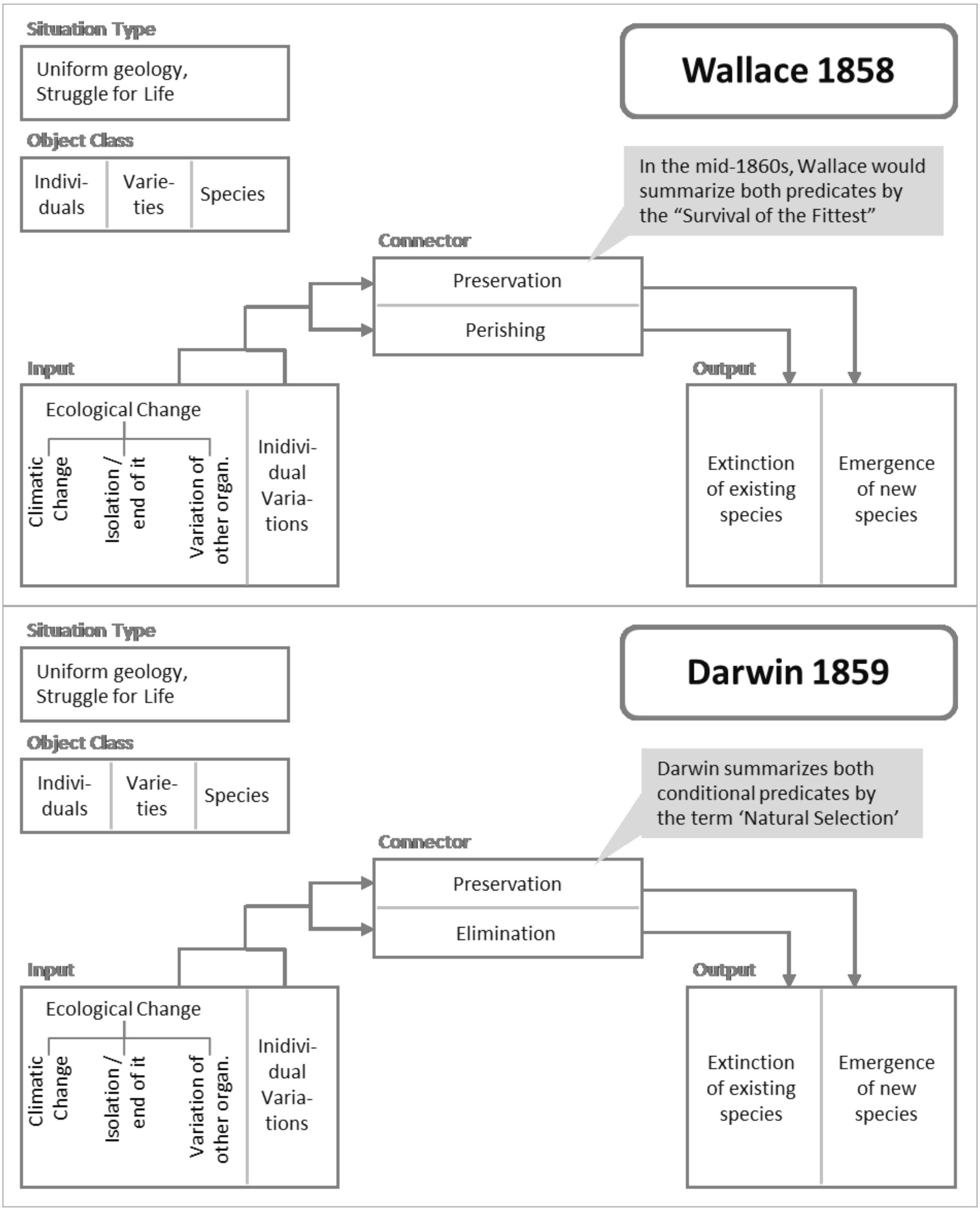

Figure 25: Wallace's and Darwin's dynamic models

vi. Summary

Overall, my comparative analysis reveals a general closeness of the dynamic models from Lamarck to Darwin; they appear as continuous steps in a development of models of evolution. The progress of empirical knowledge posed new challenges to modelers and ultimately led to increasingly complex models, i.e. models with more distinctions. This is best visible in the increasing specification of Input and Output in this series of models. (The figures on the following pages visualize this successive increase in complexity.)

Within this series, three innovations catch my eye: First, Geoffroy was the first to include extinctions in his model. Second, by taking focusing on individual variations, Wallace and Darwin significantly increased the Input of models of evolution. Third, they broke with the tradition of spontaneous generation-speculation and introduced a new and empirically observable back-ground observation as their Situation Type: Growth with Reproduction (overproduction) and the overall constancy of species, i.e. the Struggle for Life.

3.5.4 Level 3: Explanation – Narration

As I have pointed out in my analysis and the historical introduction, not all authors specified a complete narrative of evolution, notably not Cuvier and Wallace. The former denied evolution and never attempted to explain it, although he clearly championed a traditional theist narrative about the origins of life which applied after each of his catastrophes (revolutions). The latter provided only elements of a narrative, notably a Scene, the struggle for life, and a possible Purpose, the betterment or improvement of species. Thus, in terms of narratives, I will only compare the works of Chambers, Owen and Darwin to those of Lamarck and Geoffroy.

i. Agent, Purpose, Agency: Who acted how and what for?

In all important narratives of 19th century biology, God took an important role. Thus, the question was not whether God was an Agent in these narratives but whether other Agents were introduced next to God and how much autonomy these Agents were granted in terms of Purpose and Agency.

Chambers and Owen were the most traditional and less imaginative in this respect. On their accounts, there is only God, he pursues his will and acts through laws, i.e. secondary causes.[445] Owen does not specify these causes.[446] Chambers explicitly denied personification of nature. (Chambers 1845 [1844]: ix) Owen employed such personifications a few times, but never developed Nature into an Agent next to God; in his later writings, he even denied its validity as an explanatory device. (cf. Owen 2007 [1849]: 68; Owen 1868: 371, 794-795)

Lamarck concurs with Owen in the latter point: Nature is no valid Agent.[447] (Lamarck 1873b [1809]: 349) Instead, he centers his Narrative on the organisms themselves. In reaction to environmental changes, organisms use certain organs more and less frequently. Such use and disuse ultimately

[445] Remember that God was considered the First Cause and all other Agents as subordinate.

[446] As I did discuss it in the previous section, Owen introduces terms which might serve as Connectors but fails to specify the Input which such a Connector could transform into the Output.

[447] Lamarck explicitly states that the term ‘Nature’ denotes but observable objects and events : "La Nature, ce mot si souvent prononcé comme s'il s'agissait d'un être particulier, ne doit être à nos yeux que l’ensemble d’objets qui comprend : 1° tous les corps physiques qui existent; 2° les lois générales et particulières qui régissent les changements d'état et de situation que ces corps peuvent éprouver; 3° enfin, le mouvement diversement répandu parmi eux , perpétuellement entretenu ou renaissant dans sa source, infiniment varié dans ses produits et d'où résulte l'ordre admirable de choses que cet ensemble nous présente." (Lamarck 1873b [1809]: 349)

leads to evolutionary changes.[448] As for God, he is (hardly ever mentioned in *Philosophie Zoologique*; one may surely read the environmental changes as divine actions and, thus, see God as a background agent, but no more than that.

Both Geoffroy and Darwin, assign a major role to Nature in their narratives and mention it significantly more often than God.[449] However, it is only Darwin who ascribes both a clear Purpose and a clear Agency to Nature: selection for the betterment of species. (QUELLE) Geoffroy, while frequently personifying Nature, seems not develop a coherent terminology of what Nature wants or does. Thus, I cannot identify a coherent Purpose in his texts. As Geoffroy considers environmental changes to trigger evolution, these can obviously be ascribed to the Agency of Nature. With Darwin, they may either be ascribed to Nature or God.

Moreover, Darwin attributes a minor role to the organisms, namely the females. In sexual selection they select the "most vigorous, best adapted males" as mates. (Darwin 1860: 127) While this part of Darwin's narrative is less prominent than the Natural Selection part, it is equivalent to Lamarck's in that it ascribes agency to members of the Object Class, not to a third Agent. Remarkably, Darwin ascribes it to the females, not the males.

Table 15 provides an overview over Agents, Purposes and Agencies in the different narratives.

	Agents by degree of direct impact	**Purpose**	**Agency**
Lamarck (1809)	Organisms	Satisfaction of needs ("besoins")	Use and disuse
	God	God's Will	Changes in environment
Geoffroy (1835)	Nature	*Not sufficiently specified*	*Not sufficiently specified*
	God	God's Will	Changes in environment
Chambers 1845/6)	God	God's Will	Laws (secondary causes)
Owen (1848-68)	God	God's Will	Laws (secondary causes)
Darwin (1859)	Nature	Betterment of species	Selection
	God	God's Will	Origin of Life
	Female organisms	Breed with best adapted male	Sexual Selection

Table 15: Agents, Purpose and Agency in the narratives from Lamarck to Darwin

448 Remember that this was Lamarck's narrative: "Le produit des circonstances comme causes qui amènent de nouveaux besoins, celui des besoins, qui fait naître les actions, celui des actions répétées qui crée les habitudes et les penchants, les résultats de l'emploi augmenté ou diminué de tel ou tel organe, les moyens dont la nature se sert pour conserver et perfectionner tout ce qui a été acquis dans l'organisation, etc., sont des objets de la plus grande importance pour la philosophie rationnelle." (Lamarck 1873a [1809]: 28)

449 (Geoffroy Saint-Hilaire 1835) mentions Nature as an Agent throughout his text; just look for Nature with a capital N. God (Dieu, Seigneur) appears less often but in prominent places as conclusions or introductions.

ii. Act: What happened?

With respect to the Act there exist three major differences between the narratives. First, Lamarck did not speak of extinctions; at the time of his writing extinctions were not an established scientific fact yet. All later authors include it in their narratives, though often in a less prominent place than is granted to the emergence of species. Thus, neither Owen nor Chambers integrate extinction in the narrative which explains evolution. Second, Owen and Chambers had the most openly teleological view of evolution. On both accounts evolution clearly is a mindful, prearranged process which is triggered by laws of development not by ecological change. For Lamarck, Geoffroy and Darwin evolution is triggered by ecological changes to which they ascribe no Purpose.

Third, Owen and Chambers attributed both the origin of life and the origin of species to the same Agent and Agency: God produced both through laws. While both Geoffroy and Lamarck ascribed spontaneous generation to God, evolution (the origin of species) was attributed to another Agent. Darwin postulated not "lawful" spontaneous generation but a miraculous initial creation of life by God.[450] The origin of species, however, he attributed to Nature and, partly, the organisms. Table 16 displays these differences.

	Agent which produces Act	**Act**
Lamarck (1809)	God	Origin of Life
	Organisms	Development of more complex forms
Geoffroy (1835)	God	Origin of Life
	Not sufficiently specified	Development of more complex forms or extinction
Chambers 1845/6)	God	Origin of Life, Development of higher organisms
Owen (1848-68)	God	Origin of Life, Development of higher organisms or extinction
Darwin (1859)	God	Origin of Life
	Nature	Improvement relative to competitors environment or extinction

Table 16: Agent and Act in the narratives from Lamarck to Darwin

450 This is harshly criticized by Owen who complains that evolutionists postulated "primary life by miracle". (Owen 1868: 814) Cosans concurs in his statement that Darwin "no more explains how and why life came to be than Owen explains how and why all life follows the laws of morphological form." (Cosans 2009: 103) – On a side note, this decision resembles much the distinction which cosmologists draw between the Big Bang and the physical phenomena since. The beginning of the universe is considered a miracle but all subsequent phenomena are subject to physical modeling.

iii. Scene: Where did it happen?

With respect to the Scene, Darwin's narrative is definitely the most developed – to a degree where virtually outshines the differences in sophistication between the other narratives. Owen refers to a "struggle against surrounding agencies" but attributes it to extinction only, which is not the principal Act of his narrative. Beyond, his Scene is simply a well-ordered world in which God acts in omnipotence. For Chambers, this is true with respect to his entire narrative. With Lamarck and Geoffroy, the Scene appears little specified; it is neither entirely well-ordered nor a chaotic struggle. Table 17 presents these differences.

	Scene
Lamarck (1809)	Changing world to which organisms have to adapt in order to survive
Geoffroy (1835)	Changing world to which organisms have to adapt in order to survive
Chambers 1845/6)	Well-ordered changing world
Owen (1848-68)	Well-ordered changing world & Struggle against surrounding agencies
Darwin (1859)	Struggle for Life

Table 17: Scene in the narratives from Lamarck to Darwin

iv. Summary

The comparison of the narratives reveals a number of interesting points. First, as I emphasized it in the introduction of my model, narratives around God are much less sophisticated than those in which God is not the central Agent. In them, the answers to the questions for Purpose, Scene and Agency are all more or less answered by reference to God: he is an omnipotent and omnipresent Agent who pursues his will. Such a narrative is a passe-partout, it can explain any event or any object's features – such appears to be the explanatory power of the expression 'god'. Consequently, Chambers and Owen, who employ this narrative, tell no novel or exciting stories about evolution. In Jerome Bruner's words, their story is not driven by Trouble. (Bruner 2002: 34; cf. 2.1.4 iii)

As soon as one opts for another agent than God, matters become more difficult and more interesting. A non-divine agent needs to possess the means (Agency) to produce the Act and he needs to display a Purpose which relates to the Act. Consequently, these narrative aspects are much more developed in the works of Lamarck and Darwin, to a lesser degree in Geoffroy's.

Lamarck does this very thoroughly with respect to the organisms, constructing them as humanoid beings with needs (besoins) and goals. While this is a complete and innovative narrative, it did not succeed in convincing the scientists or the public. (See section iii) Geoffroy and Darwin, on the other hand, both refer to Nature as an agent, a popular and old personification in which recognizes Gillian Beer recognizes "the idea of natura naturans, or the Great Mother". (Beer 2009: 7) While Geoffroy does not develop this metaphor very far, Darwin provides a clear Purpose for Nature, the betterment of species, and – in the stroke of a genius – creates the analogy to the artificial selection of breeders. His Nature is not merely the Great Mother, it is the Great Breeder. Darwin's second great narrative innovation is the struggle for life. It is the most developed of any Scene, a very graphic and intuitive idea.[451] It seems to that it also fills some of the void left by God because the Struggle explains why a selection of organisms is necessary.[452]

Not coincidentally, the innovative narratives are found in the theories with developed dynamic models. Dynamic models describe regular, mechanistic processes in nature, no direct divine interventions. In order to connect to explanatory narratives, an autonomous Agent is required and with it, at least a compelling Purpose and an Agency which bestows plausibility on this Agent. The Agency is closely linked to the Connector of the dynamic model. If neither observed objects (Lamarck) nor God (Chambers, Owen) are Agents themselves, variations or environmental changes (the Input) cannot satisfy the Agency; only the Connector can.

Lamarck fills both voids, the Connector and the Agency with the use and disuse of the organisms. Darwin, contrarily, opts twice for selection and attributes it to his Agent: Nature. Both succeed in explaining evolution by a full-fledged dynamic model and a complementary full-fledged narrative. With Geoffroy, however, the Connector in his model does not fit with the Agents he specified in his narrative. His Connector is a change in respiration, something he can attribute neither to Nature nor God.[453] Thus, his narrative displays a glaring lack of Purpose and fails to tell a compelling story about evolution.

3.5.5 Level 4: Ontological implications

The narratives of Lamarck, Geoffroy, Chambers, Owen and Darwin conveyed different ontological implications. First, they portray God differently. Although moving beyond the theism of Cuvier or Paley, Owen and Chambers championed the most conservative views, portraying God as the sole and immediate Agent in nature – despite his acting through laws. Lamarck, Geoffroy and Darwin, in their mechanistic explanations, introduced supplementary Agents and shifted God more to the background. They opposed a rather distant God to the immediate version of Owen and Chambers. (See Table 18)

Deistic world views		**Theistic world-view**
God in the background, acting through secondary Agents	**God as an immediate Agent, acting through laws**	**God as an immediate Agent, continuously intervening**
Lamarck Geoffroy Darwin	Owen Chambers	Cuvier Paley

Table 18: Distant God vs. intervening God from Lamarck to Darwin

Second, Darwin and Lamarck threatened Man's position in Nature for they did not set him apart from animals in absolute terms. Chambers and Owen acknowledged Man's anatomical kinship to the higher apes but claimed a special position for him due to his mental and moral faculties. (Geoffroy

451 For a discussion of its origin, see section 5.1 vi.

452 The Growth with Reproduction, secondary in Darwin's narrative, can be seen as replacing the spontaneous generation, which is equally secondary in the narratives of Chambers, Lamarck and Geoffroy.

453 One could certainly argue that God brought this change in respiration about but this a rather indirect way of telling a story and Geoffroy, as far as I see, does not develop this point.

seems not to clearly address these points.) Only Chambers and Owen stress a privileged relationship of Man to God.

Third, the position of Man clearly touched the problem of slavery, or – more generally – the question how British gentleman related to "uncivilized" people and to their closest animal relatives, the apes. Is there a hierarchy of human races and/or a smooth transition to the higher apes? Darwin avoided these topics but both Owen and Chambers addressed them.

Fourth, some of the narratives seemingly threatened established social orders by portraying nature as irregular and only loosely connected to God's will. Elements of instability and purposelessness were strong in Lamarck's, Geoffroy's and Darwin's narratives. Chambers and Owen attempt to portray nature as well-ordered and emphasize God's role despite his acting through laws.

Table 19 specifies Man's position in nature and possible social and political implications.

	Man's position in nature and towards God	Elements of instability and lack of purpose (teleology)
Lamarck (1809)	Most complex part of nature, but no absolute top	Irregular branching, God in the background
Geoffroy (1835)	Unknown / Not clearly specified	Irregular branching, God in the background
Chambers 1845/6)	Anatomically a descendant of animals, but apart due to his mental and moral abilities & Special relationship to God	God in the background
Owen (1848-68)	Anatomically a descendant of animals, but apart due to his mental and moral abilities & Special relationship to God	God in the background
Darwin (1859)	Descendant of animals, no class of his own	Irregular branching, God in the background

Table 19: Man's position in nature, social and political implications from Lamarck to Darwin

In sum, each of the analyzed theories had possible implications which were controversial in 19th century Britain. Therefore, in the 1840s, Lamarck and Geoffroy were condemned for their open deism. Chambers, in his anonymous *Vestiges*, broke the first layer of ice separating the British discourse from the continent and challenged firmly established theist views in the public and scientific discourse. Owen followed his trail in the late 1840s but retreated when he faced resistance and pressure from his Oxbridge friends. In the 1860s he would return to his cautious deist positions of the 1840s. Darwin, however, championed a narrative with implications like those discussed in France, Germany or elsewhere on the continent. Thus, Darwin went significantly beyond Chambers and Owen and, in retrospect, made the controversies of the 1840s look timid and provisional. However, Chambers and Owen clearly paved some of Darwin's way, by overcoming Paley's natural theology.

3.5.6 Synthesis

In a synthesis of this synthesis, a most abstract view on my theory comparison, I find it interesting to see what aspects of my model are developed and which receive little attention. While all of these authors – Lamarck, Geoffroy, Chambers, Owen, Wallace and Darwin – provided theoretical accounts of evolution in 19th century biology, their manner of theorizing differs greatly.

On level 1, differences are minimal. Only Chambers fails to explicitly link his theory to established and challenging empirical regularities, remaining on the theoretical surface instead. On level 2 the five scientific authors address taxonomic implications, Chambers hardly does. Owen and Chambers both present sophisticated static models (interpretations) of taxonomic relations and grant an important role in theories to these static models. Neither Lamarck and Geoffroy (in his later works) nor Wallace and Darwin follow this example. On level 3, the sophisticated dynamic models are found in the texts of Lamarck, Geoffroy, Wallace and Darwin, not with Owen and Chambers. Narratives are most developed in the works of Lamarck, Chambers, Owen and Darwin, much less in Geoffroy's and hardly at all in Wallace's. There is an important difference however, between Owen and Chambers on one hand versus Lamarck and Darwin on the other: To the former, explanation is the interpretation of a static model in a religious narrative, to the latter it is embedding a dynamic model in a stand-alone narrative, with only minor religious elements. The ontological implications of level 4 are explicitly addressed by Chambers, Darwin and Owen but not by Wallace. (For Lamarck and Geoffroy, my knowledge of the French context is too limited to assess this priority.) Figure 26 displays these different priorities in a simple scheme. A light shade signals a limited priority, a darker shade a high priority, a question mark my inability to assess it.

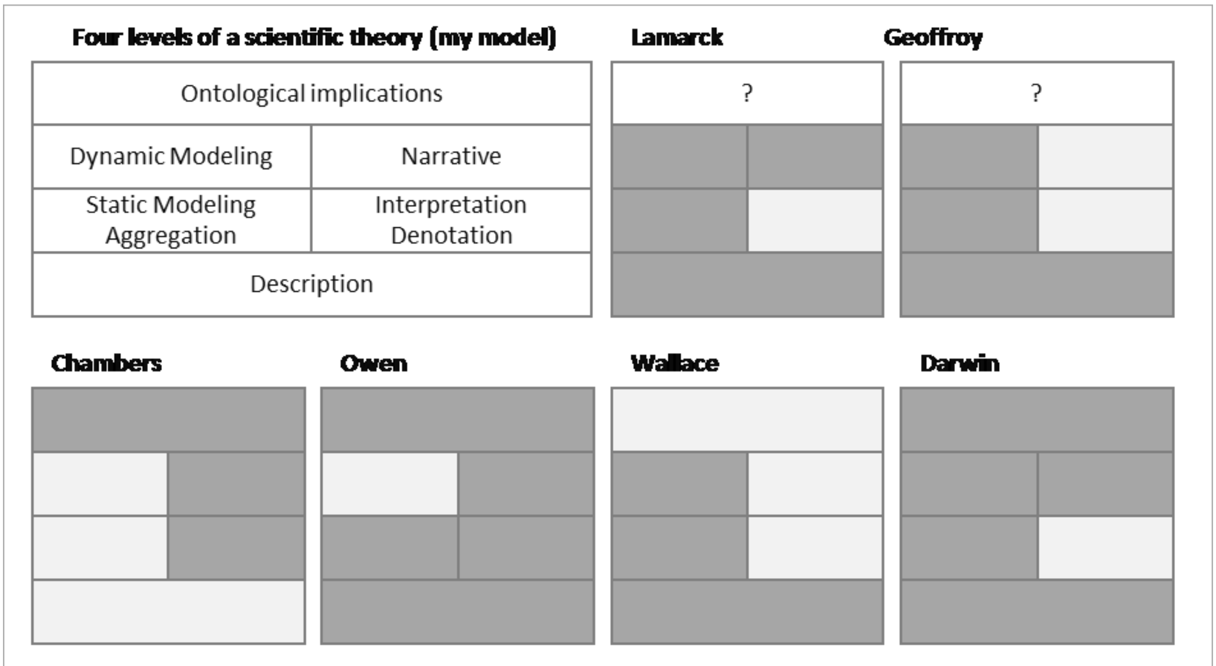

Figure 26: Argumentative emphasis on different elements of the theories from Lamarck to Darwin

4 Reception analysis: The revolution which Darwin achieved with his British recipients

4.1 Reception by the public

4.1.1 To what depth did recipients receive the theory?

The reception among the general public was very superficial; it consisted of short reviews and some polemic discussions in general journals and newspapers. Overall, the uneducated public or those lacking specific interest were hardly exposed to the intense discussion of Darwin's theory. While the Origin

> "was indeed a big sale for a scientific book … it naturally did not reach the broad public … The book was indeed a sensation, but … a literary and scientific sensation, not a popular one." (Ellegård 1958: 41; cf. Himmelfarb 1959: 209)

Actually, if one speaks of successful scientific publications of the 19th century, the Origin can only be "categorized as being at the lower end of the extraordinarily successful best-seller group." (Lightman 2007: 34) *Vestiges*, for that matter, sold twice as many copies in the first ten years as the *Origin* fifteen years later.[454] In most general publications, the debate was ignored or mentioned in passing only, for it seemed to be of little interest outside scientific or philosophical circles.[455] (Ellegård 1958: 41)

The little reception which Darwin's book received by the general public was due to its implications either for the common man's religious convictions or for the biblical account of the descent of Man (Ellegård 1958: 27, 42; cf. Beer 2008: ix). Evolution, whatever it exactly implied, definitely contradicted a literal understanding of the bible:

> "Christian or heathen, most people, and above all the uneducated paid much more attention to the theory's contradiction of the plain statements of the Scriptures. The ordinary religious man hardly accepted the existence of any other religion than the revealed religion of the Bible. Abstruse philosophical arguments on final causes and supernatural interpositions meant little to him: the Bible meant the more." (Ellegård 1958: 155)

With regard to the descent of Man, to "the uneducated majority the question was simply whether man was descended from Adam or from the apes: and most of them seem hardly to have believed that the second alternative could be seriously entertained." (Ellegård 1958: 332) Thus, in the public theory was referred to as the 'ape theory' (Ellegård 1958: 43, 295) for it was only this possible

[454] However, Darwin's Origin would eventually bypass *Vestiges.*

[455] In later years, lending libraries provided copies of the *Origin*. (Ellegård 1958: 27) Besides, Darwin pressed his editor, Murray, to produce the later editions more cheaply, so a larger public could afford the book.

implication for their Weltanschauung which the general public cared for.[456] Political or social implications of the theory were not discussed. (Beer 2008: ix; Ellegård 1958: 325)

Interest and information were significantly higher among the educated classes. Some might have read the *Origin* and many “knew of the book through reviews and notices in the better-class periodicals” (Ellegård 1958: 42) like Charles Dickens’ literary *All the Year Round*, the *Athenaeum*, *Chamber’s Journal*, the *Examiner*, or *MacMillan’s Magazine* among others. Most of the authors were journalists, only a minority of these reviews was written by scientists. Such journalistic reviews, however, hardly penetrated the heart of Darwin’s theory[457]; instead, most of them focused on the ontological implication of Darwin’s theory, i.e. its most abstract level.

Thus, the *Examiner*, *All The Year Round* and the *Guardian* all emphasized the controversial character of the *Origin* in the first couple of paragraphs of their reviews – even if they considered Darwin’s a respectable scientific theory:

> “This is a remarkable book, sure to make a mighty stir among philosophers, perhaps even among the theologians […] The doctrine [Darwin] adopts is, in fact, a revival of the old one of the transmutation of species; but he illustrates it with an amount of knowledge and ingenious appliances never before brought to its support. We are ourselves by no means convinced by his reasoning, nor do we think that it overthrows the existing theory of philosophers, founded on the evidences of geological discoveries, that the inorganic world, as we see it, is the result of a succession of creations and destructions. There will, however, we have no doubt, be many converts to Mr Darwin’s opinions, which for the perfect integrity with which they are stated are well entitled to the most respectful consideration.” (Anonymous [Crawford J.?] 1859: 772)

> “we have come upon more tolerant times, if a man can calmly support his heresy by reasons, the heresy will be listened to; and, in the end, will be either received or refuted, or simply neglected and forgotten. Mr. Darwin also enjoys the benefit of the bygone heresies of previous heretics; one heresy prepares the way for, and weakens the shock occasioned by, another. Astronomical and geological innovations render possible the acceptance of doctrines that would have made people’s hair stand on end three centuries ago.” (Anonymous 1860a: 293)

> “Is it too much to say that, in the good old times, opinions like these [Darwin’s] would have been strongly redolent of fagot and flame?” (Anonymous 1860a: 294)

> “There are forms of speculation so wild and improbable, or, at any rate, so alien to our ordinary habits of thought, that they can only obtain a fair consideration under the protection of some illustrious name. If an anonymous author [sic!], or one only known as an amateur in natural science, were to propound the startling theory, that

[456] Ellegård reports that “Punch, a faithful mirror or ordinary middle-class culture, did not take up the matter of Darwinism until November 10, 1860, and then only in passing.” (Ellegård 1958: 42) However, in 1861, it “made the gorilla and its relationship to man one of the chief features” of the year, even giving an echo of the debate on the hippocampus minor. (Ellegård 1958: 43, 50)

[457] Popular papers by Asa Gray (Gray 1888b [1860]; Gray 1860a; Gray 1888c [1874]; Gray 1888d [1874]) display similar characteristics in the American debate.

> all the various tribes of living creatures which people earth, air, and water with an infinite diversity of form and habit, are descended from some four or five progenitors, whose progeny have, by small successive degrees of difference in the lapse of ages, developed into the manifold divergence of the countless species now in existence, a busy man would be justified in turning from the unread volume with a smile of incredulity. But the case is widely different when this theory is put forward by Mr. Darwin, a man confessedly in the foremost ranks of natural philosophy, a Fellow of the Royal, Geological, and Linnæan Societies, honoured among his scientific peers …, and already favourably known to the outer world by his celebrated Journal of the Beagle. A new theory by such a man, however strange it may appear, deserves respectful attention…" (Anonymous [W.R. Church?] 1860: 134)

Even Thomas Henry Huxley, in his favorable reviews, underlined the revolutionary potential of the Darwinian theory. In his review for the *Times*, he admitted that

> "… from time to time we are startled and perplexed by theories which have no parallel in the contracted moral world; for the generalizations of science sweep on in ever widening circles, and more aspiring flights, through a limitless creation. […]We must expect new conceptions of the nature and relations of its denizens, as science acquires the materials for fresh generalizations; nor have we occasion for alarm if a highly advanced knowledge, like that of the eminent Naturalist before us [Darwin], confronts us with an hypothesis as vast as it is novel." (Huxley 1859a: 8)

In *Fraser's Magazine*, the mathematician William Hopkins lamented the "great extravagance" of Darwin's theory. (Hopkins 1860: 741)

In this dimension, the Origin was frequently linked to Chambers' 1844 *Vestiges of the Natural History of Creation*. The *Saturday Review*, for instance, reminded his readers of how not many years earlier, Vestiges had "profoundly disturbed" the educated British by its tendency "to dispense with the agency of an intelligent Creator in the work of Creation". (Anonymous 1859: 775) The writer claimed that

> "the conclusions announced by Mr. Darwin [in the Origin of Species] are such as, if established, would cause a complete revolution in the fundamental doctrines of natural history—and further, that although his theory is essentially distinct from the development theory of the Vestiges of Creation, it tends so far in the same direction as to trench upon the territory of established religious belief" (Anonymous 1859: 775; cf. Jardine 1860: 280-1)

Living Age characterized the Origin as endeavoring to establish,

> "though by a different theory and a somewhat different process of reasoning, the same conclusion which was arrived at by the French naturalist, Lamarck, and by the English author of the 'Vestiges of Creation'; — namely, that all the species, genera, orders, and classes of animal and vegetable life are essentially of one blood and lineage, having been developed out of one another, without the intervention anywhere of any act of creative power; — developed by the slow but progressive accumulation, through what is practically an infinite lapse of ages, of differences and

> variations which were at first, and for a long period of time, so slight as to be wholly imperceptible." (Anonymous 1860b: 474)

The public attention focused on three types of ontological implications which threatened three major elements of the Victorian world views, namely (i) Divine Providence, (ii) the Argument from Design and (iii) the position of Man.

i. Ontological Implications: Divine Providence

Arguably the most fundamental of these elements was the religious idea of Divine Providence, i.e.

> "the conviction that the world was placed under the watchful guidance of a higher power ... Without Divine supervision, one held, everything would disintegrate into chaos, for only chaos could result if the universe were left to the action of chance and blind, inexorable laws. Design and Purpose, the attributes of a Mind, were needed to create and sustain a Kosmos." (Ellegård 1958: 102)

Admittedly, one might interpret Darwin's model such that God had established the law of Natural Selection. Yet, the text of the Origin did not present God[458] as taking any direct action throughout the course of Evolution. (Hull 1973: 65; Ellegård 1958: 131) To many religious people this "made God appear too remote, His Providence too impersonal" and this was inacceptable to the educated Victorian public. (Ellegård 1958: 128; cf. Hull 1973: 56, 65; Argyll 1872 [1867]: 50-54)

Thus, the *Athenaeum* regretted that Darwin had forwarded a theory which stood in such obvious conflict with established British theism:

> "Theologians will say – and they have a right to be heard – Why construct another elaborate theory to exclude Deity from renewed acts of creation? Why not at once admit that new species were introduced by the Creative Energy of the Omnipotent? Why not accept direct interference, rather than evolutions of law, and needlessly indirect or remote action?" (Anonymous [J.R. Leifchild?] 1859: 659-60)

ii. Ontological Implications: The Argument from Design

Similar reserves hold for the second religious conviction which Darwin's model threatened to make obsolete: the argument from Design. In this argument, one inferred from the order and harmony of nature the existence of a benevolent God. It was argued that if the human mind was able to conceive the natural order and the laws of nature as purposeful then they bore witness to God's purpose. (Ellegård 1958: 114-5, 125) Therefore, if proponents of Design were supposed to accept Evolution at all, they had to conceive it as a purposeful process. Thus, the educated public, were expecting some sort of predetermined evolution, merging the transmutation of species with a Divine plan. (Ellegård 1958: 136, cf. 267-79)

Darwin's explanation of Evolution, however, threatened the alleged harmony and purposefulness of nature because it claimed that organisms were in a constant Struggle for Life in which only a fraction of them could survive long enough to reproduce. He called Variations accidental, hence, purposeless.

[458] In the first and second edition God hardly appeared in the *Origin*. In later editions, however, Darwin raised his profile and assigned him an increasing role.

He refused to assign the organisms any active and conscious role in the process of Evolution (except for the females regarding sexual selection). His Connector, Natural Selection, was supposed to be a blind law, void of any purpose. Finally, the result of the processes, Evolution was not to be understood as an absolute improvement but a relative adaption to random living conditions.

Such a narrative offended a substantial part of the Victorians, for instance the geologist Adam Sedgwick who, in his review in the *Spectator*, upheld his convictions against a perceived Darwinian relativism:

> "…I can see in all around me a design and purpose, and a mutual adaptation of parts which I can comprehend,– and which prove that there is exterior to, and above, the mere phenomena of Nature a great prescient and designing cause. Believing this, I have no difficulty in the repetition of new species during successive epochs in the history of the earth." (Sedgwick 1973 [1860]: 161)

Living Age strikes the same tone when, in a lengthy passage, it regretted how

> "Mr. Darwin openly and almost scornfully repudiates the whole doctrine of Final Causes. He finds no indication of design or purpose anywhere in the animate or organic world. Like Geoffroy St. Hilaire, he takes good care 'not to attribute any intention to the Almighty.' The nicest and most complex adaptations do not to him prove design. The eye was not made to see with, or the ear to hear. The fact that these organs respectively do see and hear is accounted for, on this theory, by supposing that, through an accidental and purposeless variation, some one zoöphyte or other animal very low down in the scale happened to be born with a faint glimmering of vision,— with the poor rudiment of an eye, — 'an optic nerve merely coated with pigment, and without any other mechanism'; that this 'slight accidental variation' passed down by inheritance, giving to the possessors of it a great advantage over their fellows…
> Still further: the order and symmetry which prevail throughout animated nature; the correspondence of the organic with the inorganic world; the prevalence of a few general forms of structure amid a countless number of beings, like everywhere answering to like, and an exact balance of co-operating agents being always preserved, — all the facts which have appeared to most minds so significant of unity of plan, and thereby declarative of the unity of the Creator, — all these seem to Mr. Darwin to be merely the inevitable and unforeseen results of the blind working of nature's laws." (Anonymous 1860b: 475-6)

iii. Ontological Implications: The Position of Man

The third big ontological topic was the application of Darwin's model to Man. Particular interest was raised by the debates with obvious implications for the Victorian conception of Man. (Hodge 1988: 9-10) Although Darwin had only cautiously alluded to the topic in the *Origin* (see section 3.4.5), the public debate quickly focused on Man's place in Nature, particularly his relation to "the brutes". The educated public went beyond the superficial comparisons between apes and humans, yet, critics "maintained that Darwin was denying man's uniqueness and special creation in his own image by the Great Designer." (Fishman 1997: 103) The gap between man and ape[459]

> "was held to be too big to be bridged. All races of men were clearly men, and all the various ape species were as clearly apes. There were no intermediate forms, no graduated series where each step should not appear greater than a varietal modification." (Ellegård 1958: 299)

Most of the papers immediately grasped the implications of Darwinian speculation for Man. Some tried to see this perspective as promising, like the Athenaeum:

> "Lady Constance Rawleigh, in Disraeli's brilliant tale, inclines to a belief that man descends from the monkeys. This pleasant idea, hinted in the 'Vestiges,' is wrought into something like a creed by Mr. Darwin. Man, in his view, was born yesterday - he will perish to-morrow. In place of being immortal, we are only temporary, and, as it were, incidental." (Anonymous [J.R. Leifchild?] 1859: 659-60)

> "Yes, an unbroken, sure, though slow, living progress towards animal perfectibility is a delightful vision; natural and gradual optimism is a welcome fancy. What need of distinct creation? If a monkey has become a man - what may not a man become?" (Anonymous [J.R. Leifchild?] 1859: 659-60)

Yet, most educated Victorians felt offended by the perspective; considering the brute creation a close relation, invoked revulsion and horror among the public. (Ellegård 1958: 297) The Victorians chose to ignore their supposed relation with the apes and considered their own history, so to speak, a descent from noble savages to civilized nobles. (Desmond and Moore 1995: 653-4) The *Examiner* exemplifies this tension quite well:

> "The theory supposes an unlimited progress towards improvement. By it we may hope that the race to which we ourselves belong may in the course of some millions of years become angels or demigods. This is, no doubt, consolatory, and yet it is somewhat marred by the mortifying reflection that proud man may have been once an ape, a bat, or a mere monad—nay, that even Isaac Newton may have had the very same progenitor as a drum-head cabbage. Millions of years hence … the best of us may be looked upon as no better than clever apes, which is the character in which the poet supposes "superior beings" to have admired Newton when he appeared among them. The theory, indeed, is a scientific metempsychosis, not only more ingenious but far more consolatory than that of Hindus and Buddhists, for it is all hopeful progress without any counterbalance of melancholy retrogression, or still worse, of annihilation." (Anonymous [Crawford J.?] 1859: 772-3)

Living Age was still more explicit:

> "Mr. Darwin boldly traces out the genealogy of man, and affirms that the monkey is his brother, and the horse his cousin, and the oyster his remote ancestor. The human

[459] Remember how most of Darwin's contemporaries did not see the question in the light of Darwin's concept of common descent. Thus, they were asking whether an ape could have transformed into a human, not whether both might have had a common (and possible extinct) ancestor. (see 3.2.3 i, Figure 14)

> body, in his view, is only a slowly developed zoöphyte, out of which it has grown by a process as natural and uniform as that by which a calf becomes a cow; and, by a parallel advancement, the human mind has become what it is out of a developed instinct." (Anonymous 1860b: 474-5)

and the *Saturday Review*'s comment highlights how very noticeable[460] Darwin's cautious allusions on the last pages of the Origin had after all been:

> "Except in a single brief and somewhat obscure paragraph, Mr. Darwin has avoided all reference to the origin of the human race; but in his future work he can scarcely fail to be explicit upon that point." (Anonymous 1859: 775-6)

Between 1859 and 1875, the descent of Man would remain the most visible topic within the educated public. The now-famous exchange between 'Darwin's bulldog' Thomas Henry Huxley and the Bishop Wilberforce at the 1860 meeting at the British association was not covered by the press[461] but in 1861, explorer and discoverer Paul Belloni du Chaillu returned from Africa and presented the first gorillas bodies to the British public. He toured England with his collection and published a popular book on his *Explorations and Adventures in Equatorial Africa*, enjoying remarkable popular success. (Lightman 2007: 2; Desmond and Moore 1995: 577-8)

The colorful Du Chaillu provided graphic tales of humanoid emotions in gorillas (Desmond and Moore 1995: 577), yet, coached by on anatomical details no one less than Richard Owen, he was "at pains to emphasize the differences between the beast and man." (Ellegård 1958: 299) One of these anatomical details led to the famous clashes between Owen and Huxley at the British Association's meetings in 1861 and 1862. Owen advanced Du Chaillu's accounts and specimen against the Darwinians and claimed that certain elements of the human brain could not be found in apes, notably the so-called *hippocampus minor.*

The public never followed these debates in any detail because the relationship of Man with the Ape quickly became, in the words of the 1863 Guardian, "buried beneath abstruse anatomical details". (op. cit. Ellegård 1958: 74) However, the continued debate between the established and powerful Owen on one side and the young and rising Huxley received some coverage as a struggle between two eminent scientists. Incidentally, their debate inspired Charles Kingsley to his "hippopotamus major" in the children's novel *Water Babies*. (Lightman 2007: 2)

Moreover, the obscure topic became linked to one of the burning political questions of the day: "the place of the negro". (Ellegård 1958: 74; Hodge 1988: 9-16) The American Civil War had been sparked by the slavery question and it raged during these very years of Darwinian controversy. Now, the

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460 Gillian Beer explains this in the following manner: "However much Darwin may have represented to himself and his correspondents the absence of man from the text as a matter of diplomatic restraint, the exclusion had an immediate polemical effect: it removed man from the centre of attention. An act of will by the reader was required to restore him to his centrality. This transaction in itself problematised the centrality of man to the natural order. The absence of any reference to man as the crowning achievement of the natural and supernatural order made the text subversive: it was – as at some level it must have been known to be – deeply disquieting." (Beer 2009: 54)

461 As Alvar Ellegård dryly remarks with respect to the famous encounter: "If the Oxford meeting of the British Association in 1860 was an historical event, the press missed a great opportunity. […] the Oxford meeting was exceptionally meagerly reported: in the *Times* hardly at all. (Ellegård 1958: 67) Its supposedly crucial role in the Darwinian revolution is a later construction.

British public began to debate where the Negroes belonged in their view of the world: Where they humans? Then how were the seemingly irreversible inequalities of the races to be explained? Where did the seemingly innate superiority of the Caucasians stem from? (Kenny 2007)[462] Racial commentators suggested differentiating between human races claiming

> "that at least European man's progenitors had never led a savage life. Savages [like Africans ancestors of the American blacks], on the other hand, had not received the Divine gift of civilization… In this manner the distinction between the civilized Europeans and the uncivilized races could still be upheld as divinely ordained, while the unity of the human species was retained." (Ellegård 1958: 311, cf. 301-2, 71, 74-5; cf. Desmond and Moore 2009)

Huxley clearly enunciated[463] these questions in his review for the *Times*:

> "…we are in the habit of regarding mankind as of one species, but a fortnight's steam will land us in a country where divines and savans, for once in agreement, vie with one another in loudness of assertion, if not in cogency of proof, that men are of different species; and, more particularly that the species Negro is so distinct from our own that the Ten Commandments have actually no reference to him." (Huxley 1859a: 8)

iv. Explanation: Much narration & little modeling

When Darwin's explanation via Natural Selection was addressed, it was presented as a mere story, i.e. only in its connotative component. To the educated public, the mention of the term 'natural selection' and the discussion of its possible explanatory power for the descent of Man definitely did not imply knowledge of Darwin's model. Instead, few of the educated and interested laymen knew it at all:

> "Writers in the non-scientific press seldom made any clear distinction between Evolution pure and simple, and the peculiarly Darwinian doctrine of Natural Selection. Darwinism and Development were more or less synonymous to the general reader. But when the two concepts were distinguished, it was generally in order to point out that most experts did not go as far as Darwin, especially as regards Natural Selection." (Ellegård 1958: 58, cf. 334)

In reviews, the situation is somewhat better; only the philosopher George Henry Lewes, in the Cornhill Magazine, mentions neither of the Darwinian key concepts, avoiding both the struggle and natural selection. (Lewes 1860) Yet, hardly any review addressed the logical component of Darwin's explanation, his dynamic model. The 1860 "Popular Exposition of Mr. Darwin's On the Origin of Species" by the economist and statesman Henry Fawcett from *MacMillan's Magazine* is a case in point. It mentions 'Natural Selection' only twice and in passing, provides a very brief and superficial exposition of Darwin's explanation of evolution. (Fawcett 1860) The *Athenaeum* provides a literary exposition of Darwin's explanation instead of a logical explication – all the while mentioning the key

[462] See (Kenny 2007) for an examination of the debate in ethnological and anthropological circles.

[463] I do not find any clear statements from Huxley on the question of slavery; he seemed not to have linked his anatomical arguments to the ongoing debate, at least not in his writings.

concept names in Darwin's dynamic model: Variation, Struggle for Life and employing Darwin's category shift from artificial selection to metaphorically (connotatively) introduce Natural Selection. (Anonymous [J.R. Leifchild?] 1859: 659-60)

Robert Chambers cited long passages of the Origin, thus probably giving the most prudent and most faithful summary of Darwin's thoughts, however, he does provide no further analysis, particularly no logical one. (Chambers 1859) The cases of *All the Year Round* and the *Examiner* are similar. (Anonymous 1860a; Anonymous [Crawford J.?] 1859)

Joseph Dalton Hooker's review in the *Gardener Chronicle* is an interesting case: He addresses an audience with practical knowledge on gardening but without scientific training or knowledge of the contemporary models and theories. Therefore, he refers to their experience when introducing the problem – the experience of an artificial selector. In his presentation of the Darwinian model, however, he remains in the literary sphere, providing a story for an explanation. Notably, his mention of the Struggle for Life is merely metaphorical. (Hooker 1859)

The *Saturday Review* provided this account of Darwin's theory:

> "Mr. Darwin's theory may be stated in a few words. All organic beings are liable to vary in some degree, and tend to transmit such variations to their offspring. All at the same time [they] tend to increase at a very rapid rate, and their increase is kept in check by the incessant competition of other individuals of the same species, or that of individuals of other species, or by physical conditions injurious to each organism or to its power of leaving healthy offspring. Whatever variation occurring among the individuals of any species of animals or plants is in any way advantageous in the struggle for existence will give to those individuals an advantage over their fellows, which will be inherited by their offspring until the modified variety supplants the parent species. This process, which is termed natural selection, is incessantly at work, and all organized beings are undergoing its operation. By the steady accumulation, during long ages of time, of slight differences, each in some way beneficial to the individual, arise the various modifications of structure by which the countless forms of animal and vegetable life are distinguished from each other." (Anonymous 1859: 775-6)

In *Fraser's Magazine*, the mathematician William Hopkins also introduced the concept of Natural Selection via Darwin's category shift and summed up Darwin's theory like this:

> "The principle on which Mr. Darwin's reasoning rests is that of Natural selection. An immensely greater number of animals must be born than can possibly live to what may be regarded as the natural term of their lives. A 'struggle for existence' (to use our author's phrase) must therefore necessarily ensue; and in this struggle the stronger will vanquish the weaker, and live to transmit their species to future generations. Thus nature is supposed to 'select' the best variety of any existing species, however it may have arisen, for the propagation of the race, as a breeder of domestic animals selects the best of those he may be cultivating, to breed from ; and as he dooms to more immediate slaughter the inferior portion of his flocks and herds, and thus year by year improves his stock, so nature abandons to early destruction and final extermination those inferior portions of any race of animals

> which are least able to protect themselves in the 'struggle for existence,' and thus improves the general character of succeeding generations, to which every improvement is supposed to be transmitted by descent." (Hopkins 1860: 751)

Sedgwick provided a short summary of what he considered the Origin's main hypotheses in the beginning of his article and devotes two sentences to Darwin's dynamic model:

> "The organic ascent is secured by a Malthusian principle through nature,-by a battle of life, in which the best in organization (the best varieties of plants and animals) encroach upon and drive off the less perfect. This is called the theory of natural selection." (Sedgwick 1973 [1860]: 159)

An exception to the rule is the *Times* review, which was authored by the anatomist, zoologist and great popularizer Thomas Henry Huxley.[464] Huxley's review begins with an abstract introduction of the challenges which Darwin's model was supposed to address: the concept of species, the geographical distribution of living animals and the rudimentary organs. It briefly refers to previous theoretical explanations by Lamarck and Chambers, and in the end, introduces Darwin's explanation of Evolution. The interplay of Struggle for Existence, Accidental Variations and Natural Selection is illustrated in a generic story about three varieties A, B and C and their hypothetical development in the Struggle for Life. This story is the closest thing to a logical analysis which I find in the public reviews:

> "Suppose that in the midst of this incessant competition some individuals of a species (A) present accidental variations which happen to fit them a little better than their fellows for the struggle in which they are engaged, then the chances are in favour,

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464 Huxley's role as one of the first professional scientist to popularize scientific findings and theories on a large scale. (cf. Schwartz 1999) Huxley's also explicitly addressed the working class in his famous public lectures on the Darwinian Theory in the early 1860s. In his *Lectures to Working Men*, he explained the "Knowledge of the Causes of the Phenomena of Organic Nature" in popular fashion and from the Darwinian point of view, covering the important components of Darwin's model like the Struggle for Existence, Variation and Natural Selection and estimating the merits of its explanation. (chapters 4-6) Man's place in Nature, the topic of Huxley's forthcoming monograph, was hinted at only. (Huxley 1893c [1863]: 473) While remarkably detailed and complex, these lectures do not qualify as a scientific treatment of Darwin's model but as an early example of popularized science: First, he presents evidence in illustration of his accounts but it appears highly idealized. For instance, he explains the morphology of a horse by likening its jaw to a mill its heart to a force-pump etc. (Huxley 1893c [1863]: 310-3) Second, Huxley covers only the upmost level of the model, hardly specifying its complexity. Second and instead, his explication of the model his mostly narrative; Huxley elucidates aspects through little stories and presents the whole model as a major story about the phenomena of organic nature and how they came about.

To give an overview of the topics covered: In lecture 1, Huxley provided a basic understanding of morphology, the problem of the geographical distribution and morphological relations among organisms. He mentions the idea of a unity of plan. In Lecture 2, he discusses geography and geology, the geological record, fossils, extinct organisms and relations of extinct organisms to living ones. In lecture 3, he speaks of scientific methods and their application to the vital phenomena (the living), of induction, deduction and hypotheses and how the Darwinian theory does not cover the origin of life. In lecture 4, he covered heredity and reproduction, variation and possible causes of variation as well as artificial selection and its effects. In lecture 5, he presents the exponential reproduction of unchecked organisms, the Struggle for Existence, natural selection and indirect proofs for it. In his 6th and final lecture, he discusses the merits of Darwin's model vs. explanations based on creationism and design, hybridism and sterility as theoretical problems for Darwin. Finally, he touches lightly on Man's position in Nature, addressing Man's moral and mental qualities and asking the rhetorical question, what it is that constitutes and makes man what he is. (Huxley 1893c [1863]: 473)

> not only of these individuals being better nourished than the others, but of their predominating over their fellows in other ways, and of having a better chance of leaving offspring, which will of course tend to reproduce the peculiarities of their parents. Their offspring will, by a parity of reasoning, tend to predominate over their contemporaries, and there being (suppose) no room for more than one species such as A, the weaker variety will eventually be destroyed by the new destructive influence which is thrown into the scale, and the stronger will take its place. Sur rounding conditions remaining unchanged, the new variety (which we may call B)—supposed, for argument's sake, to be the best adapted for these conditions which can be got out of the original stock—will remain unchanged, all accidental deviations from the type becoming at once extinguished, as less fit for their post than B itself. The tendency of B to persist will grow with its persistence through successive generations, and it will acquire all the characters of a new species. But, on the other hand, if the conditions of life change in any degree, however slight, B may no longer be that form which is best adapted to withstand their destructive, and profit by their sustaining, influence; in which case if it should give rise to a more competent variety (C), this will take its place and become a new species; and thus, by natural selection, the species B and C will be successively derived from A." (Huxley 1859a: 8-9)

Even Huxley's simultaneous review for *MacMillan's Magazine* was much more metaphorical and is founded on the analogy between artificial and natural selection:

> "The peculiar feature of the latter is, in fact, that it professes to tell us what in nature takes the place of the breeder; what it is that favours the development of one variety into which a species may run, and checks that of another; and, finally, shows how this natural selection, as it is termed, may be the physical cause of the production of species by modification." (Huxley 1859b: 147)

In later contributions to the debate, information on Darwin's model did not improve. Rather, reviews considered the Darwinian explanation as well-known and provided even shorter representations or discussed only isolated aspects. A case in point is the successful 1867 monograph *The Reign of Law* from the Duke of Argyll, a noble British politician without scientific experience or expertise. The book provided an extensive discussion of theological and philosophical issues as miracles or Divine Purpose, Divine Will and Divine Mind (Argyll 1872 [1867]:1-125) and argued for explaining natural phenomena from the reign of Divine law. His representation of Darwin's model, however, is only indirect and works mainly through evoking the main metaphors of Darwin's narrative. (Argyll 1872 [1867]: 219-267)

Thus, Darwin's explanation penetrated the public discourse mainly through the strong connotations of its metaphors. It became to shift the meaning of words like development, transformation or inheritance and the catchy 'Struggle for Life' quickly reached the "phraseology of everyday conversation".[465] (Ellegård 1958: 43, cf. Beer 2009: 13) Thus, within the general public, the expression 'natural selection' was employed as a metaphor, not as the name for Darwin's Connector.

[465] Thus, Darwin began to shape the shared dialogue which, before, had shaped the formulation of his theory.

v. Classification: the idea of common descent

Public information on Darwin's classification resembled information on his explanation in that it focused mainly on the connotative component of the level. Many articles explained the concept of common descent metaphorically but hardly any one provided a logical analysis of Darwin's static model. For instance, Sedgwick summed up Darwin's static model like this:

> "1st Species are not permanent: varieties are the beginning of new species.
> 2nd Nature began from the simplest forms – probably from one form – the primaeval monad, the parent of all organic life.
> 3rd There has been a continual ascent on the organic scale, till organic nature became what it is, by one continued and unbroken stream of onward movement." (Sedgwick 1973 [1860]: 159-60)

Hooker's exposition is similar in its metaphorical style:

> "Again, the whole system of animal and plant classification into individuals, species, genera, &c., presents a series strictly analogous to that of the members of the human or any other family; and we further express our notions of the mutual relations of animals and plants in the very terms that would represent their affinities as being due to a blood relationship; so that either Nature has mocked us by imitating hereditary descent in her creations, or we have misinterpreted her in assuming that she has followed one method for families and another for species." (Hooker 1859: 1052)

The *Examiner*, the *Saturday Review* and Fawcett in *MacMillan's Magazine* gave even briefer summaries:

> "The theory thus adopted by our author leads him at length to the startling conclusion, that the countless multitude of organized beings which now people and adorn our earth may have originally sprang from no more than four or five vegetable, and as many animal species; nay, indeed, that all these may have originated in a single progenitor." (Anonymous [Crawford J.?] 1859: 772)

> "All existing animals have descended from at most only four or five progenitors, and plants from an equal or lesser number. Analogy (which Mr. Darwin admits to be a deceitful guide) would even lead him to infer that "all the organic beings which have ever lived on this earth have descended from some one primordial form into which life was at first breathed." (Anonymous 1859: 776)

> "Mr. Darwin has endeavoured to bring this subject within the cognisance of man's investigations, by supposing that every species has been produced by ordinary generation from the species which previously existed." (Fawcett 1860: 83)

Lewes, in the *Cornhill Magazine*, poignantly summed up the guiding question of Darwin's classification but did not enter into a discussion of classificatory concepts:

> “Can the descendants of animals become so unlike their ancestors, in certain peculiarities of structure of instinct, as to be classed by naturalists as a different species?” (Lewes 1860: 444)

Instead, he illustrated it by comparing the development of species to the development of languages:

> “The development of numerous specific forms, widely distinguished from each other, out of one common stock, is not a whit more improbable than the development of numerous distinct languages out of a common parent language, which modern philologists have proved to be indubitably the case. Indeed, there is a very remarkable analogy between philology and zoology in this respect: just as the comparative anatomist traces the existence of similar organs, and similar connections of these organs, throughout the various animals classed under one type, so does the comparative philologist detect the family likeness in the various languages scattered from China to the Basque provinces, and from Cape Comorin across the Caucasus to Lapland—a likeness which assures him that the Teutonic, Celtic, Windic, Italic, Hellenic, Iranic, and Indic languages are of common origin, and separated from the Arabian, Aramean, and Hebrew languages, which have another origin.” (Lewes 1860: 445)

A number of reviews put Darwin’s Origin in the context of previous classificatory and explanatory concepts. All the Year Round links Darwin to the much older idea of a “natural system of classification”, the *scala natura:*

> “The natural system of classification becomes a genealogical arrangement, in which we have to discover the lines of descent by the most permanent characters, however, slight their vital importance may be; because the real affinities of all organic beings are due to inheritance or community of descent.” (Anonymous 1860a: 299)

Most reviews, however, linked Darwin to Lamarck and to Chambers’ anonymously published *Vestiges*. (Lewes 1860; Huxley 1859a; Jardine 1860; Hopkins 1860) For instance, *Living Age* claimed that in the *Origin of Species*, Darwin

> “endeavors to establish, though by a different theory and a somewhat different process of reasoning, the same conclusion which was arrived at by the French naturalist, Lamarck, and by the English author of the "Vestiges of Creation"; — namely, that all the species, genera, orders, and classes of animal and vegetable life are essentially of one blood and lineage, having been developed out of one another, without the intervention anywhere of any act of creative power; — developed by the slow but progressive accumulation, through what is practically an infinite lapse of ages, of differences and variations which were at first, and for a long period of time, so slight as to be wholly imperceptible.” (Anonymous 1860b: 474)

Only Huxley and Fawcett, seemed to explicitly emphasize how much Darwin’s theory differed from Vestiges and Lamarck:

> “We think our exposition will indicate the great difference between the speculations of Mr. Darwin and those of other theorisers upon the transmutation of species, such as Lamarck and the author of the ‘Vestiges of Creation.’ “ (Fawcett 1860: 83)

> “Lamarck's conjectures, equipped with a new hat and stick, as Sir Walter Scott was wont to say of an old story renovated, formed the foundation of the biological speculations of the "Vestiges," a work which has done more harm to the progress of sound thought on these matters than any that could be named; and, indeed, I mention it here simply for the purpose of denying that it has anything in common with what essentially characterises Mr. Darwin's work.“ (Huxley 1859a: 147)

The most elaborated information on Darwin’s classificatory system came from Huxley, again. In *MacMillan’s Magazine*, he provided a lengthy introduction on paleontology and leads to the problem of species determination. He summed up Darwin’s classification as guided by

> “the hypothesis that the forms or species of living beings, as we know them, have been produced by the gradual modification of pre-existing species” (Huxley 1859b: 146)

In both, his *Times* review and the article for *MacMillan’s* magazine, Huxley links it back to Darwin’s dynamic model:

> “…if it be true that all living species are the result of the modification of other and simpler forms, the existence of these little altered persistent types, ranging through all geological time, must indicate that they are but the final terms of an enormous series of modifications, which had their being in the great lapse of pregeologic time, and are now perhaps for ever lost.” (Huxley 1859b: 146)

> “If species have really arisen by the operation of natural conditions, we ought to be able to find those conditions now at work; we ought to be able to discover in nature some power adequate to modify any given kind of animal or plant in such a manner as to give rise to another kind, which would be admitted by naturalists as a distinct species.” (Huxley 1859a: 8)

vi. Empirics: sketches and illustrations

The public did not receive substantial information on the empirical content of Darwin’s theory, i.e. enough information to understand and assess the empirical content and implications of the theory. A number of reviews did not mention empirics at all. (Fawcett 1860; Anonymous [Crawford J.?] 1859; Hooker 1859; Anonymous [J.R. Leifchild?] 1859: 659-60; Anonymous 1859) Those which did, provided no more than illustrative sketches of what the Darwinian theory meant empirically. Frequently, reviews cited instances of artificial selection (breeding and gardening) for illustration. (Huxley 1859a; Huxley 1859b; Hooker 1859; Jardine 1860; Anonymous 1860a; Anonymous 1860b; Anonymous [W.R. Church?] 1860) While such illustrations were certainly instructive and followed Darwin’s own rhetorical maneuver, they did not provide information on Darwin’s core topic: the evolution of organisms in the wild. When natural selection was illustrated, examples were often highly idealized[466] or consisted in severe misrepresentations of Darwin's examples or in misapplications of his theory, which rendered Darwin's argument a caricature of its own.

In the infamous "a bear becoming a Whale" example, a somewhat graphic passage[467] about the similarity of bears and wales in the first edition of the *Origin* was interpreted as if Darwin suggested that

> "a bear swimming about a certain time [would grow] … into a whale…. Anti-Darwinian writers seem to have deliberately played on the ambiguity of 'a bear' and 'a whale', the word can be used to denote the individual, and to denote the class or species. The image of the swimming bear is so particular, so comic, that even a sympathetic reader will be inclined to indulge the dreamlike image of the bears with larger and larger mouths metamorphosing into something very like a whale." (Ellegård 1958: 238-41, cf. de Beer 1963: 176)

Sedgwick (purposely or not) played on the same ambiguity when he uttered that

> "In some rare instances, Darwin shows a wonderful credulity. He seems to believe that a white bear, by being confined to the slops floating in the Polar basin, might in time be turned into a ... whale: that a lemur might easily be turned into a bat; that a three-toed tapir might be the great grandfather of a horse: or that the progeny of a horse may (in America) have gone back into the tapir." (Sedgwick 1973 [1860]: 165)

The lack of substantial information on the empirical component of Darwin's theory among non-biologists is not too surprising. After all, Darwin's book mainly addressed a non-expert audience, i.e. readers outside his immediate scientific community. The *Origin*'s focus was the presentation of Darwin's dynamic and static model and the corresponding explanation and interpretation. Granted, Darwin devoted a large part of the *Origin* on sketching empirical applications of his models (their denotative meaning), yet understanding and assessing even these sketches required a large amount of previous knowledge and was not possible to non-biologists.[468]

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466 Argyll's *Reign of Law* is a striking example here: Argyll presents evidence throughout two entire chapters (Argyll 1872 [1867]: 126-207), however, his examples consist mainly of popular and easily imaginable birds like the Green Woodpecker or the Humming Bird and his representation of their anatomical features and behavior are idealized sketches only. – In his review of the book, Wallace points this weakness out right from the beginning: "The noble author represents the feelings and expresses the ideas of that large class, who take a keen interest in the progress of Science in general, and especially that of Natural History, but have never themselves studied nature in detail, or acquired that personal knowledge of the structure of closely allied forms, the wonderful gradations from species to species and from group to group, and the infinite variety of the phenomena of " variation" in organic beings, which are absolutely necessary for a full appreciation of the facts and reasonings contained in Mr. Darwin's great work." (Wallace 1870e [1867]: 264)

467 Jardine, for instance, cited the passage verbatim: "In North America the black bear was seen by Hearne swimming for hours, with widely open mouth, thus catching; like a whale, insects in the water. Even in so extreme a case as this, if the supply of Insects were constant, and if better adapted competitors did not already exist in the country, I can see, no difficulty in a race of bears being rendered, by natural selection, more and more aquatic in their structure and habits, with larger and larger mouths, till a creature was produced as monstrous as a whale." (Jardine 1860: 282; cf. Darwin 1859: 184)

468 Darwin was obviously aware of the limits of his book. He had intended to publish his theory in a "big book", a thorough empirical study named *Natural Selection*. When he was rushed into publication by Wallace's 1858 paper, Darwin did write but an abstract of his big book: the *Origin.* This abstract he wanted to call "An

vii. Synthesis

In sum, both the general and the educated public received ontological implications of Darwin's theory as well as the connotative part of his models, i.e. its interpretation and narration. However, the uneducated received of the theory but the most superficial features, i.e. the supposed relation of Man and the apes as well as Darwin's claim that the living species had not been created one by one out of the ground by God.

The educated public grasped the concept of evolution as transmutation of species beyond the descent of Man - a concept which had already been popularized by Chambers' *Vestiges*.[469] They were aware of fundamental philosophical issues raised by Evolution and adapted their world views but they refused its full application to Man. However, their reception stopped clear of Darwin's model, Natural Selection, at the connotative part of the second layer of information on Darwin's theory. In the public discourse, the model appeared as a story, its core terms 'natural selection' or 'struggle for life' were merely metaphors to the educated laymen. Neither the model's mechanism nor its links to empirical evidence were covered. Empirical evidence was sparsely presented and if so highly idealized; it served merely as an illustration of the story Darwin seemed to tell about Evolution.

4.1.2 By which criteria was the Darwinian theory assessed?

As the large and uneducated public of the time received information on Darwin's theory only on its upmost abstraction level and of this only the most superficial part, they could judge the theory only by this surface. Their criticism of Darwin's theory did therefore focus on two issues. First, they criticized Man's supposed descent from the lower animals, his supposed relation with the brutes. How much this framed the perception of Darwin among the general public is probably best exemplified by the famous 1871 caricature in Fun which depicts an ape body with Darwin's face lecturing on evolution.[470] Second, Darwin's theory contradicted a literal understanding of the Bible and, therefore, caused a stir among the general public. Judging from the general press there was no further criticism of any of the other layers. (Ellegård 1958)

The criticism in the quality press focused on the three elements of Victorian world-views which Darwin's theory seemed to threaten.

Abstract of an Essay on the Origin of Species and Varieties Through Natural Selection", only his editor, John Murray, convinced Darwin to adopt the catchier title. (cf. Freeman 1977)

469 This does not imply that they grasped the difference between Chambers' and Darwin's models. By some commentators Darwin was accused of having taken his ideas from Chambers' *Vestiges*. (Schwartz 1990: 138)

470 Julia Voss emphasizes how well-known both images of evolutionary series and of Darwin must have been for such a caricature to work in a popular magazine. (Voss 2007: 11-2) Janet Browne provides an overview on the topic of caricatures in the Darwinian debate. (Browne 2001) For a look at the caricatures just search "caricature Darwin ape" in an online image repository, e.g. Google images.

i. *Ontological criticism: Divine Providence and Design*

First, critics dismissed the agnostic[471] tendencies and aimed at amending Darwin's narrative with elements of Victorian theism. Darwin found defenders like the economist Henry Fawcett who claimed that the theory did not lessen the glory of God:

> "Those who, like Mr. Darwin, endeavour to explain the laws which regulate the succession of life, do not seek to detract one iota from the attributes of a Supreme Intelligence. Religious veneration will not be diminished, if, after life has been once placed upon this planet by the will of the Creator, finite man is able to discover laws so simple that we can understand the agency by which all that lives around us has been generated from those forms in which life first dawned upon this globe." (Fawcett 1860: 283)

However, while most supporters of Darwin avoided teleological topics – often claiming they assessed the theory on scientific grounds only – most public critics aimed precisely at these perceived ontological implication of Darwin's theory.[472] In *Fraser's Magazine*, the mathematician William Hopkins blamed Darwin for

> "the adoption of pantheistic views, and the utter rejection of the doctrine of final causes, and of the belief in a Supreme Intelligence and personal Governor of the universe. " (Hopkins 1860: 741)

Sedgwick, in the *Spectator*, stopped just inches short of accusing Darwin of atheism which, at the time, would have been a strong public defamation:

> "A cold atheistical materialism is the tendency of the so-called material philosophy of the present day. Not that I believe that Darwin is an atheist; though I cannot but regard his materialism as atheistical; because it ignores all rational conception of a final cause. " (Sedgwick 1973 [1860]: 161)

Living Age called Darwin out for taking good care "not to attribute any intention to the Almighty" and for ignoring "all the facts which have appeared to most minds so significant of unity of plan, and thereby declarative of the unity of the Creator" and condemned the biologist's intrusion into the domain of theology. (Anonymous 1860b: 475-6)

Moreover, both *Sedgwick* and *Living Age* offered an alternative ontology to Darwin's, one that could be perceived as proving God's existence and revealing his purpose[473] (Hull 1973: 57) and preserved natural harmony:

> "Species have been constant for thousands of years; and time (so far as I see my way) though multiplied by millions and billions would never change them, so long as the conditions remained constant. Change the conditions, and old species would disappear; and new species might have room to come in and flourish. But how, and

[471] The term ‚agnostic' was termed by Huxley.

[472] Indeed, opponents of the Darwinian theory often chose to address ontological issues while his supporters usually withheld from addressing these issues, often claiming that they wanted to assess the theory on scientific grounds only.

[473] See (Hull 1973: 55-66) for a close discussion of the two main forms of teleology.

> by what causation? I say by creation. But, what do I mean by creation? I reply, the operation of a power quite beyond the powers of a pigeon-fancier, a cross-breeder, or hybridizer; a power I cannot imitate or comprehend; but in which I can believe, by a legitimate conclusion of sound reason drawn from the laws and harmonies of Nature. For I can see in all around me a design and purpose, and a mutual adaptation of parts which I can comprehend,-and which prove that there is exterior to, and above, the mere phenomena of Nature a great prescient and designing cause. Believing this, I have no difficulty in the repetition of new species during successive epochs in the history of the earth.
> But Darwin would say I am introducing a miracle by the supposition. In one sense, I am; in another, I am not. The hypothesis does not suspend or interrupt an established law of Nature. It does suppose the introduction of a new phenomenon unaccounted for by the operation of any known law of Nature; and it appeals to a power above established laws, and yet acting in harmony and conformity with them." (Sedgwick 1973 [1860]: 161)

> "Now these countless differences which distinguish all living forms from each other, …, are yet just as much a part of creation — a part, so to speak, of the Divine plan — as the general laws themselves which underlie them, and which alone come within the scope and power of human science. Admitting, for the nonce, that law and order can be ascribed to the blind action of secondary or mechanical causes, these endless diversities still remain inexplicable except upon the supposition of the constant action of a free personal cause. […]thus, indeed, 'we can perceive that events are brought about, not by insulated interpositions of Divine power,' but by exertions of it so frequent and beneficent, that we come to regard them as the ordinary action of Him who laid the foundations of the earth, and without whom not a sparrow falleth to the ground." (Anonymous 1860b: 505-6)

This, alternative, however, was incompatible with Darwin's explanation, a process which lacked a teleologically acceptable power and a definite direction for evolution. An important part of the public criticism aimed precisely at filling these perceived holes in Darwin's narrative; technically speaking, Darwin's critics aimed at providing a new Agent and a Purpose. (Ellegård 1958: 102, 128-140, 150)

This line of criticism probably culminated in the Duke of Argyll's interventions in the mid-sixties. In *The Reign of Law*, he claimed that Darwin had not given any explanation

> "of the method in which Vital Forces are made to evolve a new Form of Life. But even if such explanation could be given, it would render no account at all of the fittings of that Form into the outward requirements of its life. These are Correlations which in their very nature belong to Mind, are the work of Mind, and are intelligible only in the light of Mind." (Argyll 1872 [1867]:261)

To Argyll and the majority of Darwin's opponents, there was no difference between the supernatural and the natural, both being the workings of the "Reign of Law". Therefore, they wished to interpret evolution as a product of Divine law and required amendments to the model of Natural Selection – or they would not accept it as an explanation of Evolution. (Lynch 2001: xiii) To them, there was at least a "residuum of change" in Evolution not explicable by Natural Selection alone and this residuum opened the door for Design and Divine Providence. A comment in the 1871 *Guardian*'s put this very clearly:

> "This amounts, as it seems to us, to a confession that Natural Selection may, after all, play only a secondary part in the differentiation of species, – that there may be behind and above it an 'unknown agency: giving the first impulses in certain definite directions which natural selection cannot alter ... It is a vast concession, and one which seems to us to cover all that [we] need ask for; since it is obvious that we may assign this 'unknown agency' to any cause ... and if we assign it to the finger of God, it will amount to a perpetual divine superintendence of the physical development of the world." (op. cit. Ellegård 1958: 130, cf. 274)

ii. Ontological Implications: Position of Man

On the descent of Man, opposition was equally strong. Anatomical similarities between Man and the higher apes were often admitted; for instance, Argyll admits that

> "the close and mysterious relations between the mere animal frame of Man, and that of the lower animals, does render the idea of a common relationship by descent at least conceivable. " (Argyll 1872 [1867]: 29)

However, according to most critics, the human mind, soul and reason put Man apart from all other organic beings and in a class of his own.[474] (Ellegård 1958: 311-329, Hull 2005: 149) These qualities in Man could not stem from some incipient form in animals; they must have been added independently from an outside force.[475]

> "… we cannot speculate on man's position in the actual world of nature, on his destinies, or on his origin, while we keep his highest faculties out of our sight. Strip him of these faculties, and he becomes entirely bestial; and he may well be (under such a false and narrow view) nothing better than the natural progeny of a beast, which has to live, to beget its likeness, and then die for ever." (Sedgwick 1973 [1860]: 164)

The question of morality implied social and political consequences for the social order of the time was erected upon religious truths. (Ellegård 1958: 322-5) Shattering these truths meant, in the eyes of many, shattering the fundament of the social order. (Desmond and Moore 1995: 655) Thus, rejection of the Darwinian theory frequently went hand in hand with a warning of its possible negative effect on the British society, if not the entire civilized world. As Sedgwick put it in the Spectator:

[474] For radical Darwinians, the difference between man and animals was one of degree, not of kind. (Ellegård 1958: 330; Desmond and Moore 1995: 566-569)

[475] Note that this still is the contemporary position of the Catholic Church. Pope Pius XII stated in the 1950 encyclical *Humani Generis* (Pope 1950) that "Catholics could believe whatever science determined about the evolution of the human body, so long as they accepted that, at some time of his choosing, God had infused the soul into such a creature." (Gould 1997)

> "The pretended physical philosophy of modern days strips Man of all his moral attributes, or holds them of no account in the estimate of his origin and place in the created world." (Sedgwick 1973 [1860]: 161)

The Saturday Review blank-point refused entering in the debate and issued a warning to biologists not to address the descent of man:

> "To him [Darwin], or to any other man of science who should attempt to prove to us that the moral and spiritual faculties of man have been gradually developed by the working of matter upon matter, we should reply by demurring in toto to the applicability of his reasoning. No conceivable amount of evidence derived from the growth and structure of animals and plants would have the slightest bearing upon our convictions in regard to the origin of conscience, or man's belief in a Supreme Being and the immortality of his own soul." (Anonymous 1859: 775)

Therefore, while their debate was more sophisticated, the educated public followed the uneducated in predominantly rejecting the application of Evolution to Man. (Desmond and Moore 1995: 653-4, 663)

iii. Darwin's explanation: just speculation?

As Darwin's model was hardly described in the public press, it virtually escaped methodological or logical criticism here. Sedgwick (1860: 164) accused Darwin in the *Spectator* of having "deserted the inductive track, - the only track that leads to physical truth", yet, he did not develop this point with respect to scientific methodology but embedded it in his general moral critique of Darwin's supposedly

> "unflinching materialism … [which] utterly repudiates final causes and thereby indicates a demoralized understanding on the part of its advocates." (Sedgwick 1973 [1860]: 164)

Huxley, in his December review for the *Times*, had already anticipated such moral debate when he demanded that Darwin's theory be judged on scientific grounds only:

> "This hypothesis may or may not be sustainable hereafter; it may give way to something else, and higher science may reverse what science has here built up with so much skill and patience, but its sufficiency must be tried by the tests of science alone, if we are to maintain our position as the heirs of Bacon and the acquitters of Galileo. We must weigh this hypothesis strictly in the controversy which is coming, by the only tests which are appropriate, and by no others whatsoever." (Huxley 1859a: 8)

A more detailed critique came from Hopkins in *Fraser's Magazine*. His review is untypical for general publications and rather resembles reviews for the broader scientific community in that it contains a long discussion of scientific methodology in which Hopkins compared (and largely equates) Darwin's theory with Lamarck's works and opposed both to the supposedly ideal physical theories. He blamed Darwin of not having identified actual causes and suggested that Darwin was theorizing "as if Bacon and Newton had never lived." (Hopkins 1860: 741)

Such criticism was countered by Henry Fawcett in the MacMillan's Magazine:

> "There we find it reiterated, 'This is not a true Baconian induction.' In reply to all this, it should at once be distinctly stated that Mr. Darwin does not pretend that his work contains a proved theory, but merely an extremely probable hypothesis. The history of science abundantly illustrates that through such a stage of hypothesis all those theories have passed which are now considered most securely to rest on strict inductive principle. Dr. Whewell has remarked, "that a tentative process has been the first step towards the establishment of scientific truths." Some association perchance, as the falling apple, first aroused in Newton's mind a suspicion of the existence of universal gravitation. He then had no proof of the particular law of this gravitating force; he made several guesses. The inverse square was the only one which caused calculation to agree with observation; the inverse square was therefore assumed to be the true law. The most complicated calculations were based upon this assumption; they have been carefully corroborated by observation, and in this manner the law of gravitation has been proved true beyond all dispute. Those who attack the philosophic method of Mr. Darwin ought explicitly to state how they would proceed to establish a theory on the origin of species by what they term a rigorous induction." (Fawcett 1860: 82-3)

iv. Criticism of Darwin's classification missing links and the concept of species

A group of issues which were discussed in this group figured under the term 'missing links'; Darwin himself referred to them by the formula 'the imperfection of the geological record'. The debate focused on the question whether geology (paleontology) had produced enough fossils to support the Darwinian classification, particularly the links between important classes of organisms.[476]

In the missing-links debate, it was taken as evidence against Darwin that the historical record of mankind did not contain any accounts of "specific changes in the animals that had been associated with man since ancient times"[477] (Ellegård 1958: 216) or that the paleontological record displayed extinct species but no evidence of transitional forms between these species or between those and contemporary species[478]: "Connecting links, in the sense of forms which could equally well be put in one species as in another, were rare or missing." (Ellegård 1958: 216)

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476 I do not consider these objections to be empirical but classificatory objections because they did not challenge Darwin's model by contradictory empirical evidence. Instead, they claimed that there existed not enough evidence to support Darwin's classification by common descent. Hence, challenged how Darwin aggregated and systematized the available evidence. – One might say that an empirical objection challenges a classification with positive evidence, i.e. evidence which has been gathered, while a classificatory challenge challenges a classification by negative evidence, i.e. imaginary evidence which has not been gathered.

477 For instance, it was argued that Cuvier's expedition to Egypt had revealed that mummified cats in the pyramids did not differ from cats in the 19th century.

478 Both arguments were answered by Darwin: One, if the recorded history of mankind knew no drastic Environmental Change, then no drastic Evolution was to be expected. Two, according to Darwin, competition between similar organisms was the most severe; therefore, intermediate forms were to be quickly eliminated by Natural Selection and an infinite number of gradations between species was not to be expected.

Missing links or the problem of the imperfection of the geological record were mentioned in the reviews in the majority of reviews, albeit in most cases only briefly. (Anonymous 1860b; Chambers 1859; Anonymous [J.R. Leifchild?] 1859: 659-60; Fawcett 1860; Anonymous [Crawford J.?] 1859: 772-3) The Saturday Review devoted a longer passage to geology and claimed that even "in the earliest geological record" species displayed a "perfectly definite character" and that the facts of geological did thus oppose the Darwinian theory. (Anonymous 1859: 775-6)

The geologist Adam Sedgwick devotes a lengthy passage to an overview over the established body of empirical knowledge of paleontology and then over his reading of the geological history of the earth. Sedgwick came to the conclusion that

> "the great broad facts of geology are directly opposed to [the Darwinian theory]". (Sedgwick 1973 [1860]: 159-60)

Hopkins' article in *Fraser's Magazine* is again a particular case in that it provided a more explicit criticism of Darwin's classification. Hopkins blamed Darwin and Lamarck of having an incorrect notion of species when they considered species those groups which are "convenient for the purposes of classification". (Hopkins 1860: 752) According to the mathematician Hopkins,

> "The accurate distinction between varieties and species consists in this – the former, when crossed, always produce fertile offspring: the latter either do not admit of being crossed at all, or when crossed they produce sterile offspring." (Hopkins 1860: 751)

v. Pseudo-empirical criticism: misrepresentations, sterility, Man's moral and mental qualities

Another group of objections to Darwin's model were supposed to be empirical but were founded on distorted accounts of reality or Darwin's model. These objections suggested that Darwin's model did not fit the available empirical evidence; yet they were expressed by writers from outside the immediate scientific community of paleontologists, botanists or zoologists, i.e. by writers who did not gather the relevant empirical evidence. This led them to challenge Darwin's model by a version of reality which was not (or not well) empirically founded or to challenge a distorted version of Darwin's model.

An example for the latter case is provided by the *Examiner* which equated size and physical strength with fitness and argued that the extinction of large animals contradicts Darwin's model of natural selection:

> „A comparison of extinct with existing species of the same natural families seems to us to afford an unanswerable argument against the theory of 'natural selection.' Thus, the extinct mastodons and elephants were at least equal in size and strength with the living species, and the latter could not by any superiority have displaced and extinguished them. Still stronger is the case with the class of Saurians or lizards, some of the extinct species were such monsters that a Nilotic or Gangetic alligator would have made but a poor breakfast for one of them." (Anonymous [Crawford J.?] 1859: 772-3)

Even Adam Sedgwick, the geologist, took up this line of argument in the Spectator:

> "The reptile fauna of the Mesozoic period is the grandest and highest that ever lived. How came these reptiles to die off, or to degenerate? And how came the Dinosaurs to disappear from the face of Nature, and leave no descendants like themselves, or of a corresponding nobility? By what process of natural selection did they disappear? Did they tire of the land, and become Whales, casting off their hind-legs? And, after they had lasted millions of years as whales, did they tire of the water, and leap out again as Pachyderms?" (Sedgwick 1973 [1860]: 163)

Following a similar argument, *Living Age* mentioned the simultaneous existence of higher and lower forms as contradicting Darwin's theory. (Anonymous 1860b: 496)

A number of reviews followed Hopkins' definition of species as two groups of organisms which, when crossed, can only produce sterile offspring. (Anonymous 1860b: 478; Anonymous [Crawford J.?] 1859: 772-3; Hopkins 1860: 751) This criticism, however, was unconnected to the body of biological knowledge of the time and, therefore, pseudo-empirical. To biologists, it was clear that a definition like Hopkins' could not be operationalized and, therefore, not be applied in the distinction of species.[479] Huxley had anticipated such arguments when he clarified in a lengthy passage of his *Times* review that there existed no empirical criterion for the determination of species:

> "But is it not possible to apply a test whereby a true species may be known from a mere variety? Is there no criterion of species? Great authorities affirm that there is—that the unions of members of the same species are always fertile, while those of distinct species are either sterile, or their offspring, called hybrids, are so. It is affirmed not only that this is an experimental fact, but that it is a provision for the preservation of the purity of species. Such a criterion as this would be invaluable; but, unfortunately, not only is it not obvious how to apply it in the great majority of cases in which its aid is needed, but its general validity is stoutly denied. The Hon. and Rev. Mr. Herbert, a most trustworthy authority, not only asserts as the result of his own observations and experiments that many hybrids are quite as fertile as the parent species, but he goes so far as to assert that the particular plant Crinum capense is much more fertile when crossed by a distinct species than when fertilised by its proper pollen! On the other hand, the famous Gaertner, though he took the greatest pains to cross the primrose and the cowslip, succeeded only once or twice in several years; and yet it is a well-established fact that the primrose and the cowslip are only varieties of the same kind of plant. Again, such cases as the following are well established. The female of species A, if crossed with the male of species B, is fertile; but, if the female of B is crossed with the male of A, she remains barren. Facts of this kind destroy the value of the supposed criterion." (Huxley 1859a: 8)

Henry Fawcett, the economist concurred with Huxley:

> "The following definition of a species is sometimes given: that two animals or vegetables belong to different species when they are infertile with each other. This hardly deserves the name of a definition. It is enunciated in deference to pre-

[479] The case is different for the modern concept of species. Following Mayr, species are understood as reproductively isolated populations can therefore be distinguished by the criterion suggested by Hopkins and others.

> conceived notions, and assumes the incorrectness of the theory which it is afterwards used to disprove. This definition can manifestly have little influence in diminishing that difficulty, which has been above alluded to, of deciding what is a specific difference; for it requires a test which can rarely be applied to the existing organic world, and is entirely inapplicable to those numerous species which have passed away. Thus it would be almost impossible to ascertain whether different molluscs, or insects, or testacea, are fertile with each other; and, manifestly, such an imperfect experiment in breeding cannot be made upon those animals and plants of which we have solely a geological record. Therefore it would seem that the classification of species must remain so arbitrary, that equally high scientific authorities may continue to dispute whether the plants of a limited area like England should be held to constitute two thousand or one thousand two hundred species. The question of species may thus, at the first sight, appear to be a dispute about an arbitrary classification…" (Fawcett 1860: 82)

Moreover, Hopkins doubted that varieties may transmute beyond their mother-species; according to him, they are limited to "the sphere" in which they were born. (Hopkins 1860: 76) *Living Age* expressed the same concern. (Anonymous 1860b: 490) Again, this point had been anticipated by Huxley who drew a line from Lamarck[480] to Darwin in his *Times* review and emphasized that independent minds had been doubting the doctrine of "definable limits" for some time and that there existed no empirical proof for it. (Huxley 1859a: 8)

Finally, some opponents of the Darwinian theory claimed that Man's mental and moral qualities singled him out in Nature and that, therefore, Man's descent cannot be solely due to Natural Selection. (Sedgwick 1973 [1860]: 164-5; Anonymous 1859: 775) *Living Age* provided quite good a representation of the Victorian majority opinion on the topic:

> "[Darwin] is bound … to find the means of bridging over, by imperceptibly fine gradations, the immense gap which now separates man from the animals most nearly allied to him, — a gap not only between the two structural forms, which, however unlike, may still be affirmed to be of the same kind, but between reason and instinct, where nearly all psychologists are agreed that the difference is in kind, and not in degree." (Anonymous 1860b: 501-2)

The moral qualities-argument was adopted by many scientists and laymen alike and it prevented the application of Darwin's model to all of Man. This, however, was not due to the noble British inductivism but to world-views. Mind, moral, soul and reason were subjects of theorizing and speculation, not yet of systematic empirical study. Psychology as an empirical discipline would emerge only in the 1870s, the study of mental processes in animals would require still more time. On what shaky grounds Darwin's critics were arguing with respect to differences between animals and humans in mental and moral qualities becomes clear in an 1870 statement by Wallace who clarified how little the science of the time knew about the mental processes of animals:

[480] I find it remarkable how Huxley, took the time to defend Lamarck's reputation against the widespread ridicule he had encountered in Britain, raising his profile against Cuvier and Chamber's Vestiges and stating: "The Lamarckian hypothesis has long since been justly condemned, and it is the established practice for every tyro to raise his heel against the carcass of the dead lion. But it is rarely either wise or instructive to treat even the errors of a really great man with mere ridicule, and in the present case the logical form of the doctrine stands on a very different footing from its substance." (Huxley 1859a: 8)

> "Whatever we may define instinct to be, it is evidently some form of mental manifestation, and as we can only judge of mind by the analogy of our own mental functions and by observation of the results of mental action in other men and in animals, it is incumbent on us, first, to study and endeavour to comprehend the minds of infants, of savage men, and of animals not very far removed from ourselves, before we pronounce positively as to the nature of the mental operations in creatures so radically different from us as insects. We have not yet even been able to ascertain what are the senses they possess, or what relation their powers of seeing, hearing, and feeling have to ours." (Wallace 1870b)

4.1.3 Which elements of the Darwinian theory were accepted, which rejected?

Among the large and uneducated public, Darwin's theory had no sustainable effects. The two elements of the theory which reached this audience – Man's relationship with the Apes and the idea of common descent – where considered fancies of the literary circles and received no serious consideration. An amusing example of the widespread ignorance already on Darwin's topic is reported by Gertrude Himmelfarb who quotes a country clergyman as saying:

> "I cannot conceive how a book can be written on the topic [of evolution]. We know all there is to know about it. God created plants and animals and man out of the ground." (Himmelfarb 1959: 247)

The educated public had few problems with evolution as such and embraced it quickly – even before the scientific community: It was the general periodicals of educated and interested public, not the scientific publications who first accepted the transmutation of species.[481] (Ellegård 1958: 57) Among the educated laymen Evolution steadily gained ground such that, by 1869, about three quarters of the intellectuals accepted it and "the battle for it was virtually over by 1870." (Ellegård 1958: 33; Hull 2005: 149; Desmond and Moore 1995: 605, 653)

However, this acceptance did not cover all of Darwin's model nor its philosophical implications. They accepted evolution as applied to the animals and plants but denied (i) its application to man and (ii) the mechanism supposed to produce it, i.e. Natural Selection. (Ellegård 1958: 47-8; Young 1985: 109, 121; Desmond and Moore 1995: 663)[482] Frequently, these two arguments came hand in hand. (Ellegård 1958: 331) First, it was argued that if Man possessed mental qualities not existent among the animals. Second, critics argued that Natural Selection could not account for the development of these mental qualities. Therefore, Natural Selection was an incomplete, even insufficient explanation of Evolution and it required additions. (Argyll 1872 [1867]: 220)

Thus, most educated and interested Victorians felt that Darwin's model required additions and suggested to add a 'principle of design' to it. Therefore, their concept of Evolution was more of

481 One might explain this by Chambers' *Vestiges* which had already advanced evolutionary thought from 1844 on and had enjoyed great public attention. Although ignored or dismissed by the scientists, it might have paved some of Darwin's way. (cf. Ellegård 1958:333)

482 This argument remained unaffected by Darwin's supplementing the term of 'natural selection' by Herbert Spencer's 'survival of the fittest'.

> "a pre-Darwinian evolutionism, where Design figured as if Darwin had never propounded the Natural Selection theory." (Ellegård 1958: 126, cf. 47-8)

Natural Selection was supplemented or replaced

> "by a postulate of Divine Design, so it was also possible to accept the gradual development of the soul, if it was combined with a recognition that it must have been providentially guided. The manner of that providential guidance might be obscure […, yet it] provided the foundation for all the various individual schemes of reconciling Evolution with traditional modes of thought as regards man's nature." (Ellegård 1958: 331)

This move let the public keep most of their Weltanschauung intact and steer a middle course between the revolutionary doctrine of Evolution and traditional views as Divine Providence or the argument from Design for it "did not necessitate any fundamental modification of the Design argument. All the features that on the direct Creation theory had been interpreted as indicative of foresight and Design could still be so regarded." (Ellegård 1958: 127) Such was the majority opinion among the educated public. (Ellegård 1958: 136)

4.2 Reception by the broader scientific community

4.2.1 To what depth did recipients receive the theory?

As the reception in concentric circles suggests (see section 1.3), this group received all of the public debate, i.e. philosophical and religious, social and political implications of Darwin's narrative as debated among the educated public. Some of these issues were discussed by the broader scientific community as well and usually in greater depth and complexity. However, the issues shared with the educated public were mostly religion and philosophy, politics and social implications took a back seat within the broader scientific community.

Furthermore, the debate of the broader scientific community covered a novel topic: Darwin's model. To them, it was no longer a mere narrative but also a logical structure with empirical implications. They discussed its details and sketched empirical implications. Moreover, they focused on its inner logical consistency, its compatibility with other models and its compliances with meta-models, i.e. the philosophy of science-conceptions of the time. These issues accounted for much of the debate within the broader scientific community.

i. Ontological Implications: world-views

To Darwin's surprise[483], the broader scientific community reacted to the perceived attacks of the Victorian world views in a similar intensity as the public; "… for many of [Darwin's scientific critics] … it is impossible to separate scientific and religious motives completely." (Ruse 1979: 206) Thus, even the debate on

> "…the philosophical and methodological foundations of the Darwinian theory was largely motivated by its religious implications. It was impossible to accept the theory without effecting changes in a whole system of religious and metaphysical beliefs sanctioned by tradition, or, conversely, to preserve that body of beliefs intact without rejecting the theory. To the religious, the theory was an incubus which had to be cast out, or at any rate isolated and neutralized. To attack the theoretical foundations of the theory was one of the ways, and an important one, of achieving this result: thereby the theory could be, if not directly refuted, at any rate represented as no more than a loose speculation, scientifically unjustifiable, and without any foundation in fact." (Ellegård 1958: 195)

This was very obvious in laymen contributions to the debate of the broader scientific community, for instance in two opening addresses to the Royal Society of Edinburgh by the Duke of Argyll.[484] (Argyll 1862 [1860]: 371-6; Argyll 1865 [1864]: 264-292) Another case in

[483] As Himmelfarb remarks: "When Darwin predicted that his book would find more favour with intelligent laymen than with professional scientists, it was because he thought the scientists were too committed to the old conception of species to admit new ideas on the subject. What he did not expect was that their objection would be not only professional but also religious. The religious issue having played no part in his own thinking, he was entirely unprepared for its prominence in the judgments of even the most professional and reputable scientists." (Himmelfarb 1959: 231)

[484] Argyll presided the society for a number of years in the mid-1860s, presumably one of the last times a nobleman without scientific training chaired a scientific association in Britain.

point is John Morris' review for the *Dublin Review* which addresses both the descent of Man and its political implications:

> "Mr. Darwin makes reply and says, that not only is there no difficulty in believing that an Ojibbeway, a Hottentot, and an Australian, have descended from a common parent with a Chinese and an Englishman, but that 'he believes that animals have descended from at most only four or five progenitors, and plants from an equal or lesser number:' and, much further still, that he would 'infer from analogy that probably all the organic beings which have ever lived on this earth have descended from some one primordial form, into which life was first breathed,' or in other words, 'that all animals and plants have descended from some one prototype.' (p. 484.) Truly the oscillations of Science are somewhat alarming. We should, however, be extremely sorry to leave the impression that we consider Mr. Darwin's book as empirical or unscientific. He has the misfortune not to believe in Adam and Eve, and he has filled up the gap thus left in his mind by substituting in their place some prototype of far more venerable antiquity, though it must be confessed, of rather a humiliating character to one who would fain believe himself as coming directly from the Hand of God 'a little lower than the angels;' and he looks back through a bewildering number of years to his simple progenitor, a worm perhaps, or a bit of sponge, or some animated cellule." (Morris 1860: 58-9)

However, it were not only laymen who debated these questions, many of the scientists of the scientists addressed them, too – often very overtly. For instance, the botanist, zoologist and entomologist Andrew Murray[485] published a critical review of Darwin's theory in the *Proceedings of the Royal Society of Edinburgh* in which he opposed the randomness of Darwin's accidental variations and the wastefulness of the struggle for life, defending ideas of design and a theist God:

> "[Darwin's] assumption is, that it is not alone beneficial variations which Nature makes. She makes them in any and every way; some being profitable, others the reverse; and the reason why we find all that have ever been seen on the face of the earth beneficially endowed (that is, provided with structures which, to the unilluminated eye, indicate design) is, that only those variations which happen to have been so endowed have been preserved,-the blots which Nature made having become extinct through the preponderance of the beneficially endowed. To use Mr Darwin's words, "Natural selection is daily and hourly scrutinizing throughout the world every variation, even the slightest; rejecting that which is bad, preserving and adding up all that is good, silently and insensibly working whenever and wherever opportunity offers at the improvement of each organic being, in relation to its organic and inorganic conditions of life!' (P. 84.) Now, I cannot believe in such doctrine. When I look at the anatomy of any part of the body, and see exactly the same mechanism and Contrivances had recourse to which a mechanician [sic!] would have used to secure similar results, I cannot bring myself to believe that it is fortuitous, or other than evidence of the prevalence of direct design. A belief in such design I should be most loath to surrender…" (Murray 1862 [1860]: 291)

[485] Interestingly, Murray later converted and employed Darwinian concepts.

Murray wondered aloud why Darwin had to stretch his theory to this point while other eminent biological theorists had left open the possibility for design:

> "The views of Agassiz and Oken do not challenge the fact of design existing in the wonderful adaptations of structure to purpose which we see everywhere displayed in living organisms. Their theory allowed us to retain our belief in the great argument on which the whole of natural theology is based; nay, even to place it on higher grounds, as the intelligence which performs its work by the intervention of a law or machinery designed by itself, and operating on a great scale, is superior to the intelligence which executes each individual detail directly and without such intervention. If it furnished no explanation of the causes of adaptation of structure to habit, at least it did not prevent us from holding, if we chose, that, by some unexplained means, the germ of life was supplied with such a principle of growth as, under certain physical conditions, developed itself into these adaptations. We could hold design still to be there, although its direct means of operation was shrouded from our view in the laboratory of Nature." (Murray 1862 [1860]: 290-1)

Richard Owen[486], in his article for the *Edinburgh Review* cited Darwin's passage on the Creator breathing life into the first beings and inferred that

> "Darwin formally recognises, in the so-limited beginning, a direct creative act, something like that supernatural or miraculous one which, in the preceding page, he defines, as 'certain elemental atoms which have been commanded suddenly to flash into living tissues.' … He leaves us to imagine our globe, void, but so advanced as to be under the conditions which render life possible; and he then restricts the Divine power of breathing life into organic form to its minimum of direct operation." (Owen 1860b: 511; cf. Cosans 2009: 97-8)

However, it were not only Darwin's opponents who addressed ontological implications. Huxley, in a talk before the *Royal Institution of Great Britain*, refused contempt for the lower animals[487]:

> "Another, and unfortunately a large class of persons take fright at the logical consequences of such a doctrine as that put forth by Mr. Darwin. If all species have arisen in this way, say they—Man himself must have done so; and he and all the animated world must have had a common origin. Most assuredly. No question of it. But I would ask, does this logical necessity add one single difficulty of importance to those which already confront us on all sides whenever we contemplate our relations to the surrounding universe? I think not. Let man's mistaken vanity, his foolish contempt for the material world, impel him to struggle as he will, he strives in vain to break through the ties which hold him to matter and the lower forms of life.

[486] Interestingly, Owen is among the few reviewers who addresses the fact that Darwin employed such graphic metaphors and such a compelling narrative in his explanation: "Referring to Darwin's reputation for vivid and clear writing, Owen credits Darwin for his fame 'to the Literary World, by the charming style in which his original observations on a variety of natural phenomena are recorded'. He notes that with its 'pleasing style' and 'certain artistic disposition', the Origin had already persuaded much of the reading public to believe the theory of natural selection." (Cosans 2009: 99)

[487] Note that Chambers had taken the same line of argument in 1844. (Chambers 1845 [1844]: 178; cf. section 3.1.5)

> … in the course of his development, man passes through stages which correspond to, though they are not identical with, those of all the lower animals; that each of us was once a minute and unintelligent particle of yolk-like substance; that our highest faculties are dependent for their exercise upon the presence of a few cubic inches more or less of a certain gas in one's blood; in the face of these tremendous and mysterious facts, I say, what matters it whether a new link is or is not added to the mighty chain which indissolubly binds us to the rest of the universe? Of what part of the glorious fabric of the world has man a right to be ashamed—that he is so desirous to disconnect himself from it?" (Huxley 1860a: 194-5)

Huxley repeated this position one year later in the *Natural History Review*, where he claimed that a close relationship between humans and apes would not

> "one whit diminish man's divine right of kingship over nature; nor lower the great and princely dignity of perfect manhood which is an order of nobility, not inherited, but won by each of us, so far as he consciously seeks good and avoids evil"" (op. cit. Cosans 1994: 147; cf. Cosans 2009: 105)

Zoologist and physiologist William Benjamin Carpenter, in the *British and Foreign Medico-Chirurgical Review*, went in a similar direction:

> "Nobody would think of advancing it as an objection to modern Embryology, that it teaches that the human infant, instead of first coming into existence as a fully-formed though minute *homunculus*, begins life in the condition of the simplest protozoon, and successively acquires those peculiarities of organization which end in constituting him a Man. And we do not suppose that the naturalist who first found out that butterflies and beetles were caterpillars in the earlier stage of their existence, instead of coming out from the egg in the full possession of their insect attributes, was considered on that account less religious than his neighbours. Why, then, should it be regarded as impious to maintain that an analogous development went on during what may be called the life of the world; and that the existing forms of Plants and Animals have originated by genetic descent with modification from those which preceded them, even as the latter did from yet older forms, and so on, back to the beginning of Life on our planet? To deny that such *might* have been the Will of the Creator, is virtually either to deny that His power is constantly exerted in maintaining that regular succession of similar forms, on which the notion of the "permanence of species" is based, or to set limits to the exercise of that power, by asserting that it could not have been exerted in any other mode than that which Man chooses to prescribe." (Carpenter 1860a: 379)

The geologist Frederick Wollaston Hutton, in his review for the *Geologist*, defended the deistic conception of the Darwinian theory:

> "Why should it be considered atheistical to believe the laws of the Great Perfection to be perfect. The inscrutable Eternal cannot err; why then should His laws be so defective and imperfect as to require repeated efforts of creative energy? Is this world like an old watch so much out of order as to require continual oilings and repeated repairs? Why, too, should it be objectionable to consider the laws He has

> given to nature as worthily and incessantly subservient to His will? Or why should it be thought irreligious to believe the Maker of all things in His first designs should have foreseen the necessity of future modifications to future altered conditions, and have provided accordingly in His first type-plans for their future illimitable adaptations to the ever-changing scenes presented in the progress of our earth's ever-altering conditions? Why, indeed, may we not look around us and believe in the universal bowing of all nature hourly, daily, unceasingly to the unerring laws and sustaining power of God? Why should we not see in every change His presence and His will? Why should the high position of man be brought in on all occasions in our natural history researches when we do not at present know of any link which binds him to the brute creation?" (Hutton 1860: 466)

These ontological issues would continue to mark the debate on evolution. Such, the professor of engineering Fleming Jenkin ponders religious issues in 1867 (Jenkin 1867), Wallace does so in his article on mimicry for the *Westminster Review* (Wallace 1870c [1867]), William Thomson (the later Lord Kelvin) in his 1871 Presidential Address to the British Association (Thomson 1891b [1871]) and biologist St. George Jackson Mivart in his public opposition to Darwinism in the 1870s. (Mivart 1871a; Mivart 1871b)

ii. Explanation: modeling and philosophy of science debate

The debate within the broader scientific community covered more logical aspects of Darwin's explanation, with reviews usually[488] addressing concepts beyond their names, distinguishing sub-concepts and discussing their relations. Morris, in the *Dublin Review*, mentioned use and disuse as Connectors in Darwin's dynamic model (Morris 1860: 61-7; cf. Hutton 1861) and provided a detailed account of the model:

> "But what is there in nature that can supply the place of the judgment and will in the fancier, who pairs birds or dogs with the express intention of perpetuating a modification of the original form? According to our author one thing and one thing alone can do it. The multiplication of creatures on the face of the earth is out of proportion to their means of subsistence; this produces what he styles in his title "The Struggle for Life;" and those will survive and multiply that have some advantage over their competitors in the struggle. Every little variation, therefore, if it be advantageous to the individual, and in that case only, will be perpetuated. This involves, it need not be said, the extraordinary powers of inheritance, the singular property that all creatures possess of transmitting their own properties to their progeny. And the moment that we advert to this we are conscious of the very limited nature of our knowledge of the laws that govern inheritance; for if the offspring inherits the parent's qualities, it inherits what the parent received: it has thus the tendency to have and to impart the image of the aboriginal parent, as well as the variations by which the successive generations have diverged from that standard, and, more mysterious still, the tendency to vary more or less has been transmitted

[488] Some reviews provided very little explicit information on Darwin's dynamic model and focused instead on specific issues of the ongoing debate. (Haughton 1973 [1860]; D.T.A. 1860; Murray 1862 [1860]; Huxley 1860b; Huxley 1860a)

> also. What causes one of these tendencies to prevail at one time or under one condition rather than another, so that now the progeny, retaining certain variations in other characters reverts to the ancestral type, now exactly represents its immediate parent, now again shows rather the inherited tendency to vary, we are profoundly ignorant.
> That what Mr. Darwin has well called the Struggle for Life must be very severe, no one who remembers the extraordinary fertility of all nature, can possibly doubt. […] And this struggle will be felt most severely by those who are nearest of kin, for they feed on the same food, and are liable to the same casualties; and thus the tendency throughout nature will always be for those who have an advantage slowly to supplant their congeners, who have to work their way through the same difficulties, but under some less favourable condition. Thus, an increase of one variety will be at the expense of another variety of the same species, and the prevalence of one species will have been effected by the diminution of other species of the same genus, when, as is almost always the case, the field is already fully occupied. And the more numerous a species becomes, the better chance it will have in competition with its congeners; for the greater probability there will be of the appearance of advantageous variations, and the greater strength will be derived from the interbreeding, not too close, but with individuals in slightly varying conditions of life. This gives a decided advantage to the variety over the species, and to the specific form over the generic, giving thus, it is plain, a tendency to variation to all organic beings that are subject to severe competition. With nature, then, it is as with society. As the population increases, there is a greater number of claimants for every employment, and those who are the best fitted for them, or have some other advantage over their rivals, obtain them, while sharp wits are at work devising some change or variety which may tell in their favour." (Morris 1860: 58-60)

Wilberforce, in the *Quarterly Review*, was closer to a metaphorical description, and offered little discussion of logical relations:

> "Now, the main propositions by which Mr. Darwin's conclusion is attained are these:—
> 1. That observed and admitted variations spring up in the course of descents from a common progenitor.
> 2. That many of these variations tend to an improvement upon the parent stock.
> 3. That, by a continued selection of these improved specimens as the progenitors of future stock, its improvements may be unlimitedly increased.
> 4. And, lastly, that there is in nature a power continually and universally working out this selection, and so fixing and augmenting these improvements." (Wilberforce 1860: 231)

A number of reviews began with a short narrative introduction of the Darwinian explanation but addressed the single concepts and their logical relations over the course of the text. (Hutton 1860; Hutton 1861; Carpenter 1860a) Thus, Carpenter, in the *National Review*, built upon metaphorical introduction by a discussion of Variation, Natural Selection, the Struggle for Life and the ensuing Evolution (divergence of character). (Carpenter 1860b: 192, 194-6, 196-7, 197-204, 204)

A number of authors distinguished between the denotative (logical) and connotative (literary) meaning of Darwin's metaphors, for instance Hutton in the *Geologist*:

> "[Darwin] shows that, owing to the rapid increase of animal and vegetable life, by which many more are born each year than can possibly survive, there is a continual warfare going on among them for food and other necessaries. This he calls the 'struggle for life'.
> He then shows that if any animal or plant should have, by variation, any organ or property so modified as to give it some advantage over its fellows in the struggle for life, it will, as a general rule, live longer and produce more offspring; and these offspring will have a tendency to inherit the organ or property modified in the same manner: but if in one of these offspring the organ should be still further modified, it will give him a like advantage over his brethren, and his offspring again will have a tendency to reproduce the organ in its more modified state; and so on. This he calls 'Natural Selection.'
> Mr. Darwin thinks that this, together with the minor causes of habit, use and disuse, climate, &c., are sufficient to account for all the various forms of organic life, by the gradual transmutation of one species into another." (Hutton 1861: 132)

Owen followed the same line. After separating the connotative and denotative component of Darwin's explanation, criticizes Darwin's personification (Owen 1860b: 511) Wollaston's position is similar when he complained in the *Annals and Magazine of Natural History* that

> "…to make 'nature' accomplish anything requiring intelligence and foresight, and other attributes of mind, is nothing more or less than to personify an abstraction, and must be regarded therefore as in the highest degree unphilosophical. […] who is this 'Nature,' we have a right to ask, who has such tremendous power, and to whose efficiency such marvellous performances are ascribed? What are her image and attributes, when dragged from her wordy lurking-place? Is she aught but a pestilent abstraction, like dust cast into our eyes to obscure the workings of an-Intelligent First Cause of all?" (Wollaston 1860: 138; cf. Owen 1860b: 511)

This general coverage of the Darwinian explanation was complemented with a specific line of philosophical coverage for

> "Darwin had both the good fortune and the misfortune to begin his scientific career at precisely that moment in history when philosophy of science came into its own in England." (Hull 1973: 3; cf. Ellegård 1958: 113, 174-97)

His model and explanation of Evolution triggered an extensive discussion on scientific methods, bringing "into view some fundamental problems of philosophy of science. What was a scientific explanation of an event? What was a natural law? What was a cause? What was induction, and inductive proof?" (Ellegård 1958: 175) Darwin triggered a debate on what counted as science and challenged the established standards of what constitutes good scientific practice.

This showed in the reception. Many of the reviews by the broader scientific community addressed philosophy of science aspects in one way or another. (Wollaston 1860; Hutton 1860; Owen 1860b; Huxley 1860b; Thomson 1891b [1871]) Moreover, the *Origin* motivated the three leading philosophers of science to weigh in on Darwin: In 1861, Herschel included a footnote in his *Physical Geography of the Globe*. In 1862, Mill inserted a footnote in the fifth edition of his *System of Logic*, and in 1864 Whewell added a short discussion to the preface of the seventh edition of *Astronomy and General Physics*. (Hull 2003: 181) Neither of them provided an extensive discussion of Darwin. Maybe because they considered it just one of many instance of too hypothetical reasoning and not some interesting new argument which demanded new philosophical strategies? Probably, Whewell, Mill, and Herschel expressed their previously established positions on science rather than positions which were shaped by the reception of Darwin's theory in philosophy of science-respects. (Hull 2003: 169)

iii. Classification: missing links, Man's Place and the Archaeopteryx

The debate within the broader scientific community covered more classificatory issues than the public debate; most[489] reviews went substantially beyond a mere mentioning of the concept of common descent; I count Morris' and Wilberforce's papers as the sole exceptions. (Morris 1860; Wilberforce 1860) Already Duns, in the *North British Review* addressed the difference between the concept of the *scala natura* and the actual, pragmatic mode of classification. He discussed difficulties in classification at length and debated sterility and hybridism as possible criteria for the definition of species. (Duns 1860: 461-5, 484-5)

Among the scientific authors, Hutton, in his two papers for the *Geologist*, presented a schematic diagram which illustrated the development of mollusca from prehistoric times to the Victorian present (Hutton 1860: 470) and discussed a detailed list of 23 biogeographical, paleontological and taxonomic regularities which are covered by Darwin's static model, in both cases explicating the classification. (Hutton 1861: 134-6)

Carpenter, in the *British and Foreign Medical-Chirurgical Review*, provided a lengthy discussion of common descent and applied the concept throughout the text in much detail. (Carpenter 1860a) Wollaston and Carpenter for the *National Review* discussed different definitions of species and developed genealogical – and hence historical – notions. (Wollaston 1860: 133-4; Carpenter 1860b: 189-191) Carpenter specifically claimed that

> "…no species can be fairly admitted as having a real existence in nature, until its range of variation has been determined both over space and through time; and that the species of the mere collector, who describes every form as new which does not precisely correspond with existing definitions, can only be accepted provisionally, to be verified or set aside by more extended research." (Carpenter 1860b: 190)

and explained:

> "… we fully agree with him [Darwin], that individual differences, though hitherto accounted as of small interest to the systematist, are of high importance in any philosophical inquiry into the origin of species, as being the first step towards those slighter varieties which are barely thought worth recording in works on natural history. So varieties which are in any degree more distinct and permanent, are steps

[489] Some reviews do already focus on specific issues of the debate and treat Darwin's model only on the side. (Huxley 1860b; D.T.A. 1860; Haughton 1973 [1860])

> in a regular gradation that leads through more strongly-marked and more permanent varieties to sub-species, and thence to species." (Carpenter 1860b: 209)

Owen, in the *Edinburgh Review*, went one step further. He distinguished the metaphorical concept of an ancestor-heir relation from the observable differences distinguished by anatomists (Owen 1860b: 522-3) and demanded that Darwin not only evoke the idea of a predecessors but specify (define) it, in order to move beyond mere metaphors:

> "Mr. Darwin's statements elude, by their vagueness and incompleteness, the test of Natural History facts. Thus he says:— 'I think it highly probable that our domestic dogs have descended from several wild species.' It may be so; but what are the species here referred to? Are they known, or named, or can they be defined? If so, why are they not indicated, so that the naturalist might have some means of judging of the degree of probability, or value of the surmise, and of its bearing on the hypothesis?" (Owen 1860b: 528, cf. 511)

Just like the public, the broader scientific community discussed the position of Man in Nature – only in greater depth. To them, as to everybody, it was evident that there were undisputable systematic physical affinities of man with the higher apes. However, these affinities did not necessitate that Man had developed from the higher apes. In his pre-Origin works on apes, Richard Owen had always emphasized the anatomical gap between Man and the closest apes and had classified Man in a group of his own, apart from the apes.[490] Still in 1859, Owen had claimed in a paper to the Zoological Society that there exists a

> "much greater difference between the highest ape and lowest man, than exists between any two genera of Quadrumana" (Owen 1866c [1859]:269).

In his early reviews of the *Origin* already, Huxley hinted at his differing position, one which saw gradual differences between different species of Man and different species of apes:

> "In the face of the demonstrable facts, that the anatomical difference between man and the highestof the Quadrumana is less than the difference between the extreme types of the Quadrumanous order…" (Huxley 1860a: 199)

After Owen's sharp critical review of the Origin (Owen 1860b) began a heated public debate of five years. (Cosans 1994: 147; Cosans 2009: 16) Huxley first publicly challenged Owen's classification at the 1860 meeting of the British Association.[491] In January, he specified his criticism in a paper for the *Natural History Review.* (Huxley 1861; cf. Desmond and Moore 1995: 566-7) Owen responded in

490 Towards the end of the 1850s, this debate had gained further steam trough the discovery of the Neanderthal skull near Düsseldorf, in Germany. However, neither this skull nor the 1829 Engis skull from Belgium were considered to bridge the gap between humans and apes. While it was admitted that "… they showed some transitional features, yet [, it was claimed] they were well within the range of variation of present-day human forms, and outside that of the anthropoid apes. […] Thus under no circumstances were the fossil skulls to be accepted as intermediate, they were apes, or they were men, for ape-men could not exist." This position was shared by Huxley. (Ellegård 1958: 300-1) – From today's point of view the Neanderthal skull forms such an intermediate step but clearly is human.

491 For a detailed account of the meetings of the British Association from 1860 to 1872 see (Ellegård 1958:62-94), for the episode on Wilberforce for instance (Himmelfarb 1959: 238-240). However, Ellegård points out that this episode did not stir much attention at the time; its supposedly crucial role in the Darwinian revolution is a later construction.

1861 in the *Athenaeum* and elevated the anatomical problem to one of human descent. (Desmond and Moore 1995: 569) Huxley countered by doing in 1863 what Darwin had not dared and would not dare until 1871: he published on the descent of Man in his *Evidence as to Man's Place in Nature*. (Huxley 1863; Darwin 1871) Owen meanwhile retreated to the position that there was a wide difference between the human and the ape hippocampus and that

> “the apes formed a continuous series of small steps, whereas no intermediate steps linked the chimpanzee with man.” (Ellegård 1958: 306)

The anatomical details of this debate obviously eluded both the public and the broader scientific community and they were often omitted by the two opponents.[492] The minute empirical descriptions on the question all appeared in biological journals, not in the publications of the broader scientific community. Thus, the debate remained in the rather vague sphere of whether there was an "impassable gulf" separating man and ape or not. (Ellegård 1958: 305-6, cf. 50-1, 70, 295-6)

By the mid-1860s, Huxley had “convinced the larger scientific community that Owen was wrong” with respect to the *hippocampus minor*. (Cosans 2009: 117) This, however, did not put an end to the debate on human descent. Rather, in correspondence with the public discussion, Darwin’s opponents pointed to alleged unique human qualities to support their point. The human mind, soul, reason and morality were supposed to document just how big the gap was.

Towards the end of the 1860s, this argument made Wallace switch sides. In 1869, he spoke at the British association and published an article in the *Quarterly Review*, dissociating himself from Darwin with regard to the Descent of Man. He further elaborated this criticism in a chapter of his 1870 collection *Contributions to the Theory of Natural Selection*. In a chapter named *The Limits of Natural Selection as Applied to Man*, Wallace claimed that natural selection cannot explain the development of mental faculties. (cf. Wallace 1870d) Obviously, it was a heavy blow to Darwinians to lose the virtual co-author of the theory of evolution on this issue.

Another important classification issue caused much less of a stir. In 1861, in Solnhofen in Germany, a fossil had been discovered which seemed to display features of both birds and reptiles. It was acquired by Owen who had it shipped to London and provided the first description and classification of it. (Owen 1863 [1862]: 38, 43; cf. Rupke 1994: 71-74) Owen named the fossil Archaeopteryx and classified it as a reptile – not as a bird or an intermediate. Again, Huxley would rise to contradict Owen, notably in an 1862 address to the Geological Society. (Rupke 1994: 71-4)

iv. Empirics: sketches and illustrations

Like the public, the broader scientific community received no substantial information on the empirical dimension of Darwin’s theory. Examples in the reviews of the broader scientific community were usually longer and more detailed than in the public debate. However, most of the examples were still sketches and some examples of artificial selection. (Haughton 1973 [1860]; Morris 1860; Duns 1860; Wilberforce 1860; Jenkin 1867; Wollaston 1860; Carpenter 1860b; Hutton 1860; Murray 1862 [1860]; Huxley 1860b; Huxley 1860a) Very few articles specified how Darwin’s theory related to findings of paleontology, biogeography, anatomy or morphology, and even these articles provided

[492] Already at the 1860 meeting of the British Association, Huxley had “declined to enter into a discussion of facts at the meeting, but promised to present them elsewhere.” (Ellegård 1958: 92)

highly aggregated representations of actual descriptions of empirical phenomena. (Carpenter 1860a; Owen 1860b; D.T.A. 1860; Hutton 1861) Empirical issues were confined to the journals of Darwin's immediate scientific community, the biologists. Therefore, as with the public, members of the broader scientific community did not receive the necessary information for assessing the empirical fit of Darwin's theory. This showed in the criteria by which they assessed Darwin's theory. (see below)

v. Synthesis

In sum, like the public, the broader scientific community received the connotative dimension of Darwin's theory, i.e. its interpretation and narration as well as their ontological implications. However, they also received its logical component, i.e. the main concepts and sub-concepts of Darwin's static and dynamic model. With regard to empirics, the broader scientific community received more empirical examples in greater depth but they did not receive enough information to grasp the empirical meaning of Darwin's theory in the different branches of biology.

4.2.2 By which criteria was the Darwinian theory assessed?

The broader scientific community had a deeper understanding of the Darwinian theory and grasped more of its possible implications. Consequently, opponents pursued more complex lines of criticism to avert these implications. On one hand, they highlighted how much Darwin's theory collided with Victorian world views (i) but also with established standards of scientific explanation and theorizing (ii, iii) and, finally, theories in other fields of science (v). Moreover, they attempted to uncover inconsistencies in the model (iv) and expressed classificatory and semi-empirical objections to it (v, vi).

i. Conflicts with Victorian Weltanschauung: God and his purpose

Like their laymen counterparts, many critics within the immediate scientific community opposed Darwin's theory on religious or philosophical grounds. Such concerns were sometimes uttered indirectly by scientists but very openly by the laymen writers in this group. Morris, in the *Dublin Review*, lamented that a book which seemed so "valuable" and "genuinely scientific", with a basis of fact "so unusually broad and comprehensive" and a reasoning "so dispassionate", that such a book

> "should be marred by the introduction of so gratuitous and so repulsive an idea, or that the theory should be carried to such unreasonable lengths.." (Morris 1860: 59)

Wilberforce, in his sharper tongue, portrayed the ontological implications of Darwin's theorizing as outright absurd in the *Quarterly Review*:

> "Man, beast, creeping thing, and plant of the earth, are all the lineal and direct descendants of some one individual ens, whose various progeny have been simply modified by the action of natural and ascertainable conditions into the multiform aspect of life which we see around us. This is undoubtedly at first sight a somewhat startling conclusion to arrive at. To find that mosses, grasses, turnips, oaks, worms, and flies, mites and elephants, infusoria and whales, tadpoles of to-day and venerable saurians, truffles and men, are all equally the lineal descendants of the

> same aboriginal common ancestor, perhaps of the nucleated cell of some primæval fungus, which alone possessed the distinguishing honour of being the 'one primordial form into which life was first breathed by the Creator'— this, to say the least of it, is no common discovery—no very expected conclusion.” (Wilberforce 1860: 231)

and wondered aloud how a Christian could advocate such ideas on the descent of Man:

> “Mr. Darwin writes as a Christian, and we doubt not that he is one. We do not for a moment believe him to be one of those who retain in some corner of their hearts a secret unbelief which they dare not vent; and we therefore pray him to consider well the grounds on which we brand his speculations with the charge of such a tendency. First, then, he not obscurely declares that he applies his scheme of the action of the principle of natural selection to MAN himself, as well as to the animals around him. Now, we must say at once, and openly, that such a notion is absolutely incompatible not only with single expressions in the word of God on that subject of natural science with which it is not immediately concerned, but, which in our judgment is of far more importance, with the whole representation of that moral and spiritual condition of man which is its proper subject matter. Man's derived supremacy over the earth; man's power of articulate speech; man's gift of reason; man's free-will and responsibility; man's fall and man's redemption; the incarnation of the Eternal Son; the indwelling of the Eternal Spirit,—all are equally and utterly irreconcilable with the degrading notion of the brute origin of him who was created in the image of God, and redeemed by the Eternal Son assuming to himself his nature. Equally inconsistent, too, not with any passing expressions, but with the whole scheme of God's dealings with man as recorded in His word, is Mr. Darwin's daring notion of man's further development into some unknown extent of powers, and shape, and size, through natural selection acting through that long vista of ages which he casts mistily over the earth upon the most favoured individuals of his species.” (Wilberforce 1860: 258-9)

In the broader scientific community, objections regularly found their form in suggestions for amendments to the concept of Natural Selection. Some of them had no marked divine element, yet most were distinctly Christian. And all aimed at complementing the Purpose and the Agent in Darwin’s narrative[493]:

> “Many philosophers and scientists were willing to accept evolutionary theory if only Darwin would admit divine providence. Without it they felt trapped between inexorable law and blind chance. The terminology of this position varied, but the message was always the same. Some maintained that some phenomena were law-governed, other phenomena not. Others maintained that all phenomena were law-governed. In either case, God instituted these laws and guided their action. A universe governed by divinely Instituted law did not seem so cold and barren. Add periodic miracles and the world-picture became even more intimate. Exclude God, and both accidental and law-governed phenomena became equally ‘accidental’, given the peculiar terminology of the time.” (Hull 1973: 60)

[493] Note that I have identified these two elements as crucial in any scientific narrative. (see section 2.1.4)

I will systematize the different suggestions according to the elements of Darwin's model in order to highlight where the introduction of Purpose and Agent was suggested.[494]

First, the problem with Darwin's Struggle for Life was its wastefulness. Countless individual organisms were born and only a fraction of them would survive to reproduce and again a fraction of them would bear Favourable Variations. Darwin's opponents, however, found it "impossible to believe that God had so ordained that His created beings would not find subsistence enough in the place where He had put them" (Ellegård 1958: 118)

One solution to this conflict was to be to deny injurious variations and all those individuals that did not succeed in reproducing. If one counted only the successful results one needed not "entertain the idea that any trial and error process took place." (Ellegård 1958: 123) However, it was hard to uphold this view in the face of empirical evidence. The geologist Frederick Wollaston Hutton, in the *Geologist*, suggested steering a middle course and emphasizing purpose and design as opposing forces to the wasteful struggle:

> "The beautiful perfection of our bodies – the wonderful adaptations in the forms of animals to render them efficient for their purposes of life seem so skilfully planned, that it is impossible to regard them as effects of chance, and not as inapproachably perfect designs. If we could accept the transmutation doctrines, we must concede the transmutatory laws as of pre-eminently divine origin and maintenance, purposely conceived to be ever forcibly acting in direct antagonism to the necessity of destruction and change, to which all nature seems subject." (Hutton 1860: 472)

Another, more sophisticated suggestion, was to seek the Struggle's divine purpose not in this world, but in one of Leibniz' possible worlds. If, in one of the infinite possible worlds, Evolution was harmonious and ordered it would be purposeful in this possible world. And this would justify the lesser copy in the actual world. (Ellegård 1958: 136-7) Unsurprisingly, this solution failed to convince the masses.

Second and more widespread, Purpose was assigned to the Organisms undergoing Evolution; this occurred in several forms, which were often combined and referred back to previous evolutionists like Demaillet, Erasmus Darwin, Lamarck or Chambers. However, this move usually did not imply assigning volition to the organisms. (Ruse 1971: 329-30, Ellegård 1958: 278) Instead, Evolution was sometimes ascribed to an "unconscious craving of the race, or even of Life as such". (Ellegård 1958: 278) Or, "the internal forces of the organism(s], or … fixed laws of development … were said to push the forms inevitably along the road of progressive change." (Ellegård 1958: 268, cf. 276-7) Thus, such interpretation set in on Darwin's blurring of the distinctions between Individual, Variety and Species. (see sections 3.4.2, 3.4.3)

Moreover, what most of Darwin's critics saw behind the craving of the race, or the internal forces or the laws of development was a Vital Force; and this Vital Force was either identical to God or acting on his behalf. This line of argument can again be found with Hutton in the *Geologist*:

> "In this light we might accept it, and trace back the natural divergence of life-forms to the first vital force [sic!] thrown off from the hand of the Creator, who threw off with an eternal and ever enduring force the vast clouds of vapours that have in the

494 I am leaving out Evolution for it is the element to be explained.

> roll of ages collapsed into the myriads of worlds and suns that swarm in the heavens above and around us-of which we can neither see the limits nor conceive the expanse-but which may yet be the smallest and least wonderful of all the myriads of world-clusters with which the same great Creator has stardusted His course through the realms of boundless and interminable space." (Hutton 1860: 471-2)

In the extreme, such views could lead to a totally deterministic world in which God had foreseen both the physical changes of the world and the organisms' adaption to them. On such view,

> "God was not considered as constantly intervening to achieve the perfect adaptations of living forms to their environment. Instead, he was conceived to have foreseen in advance all the various changes that would occur both in the organic and inorganic world, and to have provided the first created life-germ [sic!] with an internal 'law of development', which would carry its descendants infallibly in the direction beneficial to each. In other words, instead of spreading out the Divine interventions in time, they were concentrated into one single, and therefore the more wonderful event: the original creation of the first living organism, provided with a capability of development which would carry it further and further, and ultimately to the height reached by man." (Ellegård 1958: 132, cf. 135-6)

This point was taken up by Owen who argued in the *Edinburgh Review* that such a wonderful event is even more miraculous than the idea of continued creation:

> "[Darwin] leaves us to imagine our globe, void, but so advanced as to be under the conditions which render life possible; and he then restricts the Divine power of breathing life into organic form to its minimum of direct operation. All subsequent organisms henceforward result from properties imparted to the organic elements at the moment of their creation, pre-adapting them to the infinity of complications and their morphological results, which now try to the utmost the naturalist's faculties to comprehend and classify." (Owen 1860b: 511; cf. Cosans 2009: 100)

Third, another possibility of amending Darwin's model was to assign purpose to the Explaining Phenomena, i.e. Variation or Environmental Change. Such, Variations and Environmental Change were considered Agencies of the Agent God. As just detailed, in deterministic accounts of evolution, Darwin's critics sometimes claimed that all physical changes, the external circumstances acting on the organism were foreseen by God, hence purposeful. (Hull 1973: 62; Ellegård 1958: 132, cf. 268, 276-7) Such an argument shines through in Hutton's suggestion in the *Geologist* to consider all changes in nature as pre-ordained and lawful:

> "We should incline to think that a theory which proposed to view the development of the required races or species as concurrent with the physical changes rendering necessary their presence,-and as consequently necessarily developed by natural laws, like we see everywhere else around us so wisely and immutably preordained, apparently from the be inning of all things, by the Almighty Designer,-would be preferable to the idea of direct creations, and affording a more reasonable reply than the mere assertions of the miraculous agency with which our query is so commonly met." (Hutton 1860: 465)

More popular were reinterpretations of Variation. For instance, critics could deny the existence of Injurious Variations (see above) or they could attempt to relieve Variation of its randomness, claiming that

> “there were two sorts of variability. Ordinary variations one admitted, might be random, i.e., sometimes good and sometimes bad. But they never led to specific change. But there were other variations, of another type, which did produce new species: and these variations, it was claimed, were directed and designed.” (Ellegård 1958: 126, cf. 123)

Alternatively, the law of heredity was supposed to contain “an ‘instruction’ that … it should permit all improvements” (Ellegård 1958: 246) or Favorable Variations were supposed to be endowed “with a special power of being transmitted undiluted to the offspring. In other words, even though only one of the parents was improved, all the offspring would exhibit the favourable peculiarity in its full force.” (Ellegård 1958: 245)

Fourth and finally, one could amend the Connector of Darwin’s model itself: Natural Selection. This rarely meant understanding Nature as Agent. (cf. Ruse 1971: 329-30) Instead, according to a more popular idealist argument, Natural Selection was understood as an “operative cause” in the sense of conceptual realism. (Ellegård 1958: 245) Thus ‘natural selection’ was supposed to denote not sequences of events but an abstract entity which acted on behalf of the Final Cause, God. (see below) Besides, the process of Natural Selection was frequently understood as a purposeful law, i.e. a law designed by God as part of his Agency:

> “Granted, for the sake of the argument, that all sorts of variation occur, was it not evident that intelligence and forethought were needed to select the useful variations? Darwin's own parallel of man's selective breeding of domestic animals was cited against him. […] A religious journal expressed the same view: ‘The action which [Darwin] attributes to natural selection is clearly regulated action. Why should natural selection favour the preservation of useful varieties only? Such action cannot be referred to blind force; it can belong to mind alone’." (Ellegård 1958: 125-6)

While this conception portrayed God as an, albeit almighty, distant Agent, there were also demands to include a hands-on God who would constantly and directly interfere in the process of Evolution. Such, Herschel claimed:

> “Equally in either case, an intelligence, guided by a purpose, must be continually in action to bias the directions of the steps of change – to regulate their amount – to limit their divergence – and to continue them in a definite course.” (op. cit. Hull 1973: 61)

In sum, the amendments to Darwin’s explanation added an Agent and a Purpose to Darwin’s narrative by re-interpreting the Input and the Connector. Thus, the amendments provided answers to the questions why selection happened and what it happened for, they introduced God or Nature as an Agent (and rarely the Organisms) and they interpreted Natural Selection, Variation and Environmental Change as the means by which the Agents achieved their Purpose. Overall, Darwin’s critics, through an interpretation of his terms, transformed Darwin’s model into a narrative compatible with their Weltanschauung.

ii. Conflicts with meta-models: miracles, verae causae, design

Darwin put at least three concepts of Victorian philosophy of science at stake: miracles, the argument from Design and the idealist idea of a causal explanation. For each concept, defenders rose and opposed Darwin. First, in Mid-Victorian science miracles where fully legitimate explanations. As soon as an event could not be explained by natural laws it was considered a result of divine intervention and called ‘miracle’. Darwin rejected such classifications as explanations, refusing “to take into account anything but the facts of experience”. (Ellegård 1958: 144) Thus, he stripped a whole class of events of their Purpose and of an Agent who produced them. (cf. Ellegård 1958: 141-154)

The zoologist Wollaston, in the *Annals and Magazine of Natural History*, defended miracles in arguing that one single creation and the continuous operation of an Agent Nature – as they are suggested in the Origin – are no less miraculous than many independent creations:

> “To our mind, the wonder consists in the act at all, and not in the number of times that it may have been repeated: for a Being that can create may surely do so as often as He pleases; and we have no right therefore to limit that act,—at any rate on the question of its probability; for, if we admit that it has been exerted so much as once, there is no à priori reason why it should not have been a million times repeated, or why, if He had so willed it, it might not, at some period or other, have been in even constant operation. Such an idea is difficult to conceive, we admit; but (be it remembered) it is not one atom more so than the process of creation at all: and with respect to the marvel of it (so difficult, and impossible, to understand), it may be well to recollect that it has been contended by some of our greatest minds that even the sustaining power of Nature is, in point of fact, as much of a miracle as the creative power.” (Wollaston 1860: 142)

Duns, in the *North British Review* wondered aloud why science wanted to get rid of miracles at all, why there should not be considered satisfactory explanations[495]:

> “The question of the presence of miracle, at various points in the history of the earth, is one which has been, with a strange want of logic, almost universally regarded by eminent men with suspicion. Why? We suppose very few, if any, not even excepting Mr Darwin, would be willing to deny that there has been the exercise, at some period of the earth's history, of creative power,—in a word, miracle. But if you acknowledge its presence at any one point, why be suspicious of it, or deny its probability, at any after-point in the history? If in every respect you find, that what demanded a miracle at A, is again found existing at E, after having ceased to be before it again made its

[495] Criticism of miracles was expressed by Hutton (Hutton 1860: 295-6) and by Huxley: “I have said that the man of science is the sworn interpreter of nature in the high court of reason. But of what avail is his honest speech, if ignorance is the assessor of the judge, and prejudice foreman of the jury? I hardly know of a great physical truth, whose universal reception has not been preceded by an epoch in which most estimable persons have maintained that the phenomena investigated were directly dependent on the Divine Will, and that the attempt to investigate them was not only futile, but blasphemous. And there is a wonderful tenacity of life about this sort of opposition to physical science. Crushed and maimed in every battle, it yet seems never to be slain; and after a hundred defeats it is at this day as rampant, though happily not so mischievous, as in the time of Galileo.” (Huxley 1860a: 199)

> appearance, first at B, second at C, and third at D, is there anything to forbid the conclusion, that at every one of these stages there was miraculous action? One says, it is not God's usual way of working. But we would have needed to have witnessed the change from one well-marked epoch to another, to entitle any one to make such an answer. It would be a waste of power, adds another. But, if intelligence is not to be suffocated in the blackhole of rank atheism, there must have been ten thousand instances of such waste of power in the introduction of new species. This form of answer is even less satisfactory than the other; for it ignores the fact, that with an Omnipotent One there can be no waste of power. But, reply others, you find in the species of successive fauna, very many, with only the slightest differences to distinguish them, and others you find continue through more faunas than one. The answer to both these statements, we believe, is contained in the remarks made in reply to the second objection. We conclude, then, that all geology testifies that species are permanent; that they have continued so under all varieties of influence; and that, in every case, they have been introduced by the miraculous power of a personal God, who is the Almighty and Omniscient One revealed to man in the Bible. Mr Darwin's work is in direct antagonism to all the findings of a natural theology, formed on legitimate inductions in the study of the works of God; and it does open violence to everything which the Creator Himself has told us in the Scriptures of truth, of the method and results of His working." (Duns 1860: 485-6)

Physicist William Thomson mentions them in a theoretical excurse on explanations:

> "Is the sun a miraculous body ordered to give out heat and to shine for ever? Perhaps the sun was so created. He would be a rash man who would say it was not—all things are possible to Creative Power. But we know also, that Creative Power has created in our minds a wish to investigate and a capacity for investigating; and there is nothing too rash, there is nothing audacious, in questioning human assumptions regarding Creative Power. Have we reason to believe Creative Power did order the sun to go on, and shine, and give out heat for ever? Are we to suppose that the sun is a perpetual miracle? I use the word miracle in the sense of a perpetual violation of those laws of action between matter and matter which we are allowed to investigate here at the surface of the earth, in our laboratories and mechanical workshops." (Thomson 1891a [1868]: § 21)

Second, the argument from Design was popular not merely with the public, but also among scientists. It is supported by Murray in the *Proceedings of the Royal Society of Edinburgh*:

> "Now, I cannot believe in such doctrine. When I look at the anatomy of any part of the body, and see exactly the same mechanism and Contrivances had recourse to which a mechanician [sic!] would have used to secure similar results, I cannot bring myself to believe that it is fortuitous, or other than evidence of the prevalence of direct design. A belief in such design I should be most loath to surrender, and I am therefore glad that, on other grounds, viz. the legitimate result of the argument already discussed, I have come to be of opinion that Mr Darwin's theory is unsound, and that I am to be spared any collision between my inclinations and my convictions." (Murray 1862 [1860]: 291)

by Hutton in the *Geologist*:

> "We should incline to think that a theory which proposed to view the development of the required races or species as concurrent with the physical changes rendering necessary their presence,—and as consequently necessarily developed by natural laws, like we see everywhere else around us so wisely and immutably pre-ordained, apparently from the beginning of all things, by the Almighty Designer, —would be preferable to the idea of direct creations, and affording a more reasonable reply than the mere assertions of the miraculous agency with which our query is so commonly met." (Hutton 1860: 465)

and by William Thomson (the later Lord Kelvin) in his 1871 Presidential Address to the British Association, a discussion of the Darwinian theory at large:

> "I have always felt that this hypothesis does not contain the true theory of evolution, if evolution there has been, in biology. […] I feel profoundly convinced that the argument of design has been greatly too much lost sight of in recent zoological speculations [for] … overpoweringly strong proofs of intelligent and benevolent design lie all round us, and if ever perplexities, whether metaphysical or scientific, turn us away from them for a time, they come back upon us with irresistible force, showing to us through nature the influence of a free will, and teaching us that all living beings depend on one ever-acting Creator and Ruler." (Thomson 1891b [1871], cf. Pulte 1995: 126)

Third, to the idealists Causes and concepts as the Vital Force were substantial entities, they had an existence. (Ellegård 1958: 179-80; Bowler 1990: 203) Causes had to be *verae causae*, true causes. Herschel had famously claimed that explanations had to refer to causes "recognized as having a real existence in nature, and not being mere hypotheses or figments of the mind" (Herschel 1831: 144)[496] Empiricists like Darwin[497], however, treated causes as logical fictions. Huxley drily remarked that "all we know about the 'force' of gravitation, or any other so-called 'force' is that it is a name for the hypothetical cause of an observed order of facts." (op. cit. Ellegård 1958: 181) Darwin himself stated his opposition to such conceptual realism most clearly in the 3rd edition of the *Origin*:

> "It has been said that I speak of natural selection as an active power or Deity; but who objects to an author speaking of the attraction of gravity as ruling the movements of the planets? Every one knows what is meant and is implied by such metaphorical expressions; and they are almost necessary for brevity. So again it is difficult to avoid personifying the word Nature; but I mean by Nature, only the aggregate action and product of many natural laws, and by laws the sequence of events as ascertained by us." (Darwin 1861: 85)

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[496] The problem was to determine just what qualifies a cause as a 'true cause'. (Hull 2003: 175)

[497] Note that, during "the Darwinian controversy Darwin's supporters quite consistently sided with the empiricists, while his opponents almost equally consistently took the idealist line. The Darwinians found philosophical support in the writings of J. S. Mill, and the long British empiricist tradition, while the anti-Darwinians found theirs in the idealistic philosophical tradition from Plato onwards, and in the writings of the foremost philosopher of science of the age, William Whewell." (Ellegård 1958: 175) Hull distinguishes empiricists and rationalists but I find Ellegård's distinction more appropriate. (Hull 1973: 67)

To his critics, Darwin could not provide an acceptable account of what caused Evolution. To the mainstream idealist philosophy the task of causal scientific explanations consisted in tracking causal chains back to their beginning thus revealing the Supreme Cause or Final Cause: God. Idealist philosopher William Whewell claimed that

> "In contemplating the series of Causes which are themselves the effects of other causes we are necessarily led to assume a Supreme Cause in the Order of Causation, as we assume a First Cause in Order of Succession." (op.cit. Ellegård 1958: 178-9)

and considered both the Supreme and the First Cause names for God. (Ellegård 1958: 178-9, cf. Hull 1973: 56) Thus Sedgwick demands whether natural selection is a 'true cause', Owen goes a long way with him, Wollaston and Hutton both mention true causes. (Sedgwick 1973 [1860]: 161-4; Owen 1860b: 177, 179-80; Wollaston 1860: 137; Hutton 1860)

In sum, the *Origin* could not deliver what the idealists wished for in a scientific explanation. Therefore, Darwin's opponents demanded amendments to or corrections of the model of Natural Selection or they would not accept it as an explanation of Evolution.

iii. Conflicts with meta-models: induction and hypotheses

Beyond defending notions of miracles and true causes, anti-Darwinians based their critique of Darwin's theory on the opposition of induction and hypotheses. Their general accusation was that Darwin's theory or at least parts of it were speculative and hypothetical, that Darwin had not followed the principles of Bacon and Newton. (Ellegård 1958: 189; Lynch 2001: xi) This line of criticism can be found in virtually all of the early reviews of the Origin.

Both Carpenter and Hutton once refer to Darwin's theory or parts of the theory as speculation; (Carpenter 1860a; Hutton 1860) Wilberforce employs the term throughout his text in the *Quarterly Review* and reverend Haughton, in his review for the *Natural History Review*, tells an entire story of speculation which link Darwin to a line of speculators from Lamarck and Buffon to the old Romans. (Haughton 1973 [1860]; Wilberforce 1860) To William Thomson, much of the work of geology and biology was speculation and lacked sufficient empirical support; he maintains this throughout his interventions in the debate on the age of the earth. (see below) It can also be found with his collaborators and friends, physicist Peter Guthrie Tait and professor of engineering Fleming Jenkin. (Thomson 1864 [1862]; Thomson 1862; Thomson 1866; Thomson 1869; Thomson 1891a [1868]; Jenkin 1867; Tait 1869; cf. Pulte 1995: 113, 116)

Particularly harsh was Richard Owen's criticism on this point. In his article for the *Edinburgh Review*, he refers to the Darwinian theory as a mere hypothesis and opposes Darwin's theorizing to his own brand of sober inductive research:

> "In a joint paper on the tendency of varieties to form species by natural means of selection, [Darwin] writes:— 'Any minute variation in structure, habits, or instincts, adapting the individual better to the new conditions, would tell upon its vigour and health. In the struggle it would have a better chance of surviving, and those of its offspring which inherited the variation would also have a better chance. Let this work go on for a thousand generations, and who will pretend to affirm,' asks Mr. Darwin, 'that a new species might not be the result?'

> Thereupon is adduced the imaginary example of dogs and rabbits on an island, which we have already cited. Now this, we take leave to say, is no very profound or recondite surmise; it is just one of those obvious possibilities that might float through the imagination of any speculative naturalist; only, the sober searcher after truth would prefer a blameless silence to sending the proposition forth as explanatory of the origin of species, without its inductive formation.“ (Owen 1860b: 516)

> “all these instances of exaggerated peculiarities of structure and instinct are manifested in individuals which never could have transmitted them.
> No zoologist, perhaps, is better acquainted with these fatal exceptions to his principle of the organisation of species by hereditary transmission of variation-characters, than Mr. Darwin. He could not, with any pretension to free and candid discussion, pass over the chief instances which have checked the natural disposition of all zoologists to obtain inductively an infallible idea of the most mysterious phenomena of their science. But the barrier at which Cuvier hesitated, Mr. Darwin rushes through….“ (Owen 1860b: 525)

> „…instead of satisfying our craving with the mature fruit of inductive research, Mr. Darwin offers us the intellectual husks above quoted, endorsed by his firm belief in their nutritive sufficiency!” (Owen 1860b: 526)

However, as the debate evolved, it became clear within the scientific community that one could not condemn the use of hypotheses[498] per se. After all, both the empiricist John Stuart Mill and the idealist William Whewell acknowledged their necessity for science.[499] (Ellegård 1958: 191, Hull 1973: 5) Instead, anti-Darwinians began to contest the content of Darwin’s hypotheses:

> “Whewell demanded that [hypotheses] should be ‘clear and appropriate’, terms which he discusses at some length. The first of these requirements put a premium on mathematical concepts - such as gravity -, the second, which Whewell himself recognized was difficult to apply, was in reality a conservative criterion, serving to exclude such hypotheses as clashed with established view. As instances of inappropriate conceptions he cited mechanical and chemical hypotheses to explain vital powers.” (Ellegård 1958: 184)

Likewise, the *Dublin Review* recommended scientists to mistrust those hypotheses that clash “with portions of truth already firmly established”, i.e. the established Weltanschauung. (Ellegård 1958: 191) Overall, Herschel, Whewell and Mill agreed on the estimate that Darwin’s theory, at best, was not good enough, and certainly not as credible as the theory of creation by a designing intelligence.

498 Huxley defended Darwin on this point already in his 1860 article in the *Westminister Review*, claiming that: “There cannot be a doubt that the method of inquiry which Mr. Darwin has adopted is not only rigorously in accordance with the canons of scientific logic, but that it is the only adequate method. Critics exclusively trained in classics or in mathematics, who have never determined a scientific fact in their lives by induction from experiment or observation, prate learnedly about Mr. Darwin's method, which is not inductive enough, not Baconian enough, forsooth, for them. But even if practical acquaintance with the process of scientific investigation is denied them, they may learn, by the perusal of Mr. Mill's admirable chapter ‘On the Deductive Method,’ that there are multitudes of scientific inquiries in which the method of pure induction helps the investigator but a very little way.” (Huxley 1893d: 465)

499 Interestingly, Darwin did make at least one assumption less than his predecessors. Just like Laplace, Darwin omitted the hypothesis of assuming the existence of God.

At worst, it was not a legitimate scientific theory at all." (Hull 2003: 169) Herschel uttered his dismissal thus:

> "We can no more accept the principle of arbitrary and casual variation and natural selection as a sufficient account, per se, of the past and present organic world, than we can receive the Laputan method of composing books … as a sufficient one of Shakespeare and the Principia. Equally in either case, an intelligence, guided by a purpose, must be continually in action to bias the directions of the steps of change - to regulate their amount – to limit their divergence - and to continue them in a definite course." (Herschel 1831: 12)

Thus, the seemingly philosophical debate on scientific methods turned out to be about world views. Religious science clashed with irreligious science and each side defended their conception of the world and what role science should play in it. (Ellegård 1958: 337, Hull 1973: 65) In sum, the Anti-Darwinian line of argument was to reveal the irreligious Weltanschauung suggested by Darwin and his allies[500] and to reject it for its philosophical and religious implications.

iv. Alleged inconsistencies: evolution to a limit

Positive arguments for amendments of Purpose and Agent were flanked by attempts to dismiss Darwin's model by revealing technical inconsistencies in it. Such attempts were either mathematical or logical objections and they were championed by

> "…a 'North British' group composed of Glasgow professor of natural philosophy William Thomson, Scottish natural philosophers James Clerk Maxwell and Peter Guthrie Tait, and the engineers Fleeming Jenkin and Macquorn Rankine. These men found the perceived anti-Christian materialism of the metropolitan scientific naturalists quite distasteful, and they were prepared to enter into an alliance with Cambridge Anglicans to undermine the authority of Huxley and his allies. They promoted a natural philosophy in harmony with, though not subservient to, Christian belief." (Lightman 2007: 7-8)

These men pursued two lines of technical objections against the Darwinian model. First, they claimed that the small random variations described by Darwin could not produce evolution, i.e. substantial changes in larger populations. Second, they argued that the earth was too young to allow for the slow-working natural selection to produce evolution.

The first argument was brought forward by Fleeming Jenkin in his 1867 Review of the *Origin* in the *North British Review*. He argued that variation occurred within limits and could, therefore, not lead to evolution as described by the Darwinists:

> "Although many domestic animals and plants are highly variable, there appears to be a limit to their variation in any one direction. This limit is shown by the fact that new points are at first rapidly gained, but afterwards more slowly, while finally no further perceptible change can be effected. Great, therefore, as the variability is, we are not

[500] Ellegård points out that "the leading Darwinians of the time – Darwin, Huxley, and Hooker - were all agnostics (a term invented by Huxley), while the leading anti-Darwinians, Owen and Mivart, were decidedly religious men." (Ellegård 1958: 337)

> free to assume that successive variations of the same kind can be accumulated." (Jenkin 1867: 311; Ruse 1979: 204)

Jenkin supported his argument by the claim that single large variations ("sports") could never shift whole populations in new directions[501] – despite their being more likely to survive and reproduce than other individuals:

> "The advantage, whatever it may be, is utterly outbalanced by numerical inferiority. A million creatures are born; ten thousand survive to produce offspring. One of the million has twice as good a chance as any other of surviving; but the chances are fifty to one against the gifted individuals being one of the hundred survivors. No doubt, the chances are twice as great against anyone other individual, but this does not prevent their being enormously in favour of some average individual." (Jenkin 1867: 314)

Furthermore, even successful reproductions of favourable variations would inevitably be diluted in the much larger surrounding population. Figuratively speaking, one Grizzly Bear could not blacken a colony of Ice Bears. (cf. Ellegård 1958: 242) Underlying Jenkin's argument was the concept of *Blending Inheritance*, the idea that in reproduction the parental characters were blended in the offspring. This comprised

> "the intermediate expression of two different parental characters in the offspring (a white-flowered plant producing a descendant with pink flowers when crossed with a red-flowered plant); offspring being a mixture of unblended parental characters (a child could have his father's eyes, hair, and walk but his mother's smile, skin color, and disposition); and the statistical contribution made by a variation within a population or a succession of populations." (Jenkin 1867: 345)[502]

Darwin reacted to such criticism by shifting his focus from strongly marked yet infrequent variations to less strongly marked but frequent ones as accounting for most of the preserved variations. (Ellegård 1958: 244-5; Hull 1973: 302-3; Ruse 1979: 211; Bowler 1990: 198-200)[503] Hence, he chose to modify the Input or Situation Type of his model instead of its Connector: Natural Selection was not be touched upon. This choice implied, however, that Darwin needed more time: if variations were less strongly marked, it would take more generations to produce the same evolutionary effects. This drove Darwin in the second flank of the North British attack.

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501 This problem was solved only in the 1950s when population geneticists have begun modeling the effects of individual variations on entire populations. Ronald Aylmer Fisher (1890-1962) is one of the famous scientists to have contributed to this strand of research.

502 Modern genetics tells us that Jenkin's argument is unfounded; parental characters do not blend in their offspring but are both preserved in the genotype – unless a mutation occurs. (This is not easy to discern as only the dominant characteristics are visible in the phenotype. For a more complete discussion of the issue, see for instance (Hull 1973: 345-349).) However, in the 1860s, such arguments caused Darwin severe trouble, as he admitted in a letter to Wallace: "F. Jenkin argued in the 'North British Review' against single variations ever being perpetuated, and has convinced me, though not in quite so broad a manner as here put. I always thought individual differences more important; but I was blind and thought that single variations might be preserved much oftener than I now see is possible or probable." (Darwin 1869, op. cit. Hull 1973: 302-3)

503 I do not discuss the concept of pangenesis here, because it never made its way into the *Origin.*

v. *Conflicts with physical models of the age of the earth*

In the first half of the 19th century, geology had not bothered to provide quantitative estimates of its timescales: Lyell considered geological time to be indefinite. (Desmond and Moore 1995: 638) Accordingly, Darwin had taken such virtually infinite time spans as his starting point in the *Origin*[504], still, he "thought it necessary merely to illustrate, not prove, the vastness of geological time." (Burchfield 1974: 305)

In 1860, the lack of proof began to fall back on Darwin. In his *Life on the earth*, the geologist John Phillips attacked Darwin's estimate of the age of the Weald, a geological formation in South East England. In the first edition of the *Origin* had calculated the Weald to be approximately 300 years old; Phillips, however, offered 1.3 million years, a fraction of Darwin's estimate. In the same go, he claimed that the absolute earth time would not exceed 95 million years. (Philips 1860) Yet, other geologists disagreed with Phillips estimations, taking the debate out of the realm of both the public and the broader scientific community (Ellegård 1958: 87, 236): If the supposed specialists, the geologists, could not agree and "were on the whole hardly in a position to translate their time-scale into absolute figures", what weight was to be attributed to Phillips' objection? (Ellegård 1958: 236) Still, in the third edition of the *Origin* in April 1861, Darwin omitted the calculation and withdrew to vaguer statements. (Ruse 1979: 222-3; Burchfield 1974: 305-7)

Shortly thereafter, a more formidable foe entered the ring, girt with modern mathematics and the fundamental laws of physics – "which to most scientists seemed far more reliable than the flimsy theories of the geologists." (Bowler 1990: 194; cf. Pulte 1995: 126-7) William Thomson, the later Lord Kelvin, came to question Darwin's starting point and his mentor, Charles Lyell. Thomson claimed that Lyell had overlooked the "essential principles of Thermo-dynamics" (Thomson 1864 [1862]: §1) and flat-out declared uniformitarianism wrong, asserting that:

> "geological speculations assuming somewhat greater extremes of heat, more violent storms and floods, more luxuriant vegetation, and hardier and coarser-grained plants and animals, in remote antiquity, are more probable than those of the extreme quietist, or 'uniformitarian', school." (Thomson 1864 [1862]: §3)

Thomson's argument was based on the observation that the temperature of the earth increases with the depth by about 1° Fahrenheit per 50 British feet of descent. (Thomson 1864 [1862]: §6) Since "the upper crust does not become hotter from year to year, there must be a secular loss of heat from the whole earth." (Thomson 1864 [1862]: §7) Through an application of Fourier's mathematical theory of the conduction of heat he calculated "with much probability" that the consolidation of the earth's crust

> "cannot have taken place less than 20,000,000 years ago, or we should have more underground heat than we actually have, nor more than 400,000,000 years ago, or we should not have so much as the least observed underground increment of temperature." (Thomson 1891a [1868]: § 11)

[504] Darwin spoke of "immense ages" already in his 1842 *Sketch* and the 1844 *Essay*. (cf. Burchfield 1974: 302;)

The implication for Darwin's model was obvious: according to Thomson's estimate too little time had passed to allow for the evolutionary effects Darwin had modeled. (Ellegård 1958: 235, cf. Hull 1973: 12-3)

Thomson affirmed his objection in 1866 and Jenkin repeated Thomson's objections in his own article for the *North British Review*. (Thomson 1866; Jenkin 1867) However, it was not until Thomson himself addressed the question before the Geological Society of Glasgow that the geologists felt obliged to respond to Thomson's high-handed claim that "a great reform in geological speculation seems now to have become necessary" (Thomson 1891a [1868]: §1).

It is important to note that Thomson's "arguments were entirely physical […] and completely ignored geological evidence" (Burchfield 1974: 308-9): he had applied physical models on physical evidence and referred to the calculated result as 'the age of earth'. His results conflicted with the geologists estimates, i.e. it conflicted with what the geologists called 'the age of the earth': the result of applying geological models to geological evidence. In sober fact, two disciplines were fighting for the right to name their evidence interpreted by their models 'age of the earth'.

Yet, "[s]o great were Kelvin's prestige and the apparent strength of his argument that most geologists began to rework their theories to incorporate much faster rates of change than those postulated by Lyell." (Bowler 1990: 194; Burchfield 1974: 318) Darwin followed; the fifth edition of the Origin, published in December 1868, "contained the most significant changes Darwin was ever to make in his treatment of geological time. He was much more tentative and cautious in his pronouncements, and much more willing to admit that his earlier demands for time had been excessive." (Burchfield 1974: 311)

Finally, Hooker and particularly Huxley met the physicists' attack. (Hooker 1868; Huxley 1869; cf. Burchfield 1974: 309; Hull 1973: 350) In his Presidential address to the Geological Society of London, Huxley dismissed the physicists' interference with the geological debate in presumptuous manner. He contested the supposedly exact grounds of Thomson's calculations, claiming that "pages of formulae will not get a definite result out of loose data." (Huxley 1869: 333)

Huxley stressed that they were talking of different times, i.e. that the terms 'time' and consequently 'age of earth' denoted different things[505] for the physicists and biologist:

> "Biology takes her time from Geology. The only reason we have for believing in the slow rate in the change of living forms is the fact that they persist through a series of deposits which, geology informs us, have taken a long while to make. If the geological clock is wrong, all the naturalist will have to do is to modify his notions of the rapidity of change accordingly' (Huxley 1869: 329)

Despite new contributions by Tait and Thomson, the debate resulted in a dead end. (Tait 1869; Thomson 1869; Thomson 1891b [1871]) Darwin compromised partly, strengthening the Lamarckian

[505] I find it interesting how very clearly Huxley states the conflict here. Physicists and geologists / biologists were not fighting over empirics; neither disputed the validity of the others' observations. Rather, they fought for the right to use the term 'age of the earth'. The question was whose empirical findings justified using the term and telling the history of the world in the public sphere. - (Hattiangadi 1971: 506) describes this relation between the competing theories as one of incommensurability. For once, this seems like an appropriate use of the term: these theories did indeed display no common measure by which they might have been compared. (see annex, section 6 iv)

concept of inheritance of acquired characteristics. (Ruse 1979: 224) Yet, at some point, he "rather miserably dug in his heels and refused to defer to the physicists". (Ruse 1979: 224) In a letter to Hooker of July 1869 Darwin expressed the "conviction that the world will be found rather older than Thomson makes it, and far older than [Tait] makes it." (cf. de Beer 1963: 175)[506] His biological model would not be subordinate to the physical models, it demanded to be accepted in its own right. (Ruse 1979: 210-1; Bowler 1990: 195; Desmond and Moore 1995: 638-9)

vi. Classificatory debates: missing links, the hippocampus & the Archaeopteryx

As in the public debate, the missing links-issue was brought up quite frequently within the broader scientific community, both by supporters and opponents of the Darwinian theory. In the reviews, it usually figured as an objection to the Darwinian theory, for instance in the reviews of Duns for the *North British Review*, Wilberforce for the *Quarterly Review* and the unknown author D.T.A. for the *Dublin University Magazine*:

> "This is the theory which really pervades the whole volume. Man, beast, creeping thing, and plant of the earth, are all the lineal and direct descendants of some one individual ens, whose various progeny have been simply modified by the action of natural and ascertainable conditions into the multiform aspect of life which we see around us. This is undoubtedly at first sight a somewhat startling conclusion to arrive at. To find that mosses, grasses, turnips, oaks, worms, and flies, mites and elephants, infusoria and whales, tadpoles of to-day and venerable saurians, truffles and men, are all equally the lineal descendants of the same aboriginal common ancestor, perhaps of the nucleated cell of some primæval fungus, which alone possessed the distinguishing honour of being the 'one primordial form into which life was first breathed by the Creator'— this, to say the least of it, is no common discovery—no very expected conclusion." (Wilberforce 1860: 240)

> "But if the zoology be so very far from satisfactory, when we come to the purely geological portion we are made to feel that it is far worse. It is the most feeble part of the volume; and no apology which Mr Darwin may make for it, even in his most insinuating style and greatest smoothness of speech, will ever be reckoned a substitute for the fact, that in that one department of nature in which we have a right to ask the author to show us the proofs, or even the remote corroborations of his theory, not one is to be found. […] The truth is, that if the author has wholly and signally failed to produce even one unquestioned corroborative proof of true transitional variety among present forms of life, he cannot discover material in the geological record for a chapter on transitional varieties in palæontology." (Duns 1860: 484-5; cf. D.T.A. 1860)

Scientists used the argument, too. The biologist Murray, in the *Proceedings of the Royal Society of Edinburgh*, and the engineer Jenkin, in the *North British Review*, both refused to follow Darwin's argument on the imperfection of the geological record:

[506] Today's science is on Darwin's side, estimating the age of the earth at approximately four and a half billion years. Ironically, these calculations are once again based on physical methods and models, radiometric age dating. Nowadays, biology and physics can agree on what should be named 'the age of the earth'.

> "Now I believe no one will dispute as an abstract proposition the extreme imperfection of the geological record. But I cannot admit that its imperfection is of that character or degree that will entitle Mr Darwin to plead it in his favour. He dwells on the poorness of our palæontological collections—the great spaces of time wholly, or nearly wholly, unrepresented in them—the extreme rarity of terrestrial animals in the deposits—the destruction of the soft parts of most animals, and the crushed state of many others. I shall not follow him into his details on these points. All that he says on the subject may be very true—is very true— but will avail him nought if, in any portion of the geological records, we can find any one succession of strata of moderate depth which may be fairly held to have been deposited unintermittently, and in which we find a liberal representation of the animals of any one class." (Murray 1862 [1860]: 283)

> "Something might be said as to the alleged imperfection of the geological records. It is certain that, when compared with the total number of animals which have lived, they must be very imperfect; but still we observe that of many species of beings thousands and even millions of specimens have been preserved. If Darwin's theory be true, the number of varieties differing one from another a very little must have been indefinitely great, so great indeed as probably far to exceed the number of individual which have existed of any one variety. If this be true, it would be more probable that no two specimens preserved as fossils should be of one variety than that we should find a great many specimens collected from a very few varieties, provided, of course, the chances of preservation are equal for all individuals." (Jenkin 1867: 317)

Owen, in the *Edinburgh Review,* was especially candid in his dismissal of the Darwinian classification:

> "The geological record, it is averred, is so imperfect! But what human record is not? Especially must the record of past organisms be much less perfect than of present ones. We freely admit it. But when Mr. Darwin, in reference to the absence of the intermediate fossil forms required by his hypothesis—and only the zootomical zoologist can approximatively appreciate their immense numbers—the countless hosts of transitional links which, on 'natural selection,' must certainly have existed at one period or another of the world's history—when Mr. Darwin exclaims what may be, or what may not be, the forms yet forthcoming out of the graveyards of strata, we would reply, that our only ground for prophesying of what may come, is by the analogy of what has come to light. We may expect, e.g., a chambered-shell from a secondary rock; but not the evidence of a creature linking on the cuttle-fish to the lump-fish." (Owen 1860b: 530)[507]

[507] Interestingly, Owen did not only criticize that Darwin's classification was not sufficiently supported, he also demanded that Darwin specified the features of the ancestral forms he supposed to have existed: "He [Darwin] has, doubtless, framed in his imagination some idea of the common organic prototype; but he refrains from submitting it to criticism." (Owen 1860b: 511) Owen's demand makes sense in his focus on static modeling and his neglect of dynamic models. But this was not Darwin's perspective, he was not to provide a graphic representation of an archetype against which future fossils might be checked. (see section 3.5.6; cf. Cosans 2009: 100)

However, there were also supportive references to the geological record. Hutton, the geologist, and Carpenter, the zoologist and physiologist, were much more optimistic on the matter and concurred with Darwin in their articles for the *Geologist* and the *British and Foreign Medico-Chirurgical Review*:

> "This record Darwin justly says is defective. No doubt, it is; no doubt there are great gaps in the earth's past history of which no trace remains—and many, and far more numerous gaps which scientific investigations have not yet filled up. Still, we may hope to find, and by patience and research no doubt we ultimately shall mark out, the great points in the picture around which the details may reliably be filled in by correctly drawn inferences." (Hutton 1860: 469; cf. Hutton 1861)

> "We are fully satisfied that [Darwin] does not in the least exaggerate the imperfection of the geological record…" (Carpenter 1860a: 400)

One important missing link could have existed in the class which Linnaeus had called the primates, a group of species which included both Man and the apes. In the debate on the *hippocampus minor*, Owen argued for a large gap and an absolute limit between humans and apes while Huxley argued for gradual transitions and minor differences. In his opposition to Owen, Huxley did not dispute Owen's empirical findings but their interpretation: Owen had based his classification on means and on dynamics in brain development, i.e. he had asked how large human and ape brains are on average and how they develop over time. Huxley, contrarily, based his classification on extremes and on mature specimen, i.e. he asked whether extreme variants of mature apes and humans displayed significant differences.[508] In sum, the debate on the hippocampus minor was a struggle over classifications and criteria for classification; it was a debate on the interpretation of empirical evidence not on the evidence itself.[509] Huxley's classificatory criteria seemed to have stuck better; he won the debate. Owen, however, did not back down and upheld his position.[510]

A second missing link could have been the Archaeopteryx, a fossil which displayed both reptilian and bird-like features. It was first described by Owen in 1862 and classified as a reptile, not a bird or an intermediate form.[511] (Owen 1863 [1862]) This brought along another opportunity for Huxley to publicly contradict Owen. In 1862, he praised the Archaeopteryx as one of the missing links which Darwin's critics had demanded. (Rupke 1994: 71-4) As in the debate on the hippocampus minor, Huxley did not dispute Owen's description of the fossil but his classification of it; thus, their debate was a classificatory one, not one of empirics.

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508 Christopher Cosans provides an in-detail analysis of the debate. (Cosans 1994; Cosans 2009)

509 Cosans links these differences back to „different metaphysical attitudes on the observer's role in biology" and attempts to identify different epistemological positions in Owen and Huxley which he supposes to have influenced their roles as observers. (Cosans 1994: 154) Among other points, he mentions Owen's opposition to slavery and Huxley's not linking intelligence to the brain. (Cosans 1994: 137, 152; Cosans 2009: 115, 124) – I do not know whether Cosans is right in ascribing these positions to Owen and Darwin, he may well be. However, I do not think that his argument is accurate: Huxley never disputed that Owen made wrong observations, he merely disputed how Owen interpreted his observations. Cosans seems to mix up descriptions and classifications based on such descriptions, a typical fallacy of proponents of the so-called theory-ladenness of observation. (See annex, annex, section 6 iv)

510 As Cosans reports "In 1865, [Owen] published the book Memoir on the Gorilla, which repeats the arguments from his 1851 and 1859 papers virtually word-for-word." (Cosans 1994: 154)

511 Rupke reports that this led to a discussion with a referee of the Royal Society. (Rupke 1994: 71-4)

vii. *Pseudo-empirical objections: complexity, rudimentary organs, sterility & Man's moral qualities*

As in the public debate, critics in the broader scientific community forwarded pseudo-empirical objections, i.e. allegedly empirical objections which were founded on distorted representations of reality. One line of allegedly empirical arguments focused on highly complex structures as the human eye, the constructive instinct of the hive bee or the neck of the giraffe. (Ellegård 1958: 249; cf. Haughton 1973 [1860]) It was argued that these organs were special and could not be derived from any incipient prototype for the removal of any part of their complex whole would stop these organs to function altogether.[512] This line of criticism usually came from laymen whose knowledge of complex organs rarely exceeded idealized model versions of such organs.[513] In the reviews of the *Origin*, this argument was forwarded by the bishop Wilberforce who suggested in the *Quarterly Review* how very unlikely it was that Natural Selection could have produced something as fascinating as the eye:

> "Sometimes Mr. Darwin seems for a moment to recoil himself from this extravagant liberty of speculation, as when he says, concerning the eye,—'To suppose that the eye, with its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest possible degree.'—p. 186.
> But he soon returns to his new wantonness of conjecture, and, without the shadow of a fact, contents himself with saying that—'he suspects that any sensitive nerve may be rendered sensitive to light, and likewise to those coarser vibrations of the air which produce sound.'—p. 187.
> And in the following passage he carries this extravagance to the highest pitch, requiring a licence for advancing as true any theory which cannot be demonstrated to be actually impossible:— 'If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down. But I can find no such case.'—p. 189." (Wilberforce 1860: 248-9)[514]

A second type of allegedly empirical objections concerned incipient structures and rudimentary organs. It was argued that Darwin could not demonstrate that all the steps by which organs are being developed during the growth of an organism are more favourable than the previous step. (Ellegård 1958: 247) This line of argument, however, gained little steam for it threatened to hurt the anti-Darwinians themselves who perceived any organ as useful and could hardly argue for the uselessness of incipient structures and rudimentary organs. (Ellegård 1958: 250-1)[515]

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512 The same argument is still employed by modern Creationists like Intelligent Design proponent Michael J. Behe. (Behe 2000) – In a very simplified form these arguments also reached the public.

513 See (Zacharias and Schulz) for an analysis of this fallacy in modern arguments for intelligent design.

514 The last point of criticism by Wilberforce is directed at what modern philosophy of science calls 'abduction', i.e. the expression of a far-reaching theory before the necessary evidence is provided. Indeed, Darwin's theory was not sufficiently specified to assess whether it fit with all available or future evidence.

515 Sometimes, anti-Darwinians sought refuge in the claim that the supposedly useless structures were useful to man. Such, it was "maintained that the rings of the rattlesnake were created to warn its unfortunate victims off … A variant of this argument was that many structures in the organic world had been created

A third type of objections focused on sterility, namely the assumption that members of different species cannot breed with one another and that therefore, one could test whether a new species has emerged by experimentally testing whether its members could still breed with their original type. It was held that if Darwin's theory was true then

> "experiments ought to give evidence of the appearance of successive variations, leading by a series of small steps from one species to another. [Hitherto, no] such evidence had been produced…" (Ellegård 1958: 216)

The sterility argument was uttered with much conviction by the laymen authors who addressed the broader scientific community; it can be found with Morris, Wilberforce and also with Duns, who confidently claimed in the *North British Review*:

> "As to Hybridism, we accept the admission made [by Darwin] at page 252, 'I doubt whether any case of a perfectly fertile hybrid animal can be considered as thoroughly well authenticated.' The early recognition of this by the author would have taken more than thirty pages from his book. The sterility of true hybrids affords another evidence of the jealousy with which the Creator regards all attempts to introduce confusion into His perfect plan." (Duns 1860: 484; Morris 1860: 71-3; Wilberforce 1860: 275, 277)

The scientist-authors were much more cautious on the matter, raising the matter but putting not too much weight on it. (Owen 1860: 524-6; Murray 1862 [1860]: 276, 279; Carpenter 1860a: 397-9) Huxley, as in his December article for the *Times*, urged for caution with respect to this difficult criterion:

> "Not only do these great practical difficulties lie in the way of applying the hybridisation test, but even when this oracle can be questioned, its replies are sometimes as doubtful as those of Delphi. For example, cases are cited by Mr. Darwin, of plants which are more fertile with the pollen of another species than with their own; and there are others, such as certain *Fuci*, the male element of which will fertilise the ovule of a plant of distinct species, while the males of the latter species are ineffective with the females of the first. So that, in the last-named instance, a physiologist, who should cross the two species in one way, would decide that they were true species; while another, who should cross them in the reverse way, would, with equal justice, according to the rule, pronounce them to be mere races. Several plants, which there is great reason to believe are mere varieties, are almost sterile when crossed; while both animals and plants, which have always been regarded by naturalists as of distinct species, turn out, when the test is applied, to be perfectly fertile. Again, the sterility or fertility of crosses seems to bear no relation to the structural resemblances or differences of the members of any two groups." (Huxley 1860b: 553)

In the course of the 1860s, it was attempted to address this question experimentally but the outcomes were inconclusive and the debate faded out. (Ellegård 1958: 218-223, 206-9; Hull 1973:

solely for the sake of beauty, wholly irrespective of use." (Ellegård 1958: 250-1) A similar case is made by the Duke of Argyll. In *The Reign of Law,* he argues that the beauty of the humming bird fulfills one function only: to praise God. (Argyll 1872 [1867]: 230; cf. Desmond and Moore 1995: 616, 623-4)

50) There never existed any substantial evidence for or against Darwin's model with respect to sterility.[516]

A fourth pseudo-empirical objection surfaced in the debate on Man's descent, mostly after Owen had lost the *hippocampus* debate to Huxley. (see below) Critics claimed that Man might resemble the apes in his anatomical and morphological structure but that he displayed moral and mental qualities which put him apart from all animals. The broader scientific community shared this argument with the public but could bestow more scientific credibility upon it, notably after Alfred Russel Wallace adopted the argument. In 1869, Wallace claimed before the British Association that

> "Neither natural selection nor the more general theory of evolution can give any account whatever of the origin of sensational or conscious life ..." (op. cit. Ellegård 1958: 308; cf. 278; Hull 1973: 64; Desmond and Moore 1995: 642)

One year later, a chapter of his *Contributions to the Theory of Natural Selection* was named *The Limits of Natural Selection as Applied to Man*. In this chapter, Wallace claimed that natural selection cannot explain the development of mental faculties[517]:

> "…the same power which has modified animals has acted on man; and … as soon as the human intellect became developed above a certain low stage, man's body would cease to be materially affected by natural selection, because the development of his mental faculties would render important modifications of its form and structure unnecessary. It will, therefore, probably´ excite some surprise among my readers, to find that I do not consider that all nature can be explained on the principles of which I am so ardent an advocate; and that I am now myself going to state objections, and to place limits, to the power of 'natural selection.' I believe, however, that there are such limits; and that just as surely as we can trace the action of natural laws in the development of organic forms, and can clearly conceive that fuller knowledge would enable us to follow step by step the whole process of that development, so surely can we trace the action of some unknown higher law, beyond and independent of all those laws of which we have any knowledge. We can trace this action more or less distinctly in many phenomena, the two most important of which are the origin of sensation or consciousness, and the development of man from the lower animals." (Wallace 1870d: 332-3)

viii. *Synthesis*

In sum, the critique by the broader scientific community focused on Darwin's explanation. The arguments on missing links, complexity and rudimentary organs centered on the model's relation to allegedly empirical facts. The technical objections centered on the model's inner logic and its

[516] Darwin, after the study of Primula (primroses, cowslips) realized that sterility was linked to self-fertility and made some changes on the topic in the 4th edition of the Origin. (Ruse 1979: 214-9)

[517] Hull points out just how many prominent scientists and philosophers agreed with Wallace: "There were those like Sedgwick and Agassiz who wished to retain special creation to lend significance to their teleological claims. A majority of philosophers and scientists, however, gradually abandoned the notion of special creation but still wished to retain teleology as a significant doctrine. Whitehead, Dewey, and Peirce all espoused creative evolution, Wallace, Asa Gray, and Lyell belabored Darwin with arguments for admitting divine providence, especially with respect to man's mental and moral faculties." (Hull 1973: 64-5)

conflicts with physical models. Finally, the philosophy of science objections focused on its compliance with meta-demands about proper scientific methods.

4.2.3 Which elements of the Darwinian theory were accepted, which rejected?

Like the public, the broader scientific community came to accept Darwin's static model and its interpretation via the concept of common descent. However, again like the public, amateur scientists and scientists from other disciplines predominantly refused a close link between Man and the supposedly lower apes. After Huxley had won the debate on the *hippocampus minor*, critics retreated to the same mental and moral qualities of Man which had been cited in the public debate. Their most prominent advocate was obviously Wallace, the co-author of the evolution theory, who claimed that natural selection was unable to explain sensational or conscious life.

With regard to Darwin's explanation, there was a general ambiguity towards Natural Selection. [518] Many were "hesitant about Darwin's mechanism of natural selection. There were always doubts about its power to do all Darwin claimed, and by the early 1870s support for it had declined even further." (Ruse 1979: 229; cf. Himmelfarb 1959: 252; Bowler 1990: 183) The overall consensus among the broader scientific community may correspond to the account Huxley gave in his 1878 article on evolution in the *Encyclopedia Britannica*. There, he addressed the history of biology, the history of evolutionary thought and the etymology of the term 'evolution'. He provided an abstract description of the domain of Darwin's model, but presented no factual evidence. Huxley mentioned variation and natural selection but did not discuss their logical links and omitted the struggle. (Huxley 1893a [1878])

Even if recipient accepted 'natural selection' to denote a process in nature and admitted that this process had been correctly identified by Darwin, they demanded supplements to its connotation and the narrative in which it was embedded. (Ruse 1979: 205-6; Himmelfarb 1959: 252; Bowler 1990: 178, 183) Like the public, scientists suggested amending more elements of Purpose and Design to the theory as well as attributing God a larger and more direct role in evolution.[519]

518 Michael Ruse suggests tactical reasoning behind this dichotomy: "There was therefore a tactical advantage to accepting evolution: one could show one's 'reasonableness', one could accept all of Darwin's arguments that one found attractive, one could avoid an all-out negative war, and therefore one could more easily balk at selection." (Ruse 1979: 229)

519 Peter J. Bowler suggests that Darwin achieved a "revolution in the values accepted by scientists" in that law-like explanations gained more ground in biology. (Bowler 1990: 177-9) It seems to me that some of his observations reach beyond the known facts. For instance, I am not sure that the following statement describes a majority position around the 1870s: "The Darwinists' success clearly points to a change of attitude within the scientific community, … the new movement was committed to a causal interpretation of the development of life, repudiating not only divine creation but any teleological explanation in which evolution was drawn toward predetermined goals. The permanent success of Darwinism lay in the triumph of this attitude, because the arguments over natural selection itself did not diminish as the century drew to a close. One might still hope – as Darwin himself did at times – that the laws of evolution would produce a gradual ascent of life toward higher forms, but it was no longer legitimate to use future goals to explain evolutionary trends. If the Creator designed the laws of evolution, His actions were no longer demonstrable by science and His role in the universe had to he accepted as a matter of faith. The rise of Darwinism corresponds to the emergence of a new generation of biologists determined to allow the scientific method complete access to the question of the origin of species." (Bowler 1990: 184-5)

4.3 Reception by the immediate scientific community

4.3.1 To what depth did recipients receive the theory?

Biologists were the only group to receive information on Darwin's theory on all four levels of my model; articles in their publications and specialized monographs addressed issues of description, classification, explanation and ontological implications alike.

i. Application of the static and the dynamic model in empirical case studies

Within the biological journals, most references to the Darwinian theory occurred in papers which applied Darwin's static and his dynamic model in empirical case studies. The first such paper was authored by appeared in *Ibis* and employed the Darwinian model in an explanation of ornithological observations in Northern Africa. (Tristram 1859: 415-435) Its author, the reverend and ornithologist Henry Baker Tristram (1822-1906), mentioned the joint paper[520]:

> "Writing with a series of about 100 Larks of various species from the Sahara before me, I cannot help feeling convinced of the truth of the views set forth by Messrs. Darwin and Wallace in their communications to the Linnean Society … 'On the Tendency of Species to form Varieties, and on the Perpetuation of Varieties and Species by natural means of selection.' It is hardly possible, I should think, to illustrate this theory better than by the Larks and Chats of North Africa." (Tristram 1859: 429)

and employed Darwin's argument, mentioning both the struggle and natural selection and demonstrating the applicability of Darwin's dynamic model. (Tristram 1859: 430, 432)

Physiologist William Benjamin Carpenter (1813-1895) published a series of articles on Foraminifera, a marine plankton group. The last of these articles appeared in the *Philosophical Transactions of the Royal Society of London* in 1861. In the conclusion, Carpenter explicitly linked his findings to Darwinian evolution and demonstrated the applicability of Darwin's static model to complex classifications.[521] (Carpenter 1861[1860]: 570-85)

The same year, botanist and friend of Darwin, John Dalton Hooker published an extensive overview over the distribution of arctic plants in the *Transactions of the Linnean Society* and came to the conclusion that it did indeed concur with the Darwinian model:

> "It appears, therefore, to be no slight confirmation of the general truth of Mr. Darwin's hypothesis, that, besides harmonizing with the distribution of arctic plants within and beyond the polar zone, it can also be made, without straining, to account for that distribution and for many anomalies of the Greenland flora, viz., 1, its identity with the Lapponian; 2, its paucity of species; 3, the fewness of temperate plants in temperate Greenland, and the still fewer plants that area adds to the entire

520 I mention this paper because it explicitly referred to the Darwinian part of the joint paper, notably natural selection, which Darwin then developed in the Origin. One might also count it as reviewing the joint paper and ignore it for the reception of the *Origin*.

521 Carpenter did not employ any of the key terms of Darwin's dynamic model.

> flora of Greenland; 4, the rarity of both Asiatic and American species or types in Greenland; and 5, the presence of a few of the rarest Greenland and Scandinavian species in enormously remote alpine localities of West America and the United States." (Hooker 1862 [1860]: 254)

In the *Transactions* of the following year, the entomologist, friend and travel companion of Wallace, Henry Walter Bates (1825-1892) published a long paper on the Heliconidae (Lepidoptera, butterflies) of the Amazonas Valley in which he mentioned all the key terms of Darwin's dynamic and static model and applied both in his explanation of a large-scale classification. He even mentioned sexual selection and reproductive isolation:

> "The process of the creation of a new species I believe to be accelerated in the Ithomiae and allied genera by the strong tendency of the insects, when pairing, to select none but their exact counterparts: this also enables a number of very closely allied ones to exist together, or the representative forms to live side by side on the confines of their areas, without amalgamating." (Bates 1862 [1861]: 501)

Alfred Russel Wallace provides two further such applications in the transactions of the Linnean Society and the Royal Entomological Society (Wallace 1865 [1864]: 1-72; Lubock 1867: xliii-xlviii). The first paper is treats the variation and geographical distribution of Papilionidae (butterflies) in the Malayan Region and displays heavy usage of the both the static and the dynamic model of evolution. The second application occurs not in a paper but in a report on a discussion at an 1866 meeting of the Royal Entomological Society in which both Wallace and Bates intervened. Wallace defended evolution theory in a lengthy reply to a Dr. Sharp in which he addressed several objections and applied concepts of both the static and dynamic model of evolution, even mentioning the 'Survival of the Fittest' as a synonym of 'Natural Selection'.[522]

Towards the end of the analyzed period, banker-naturalist John Lubock (1834-1913) contributed a short paper to the zoology section of the Linnean Society. His *On the Origin of Insects* provides a very general and abstract explanation of the evolutionary origin of a large class of organisms. (Lubock 1873 [1871]: 422-5)

In the same volume, American missionary and naturalist John T. Gulick (1832-1923) published the paper *On Diversity of Evolution under one set of External Conditions*. He addressed evolution without ecological change or migration, solely triggered by variation. His argument is definitely one of the most sophisticated in the application of the Darwinian explanation; he weighs different sets of explanatory factors (Inputs) and concludes that under constant external conditions, evolution can only take place if one assumes a tendency towards reproductive separation (reproductive isolation):

> "A comparison of the distribution of island mollusks with the widely contrasted distribution of continental species, leads me to believe that the evolution of many different species may take place without any difference in the food, climate, or enemies that surround them. […]
> If we suppose separation without a difference of external circumstances is a condition sufficient to ensure variation, it renders intelligible the fact that, in nearly allied forms on the same island, the degree of divergence in type is in proportion to

522 Herbert Spencer introduces the term in a paper in the same volume. (Spencer 1865: 418)

> the distance in space by which they are separated. The difference between two miles and ten miles makes no change in climate; but it is easy to believe that it is the measure of a corresponding difference in the time of separation. In forms that differ more essentially, the separation may have been as complete and as long-continued in the case of those which now inhabit one valley as in the case of those which are separated by the length of an island. When a wide degree of divergence has been established, hybridation would be precluded. We accordingly find that the difference between species of different genera or subgenera is in most instances equally great whether we take for comparison those from the same or from different valleys. If, on the other hand, we suppose that a difference in the external conditions is necessary to the evolution of distinct forms, these and other similar facts remain unexplained." (Gulick 1873 [1872]: 504-5)

ii. Discussion of narrative, ontological implications

Within the immediate scientific community, world views are a much less frequent topic; only a few handful of biological articles and monographs address ontological topics and none enter into a discussion of Darwin's narrative and its ontological implications. An exception is Owen who, time and again, confirmed his opposition to Darwinism in the conclusion of his articles, notably in his paper 1866 on the Aye-Aye for the Zoological Society and an 1873 paper *On the American King-Crab*. (Owen 1866a [1862]: 33-101; Owen 1873: 459-506) Moreover, in the third volume of his *Anatomy of Vertebrates* Owen explicitly addressed the Darwinian narrative and deconstructing it and offering a deist narrative as an alternative. (Owen 1868: 694, 814, 818; see below)

Beyond these few interventions on narrative and ontological issues, however, members of the immediate scientific community could access the debate in the more general publications.

iii. Meta-perspective and philosophy of science

Towards the end of the period, a number of reviews appear which touched upon the impact of the Darwin on biology. Three examples stand out. In 1871, Wallace, as the president of the Entomological Society, reviewed a catalogue of European Lepidoptera and highlighted that

> "A very good feature in this catalogue is the separation of accidental variations from true local varieties or races. The former are called 'aberrations,' the latter only 'varieties.' Those forms which some naturalists class as varieties, while others consider them to be good species, are termed 'Darwinian species.' " (Wallace 1871: lx-lxi)

In December 1874, 15 years after the publication of the Origin, Russian paleontologist Wladimir Kowalevsky (1848-1935), in his paper *On the Osteology of Hyopotamidae*, praised Darwin more explicitly:

> "The wide acceptance by thinking naturalists of Darwin's theory has given a new life to palaeontological research; the investigation of fossil forms has been elevated from a merely inquisitive study of what were deemed to be arbitrary acts of creation to a deep scientific investigation of forms allied naturally and in direct connexion with

> those now peopling the globe, and the knowledge of which will remain imperfect and incomplete without a thorough knowledge of all the forms that have preceded them in the past history of our globe." (Kowalevsky 1874 [1873]: 20-1)

Huxley, in a general paper on taxonomy one year later, assessed the contribution of evolution theory to taxonomy, highlighting it as introducing:

> "a new element into Taxonomy" and emphasizing that "Phylogeny, or the history of the evolution of the species, becomes no less important an element than Embryogeny in the determination of the systematic place of an animal. The logical value of phylogeny, therefore, is unquestionable…" (Huxley 1876 [1874]: 200)

but also discussing its limits[523]

> "the misfortune is, that we have so little real knowledge of the phylogeny even of small groups, while of that of the larger groups of animals we are absolutely ignorant." (Huxley 1876 [1874]: 200)

iv. Synthesis

In sum, members could receive and understand information of all levels, i.e. on descriptions of empirics, on classifications, explanations and on their ontological implications. This does not mean that everyone could judge anything but that anybody could check Darwin's unifying theory against the facts in his particular domain, be it in zoology, botany, anatomy, morphology, or paleontology.

4.3.2 By which criteria was the Darwinian theory assessed?

i. Narrative and Philosophical implications

As few papers in biological journals addressed Darwin's narrative, few criticized it. All papers which I could find came from Richard Owen. First, in his 1866 paper on the Aye-Aye, Owen concluded a long description of the ape with a discussion of its origin and its relation to Man. He suggested degeneration as a possible explanation and dismissed both the Lamarckian and the Darwinian explanation in favor of a deist narrative, the creation by law:

> "Whilst admitting the general evidence, therefore, in favour of 'creation by law,' I am compelled to acknowledge ignorance of how such secondary causes may have operated in the origin of the Chiromys. Darwin seems to be as far from giving a satisfactory explanation of them as Lamarck." (Owen 1866a [1862]: 99)

In the volume of *The Anatomy of Vertebrates*, Owen attempted what may have been the only public deconstruction of the Darwinian narrative. (Owen 1868) He explicitly criticized Darwin's personification and his core metaphor 'natural selection':

[523] The same point was made by Brady, Parker and Jones some years earlier without mentioning Darwin. (Brady, Parker, and Jones 1871 [1869]: 198)

> "Assuming, then, that Palaeotherium did ultimately become Equus, I gain no conception of the operation of the effective force by personifying as ' Nature ' the aggregate of beings which compose the universe, or the laws which govern these beings, by giving to my personification an attribute which can properly be predicated only of intelligence, and by saying, 'Nature has selected the mid-hoof and rejected the others.' … to say that Palaeotherium has graduated into Equus by 'Natural Selection' is an explanation of the process of the same kind and value as that which has been proffered of the mystery of 'secretion.' [..] Such figurative language, I need not say, explains absolutely nothing of the nature of bilification." (Owen 1868: 794)

A couple of pages later, Owen drove his point even further and demonstrated to what absurdities the Darwinian metaphor could be stretched:

> "Amber or steel when magnetised seem to exercise a 'selection': they do not attract all substances alike." (Owen 1868: 818)

In his paper 1873 paper on the American King-Crab, Owen concluded a long description with a discussion of the genealogical position. (Owen 1873: 459-506) Only last paragraph addresses ontological questions and Owen statement sounds more like a proud declamation in a long-lost battle than an attempt to convince the readers by his explanation:

> "That old Ocean should have afforded the chance conditions of origin of crustaceous subclasses, orders, genera, species, by ' Natural Selection,' is not conceivable by me: the metaphysical fact that there is ' will,' that a ' sense of the beautiful' exists, that ' a love of virtue' operates, opposes the supposition. Such fact sufficeth for the rejection of a ' Nature ' working without will, taking no counsel of either the good or the beautiful, casting up from her dark abyss only eternal transformations of herself, furthering, with the same restless activity, decline and increase of organs, death and life of individuals, extinction and origination of species. Nevertheless I hold by the conviction that till forms and grades of Articulata are due to ' secondary cause or law' as strongly as when I expressed the same belief in regard to the Vertebrata, and denned it as 'the deep and pregnant principle in Philosophy' evolved in the researches on the General Analogies and Archetype of the Vertebrate Skeleton." (Owen 1873: 501-2)

ii. *Empirical fit of Darwin's dynamic and model*

Papers which challenged Darwin's dynamic model in its application to empirics were equally rare.[524] The above-mentioned Dr. Sharp specified a number of observations or non-observations with which, on his account, the Darwinian model did not comply. (Lubock 1867: xlv-xlviii)

James Murie, the prosector to the Zoological Society, and St. George Jackson Mivart[525] present another supposedly[526] empirical challenge in their paper on the anatomy of Lemuroidea (lemurs).

524 It seems that most opponents of the theory ignored it in their papers in biological journals rather than opposing it.

525 Mivart was a Darwinian early in his career but dissociated himself from Darwinian materialism, notably with respect to Man's supposedly unique features, morals, soul and reason. This led to a rupture with Huxley, Darwin and Hooker. (Desmond and Moore 1995: 643, cf. 689-90)

They describe a “peculiar modification of the nail of the petal index” and question its utility, challenging:

> “How this mutilation can have aided in the struggle for life, we must confess, baffles our conjections on the subject; for that a very appreciable gain to the individual can have resulted from the slightly lessened degree of required nourishment thence resulting (i.e. from the suppression) seems to be an almost absurd supposition.” (Murie and Mivart 1872 [1866]: 91-2)

The empirical fit of Darwin’s static model, i.e. its adequacy as a classification, was no big issue. While the empirical papers on the relationship of Man with the apes and on the Archaeopteryx appeared in the biological journals, the battles on their interpretation were fought in the more general publications. (cf. Owen 1857; Owen 1862a; Owen 1866a [1862]; Owen 1863 [1862]; Owen 1865) I found one paper named *On the Posterior Lobes of the Cerebrum of the Quadrumana* in which anatomist William Henry Flower (1831-1899) took up the question, mentioned opposing reports on the existence of a hippocampus minor in apes but denied the relevance of the *hippocampus minor* with respect to the descent of Man:

> “whatever inferences others may draw from the facts related, for my own part I see no reason to assign any special importance, in determining the value of such a theory, to the condition of the particular portion of the cerebral organization now under consideration, especially as the general dose resemblance between the physical structure of Man and the Quadrumana has long been a matter of common observation.” (Flower 1862: 187-9)

4.3.3 Which elements of the Darwinian theory were accepted, which rejected?

i. Overview

Of the 1.916 articles published in biological journals between 1859 and 1875/6, 88 mention the concept natural selection (4.59%), 150 the concept evolution (7.69%), 192 the concept homology (10.02%).[527] Both Darwinian concepts overlap in 46 articles, i.e. 46 of the 150 articles which mention evolution (30.67%) and 46 of the 88 articles which mention natural selection (52.27%) do also mention the other concept. Overall, 192 of the 1.916 articles mention at least one of the Darwinian concepts, exactly the same share as for homology. (10.02%)

On the 34.209 journal pages, 271 hits were counted for natural selection, 580 for evolution, and 915 for homology. The concept natural selection was thus employed with an average intensity of one hit

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526 From a Darwinian point of view this challenge is based on a fallacy for it presumes that every sustainable change is covered by the Darwinian model.

527 The medians were 4.41% for natural selection, 7.69% for evolution and 8.60% for homology.

every 126 pages. Usage[528] of evolution was twice as intense; references could be found every 59 pages. Homology was mentioned every 37 pages.[529]

26 papers mention evolution five or more times. Of these, five papers come from Wallace, and two apiece from Darwin and Huxley and the Duke of Argyll in his presidential addresses to the Royal Society of Edinburgh. No other author contributed more than one. 13 of these 26 papers mention evolution ten or more times. Of these 13 papers, three come from Wallace, two from Darwin, two from Argyll; no other author contributed more than one. Natural selection is mentioned more than five times in 8 articles and more than ten times in 6 articles. All of these latter articles overlap with the high-intensity articles on evolution; any paper which mentioned natural selection at least five times did also mention evolution at least five times. The same is true for articles with ten or more hits.

ii. Development over time[530]

Before 1859, 10 volumes with 194 articles contained zero references to natural selection (as was expected), 7 to evolution (3.60%) and 16 to homology (8.24%). Thus, from the pre-Origin period to the post-Origin period, the frequency[531] of the concept evolution doubled while hits for homology increased by ca. 25%. In its best three years, from 1865 to 1867, natural selection was referred to in 8.05, 8.26 and 8.85 percent of all articles. In its worst three years – 1859, 1863, 1864 – it was mentioned in 2.36, 0.00 and 2.67 percent of all articles.[532] Evolution was mentioned most frequently in 1866, 1867 and 1871 when 15.04, 21.84 and 9.80 percent of all articles mentioned it. In its worst years – 1860, 1868 and 1874 – references decreased to 2.22, 2.15 and 4.21 percent. Homology had its peak years in 1862, 1866 and 1869 when it was employed in 16.85, 15.04, and 15.69 percent of all articles. Its worst years – 1860, 1861 and 1864 – saw 4.44, 2.65, and 6.67 percent of articles mentioning homology.

When one divides the analyzed period in thirds and looks at six-year spans[533], natural selection was mentioned most in the middle period, from 1865 to 1870, in 6.25% of all articles. From 1859 to 1864 it was mentioned least frequently (3.53%) and from 1871 to 1875/6 second most often (4.05%). For evolution, the trend is similar; its use changed from 5.79% in the first to 10.00% in the second, to 7.92% in the third period. References to homology display less peaks and increase steadily from 9.04% to 10.47% to 10.74% over time.

528 These differences are more marked than the differences between the percentages of articles which cite the concepts. Thus, the concepts which appear in more articles are also more frequently used within these articles.

529 The medians were 238 for natural selection, 70 for evolution and 45 for homology.

530 Remember that articles were attributed to the publication year of the volumes in which they were published not to the year in which they were read. For journals which did not publish yearly volumes, trends are delayed.

531 By ‘frequency’ I denote the number of articles which mention the concept, by ‘intensity’ the overall number of hits in relation to the number of pages.

532 In 1863, only two volumes were published – by the Ibis and the Royal Society of London – and the number of when the number of articles and pages was below 50% of the average. Within the analyzed period, it is thus the year with the smallest sample size. This explains much of the extremes.

533 In some case the latest considered volume was published in 1875 and the third period comprises five years only.

Regarding intensity, trends are similar. In its peak years 1859, 1862, 1866, natural selection was mentioned every 40, 35 and 65 pages. In 1868, 1872 and 1875/6 it was cited only every 436, 623 and 561 pages. Evolution peaked in 1862, 1866 and 1867 at one reference every 21, 28 and 36 pages. Homology reached its highest intensity in 1859, 1862 and 1866 at 16, 18 and 19 pages between references and its lowest in 1860, 1861 and 1864 at 114, 125 and 114 pages between references. Figure 27 and Figure 28 provide an overview over the timely development, Table 20 more details.

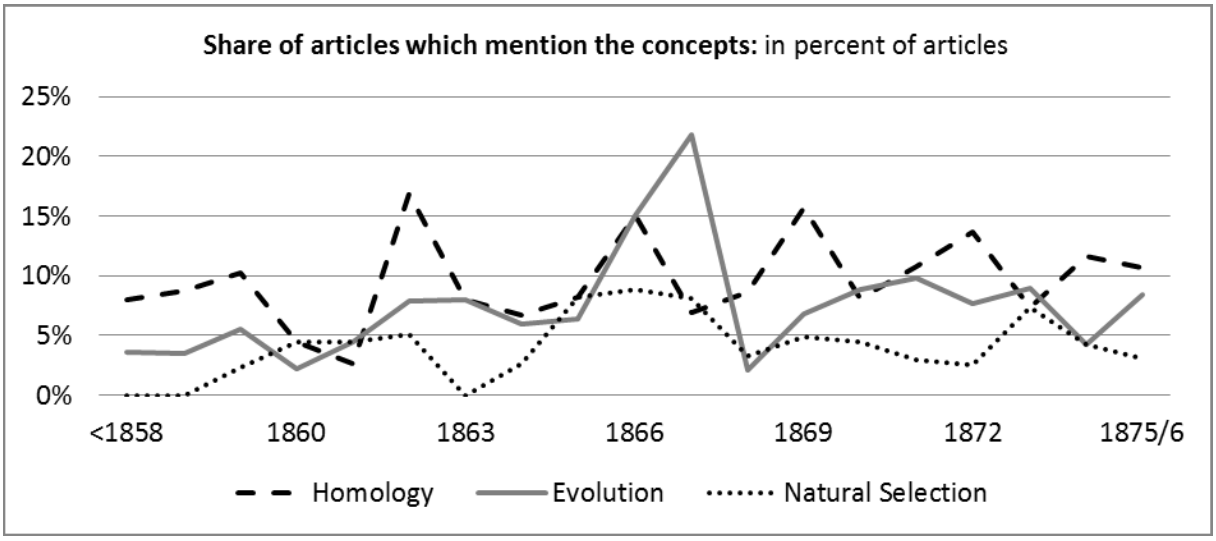

Figure 27: Mentions of concepts: homology, evolution, natural selection (1857/8-1875/6)

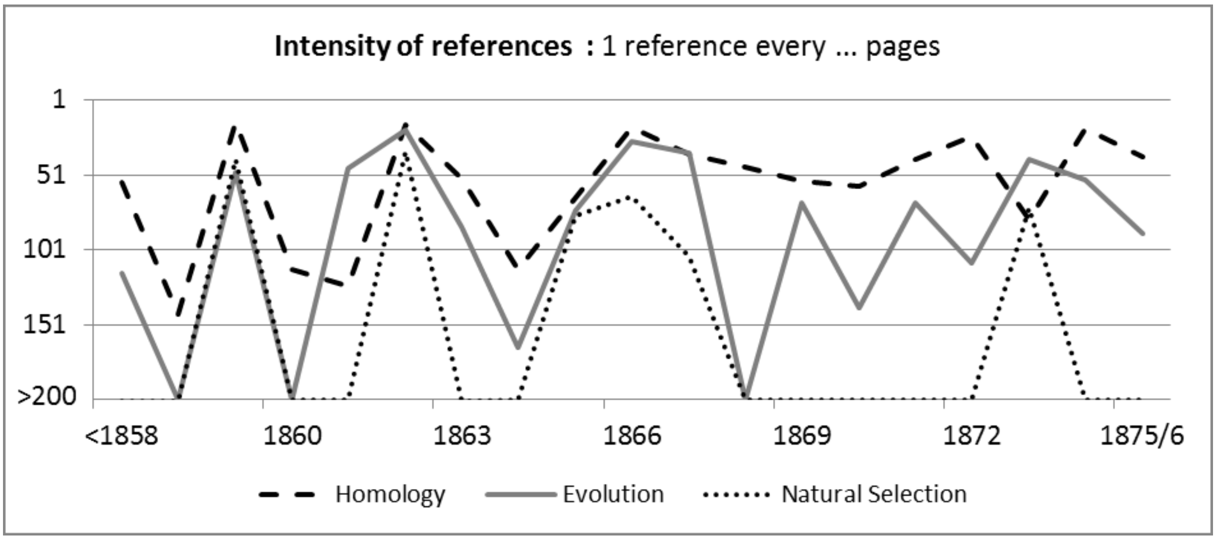

Figure 28: Intensity of usage: homology, evolution, natural selection (1857/8-1875/6)[534]

This independence of the dissemination of the Darwinian concepts and Owen's homology complies well with an episode which Nicolaas A. Rupke reports:

> "…in 1870 Huxley's friend E. Ray Lankester proposed to abandon the term 'homology' because as he disdainfully argued - it belonged 'to the old Platonic school' and was connected with the notion of an ideal type [e.g. Owen's archetype]. Before Darwin, embryonal development had already been accepted as the reliable guide to homology, and since the appearance of the Origin of Species, it had become common descent: Lankester now suggested that 'homology' he replaced with two other terms,

[534] For frequencies below 200 pages between references exact values are not displayed. (see Table 20)

> 'homogeny' to indicate genetically related structures; and as no genetic identity exists between, for example, legs and arms: he proposed for the phenomenon of such serially homologous parts the term 'homoplasy' or, under particular conditions of origin, 'homotrophy'." (Rupke 1994: 217)

Lankester's suggestion petered out. Owen's concept continued to be used for the aggregation of empirical descriptions and was combined with Darwin's interpretation of the resulting static model and, by some, with Darwin's explanation. Just as Darwin had reinterpreted Owen's archetype as an actual and observable progenitor, homologies could be interpreted as indications of actual evolutionary relations and this reinterpretation did not require a renaming of Owen's terminology.

iii. Positive, neutral and negative hits[535,536]

Negative hits are rare; 7 of the 88 references to natural selection dismissed the concept, 4 of the 150 references to evolution. No year saw more than two dismissive references for either concept; the number is too small to deduce any pattern from it. The eleven dismissive references come from nine articles, four authors and three journals only: Four of the articles were authored by Richard Owen and published in the *Transactions of the Zoological Society* in 1866, 1869 and 1872. Two of the articles were presidential addresses to the Royal Society of Edinburgh in 1860 and 1864 and came from the Duke of Argyll, the politician who presided at the Association at the time. (Argyll 1862 [1860]: 350-77; Argyll 1865 [1864]: 264-311) Another article from the Edinburgh Proceedings was authored by Andrew Murray read in 1860. (Murray 1862 [1860]: 274-291) Finally two critical articles came from presidential addresses to the *Transactions of the Royal Entomological Society*. (Westwood 1872: liv-lxi; Westwood 1873: xxxix-xlv) If one excludes the articles from the Duke of Argyll, who was no scientist, then seven articles from three authors remain – among 1.916 articles over 17 years.

Of the 88 references to natural selection 77% are positive (3.55% of all articles) and 15% neutral. To evolution, 73% of the 150 references were positive and 24% neutral such that 5.74% of all articles supported the concept. The articles with positive references to either of the concepts overlap in 34 articles such that exactly half of all articles which use or support the concept natural selection also use or support the concept evolution. Conversely, 34 of the 110 articles which employ or support evolution do also employ or support natural selection. (30.91 %) Consequently, the number of articles which support at least one of the concepts amounts to 144, i.e. 7.52%.

Over all three six-year spans, the absolute number of neutral references remained about constant for both concepts. In the second span (1865-70), however, the absolute number of positive references increased. Therefore, in these six years of heated public debate, the relative relation between both changed to 80% positive references and 13% neutral references for natural selection as well as 78% positive and 19% neutral references for evolution.[537] (For more details, see Table 20)

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535 Remember that a mere mention of a concept was counted as a neutral use. Explicit approval of a concept or its application to specific cases was counted as a positive use. Explicit criticism or disapproval of a concept was counted as a negative case.

536 Remember that or homology, this was not studied because the concept had much less theoretical import than Darwin's concepts and encountered less much criticism. Therefore, rejections were not expected.

537 By my estimate by far the largest number of positive references throughout the entire studied period are cases where the author applies one of the Darwinian concepts in order to explain a specific set of observations. Explicit praise of the concepts was rare, though not as rare their explicit rejection.

25 of the 26 which mention evolution five or more times and 12 of the 13 papers which mention it ten or more times are positive, i.e. endorse or employ the concept. The lone exception is the same 1866 paper from Richard Owen for the Transactions of the Zoological Society. 6 of the 8 articles which mention natural selection five or more times are positive and 3 of the 6 articles which mention it ten or more times. Thus, high-intensity articles support evolution but half of them dismiss natural selection.

iv. Concepts and keywords

The 271 references to the concept natural selection contained the string 'select' 138 times (50,92%), the string 'preserv' 79 times (29.15%) and the string 'struggle' 54 times (19.93%). Over the three six-year spans uses of the string 'select' decreased remarkably, from 53.57 to 58.76 to 33.87 percent of all references to the concept natural selection.[538] Meanwhile, the share of 'preserv' increased from 23.21 to 24.74 to 46.77 percent.

The 580 references to the concept evolution are distributed rather unequally and the distribution shifts over time. Only the strings 'origin' and 'descen' accounted for more than 10 percent of the hits throughout the three six-year spans; on average 'origin' produced 37.07% of the hits, 'descen' 19.83%. 'evol' is hardly mentioned in the first two spans but accounts for 17.39% of the hits between 1871 and 1875. 'progen' and 'inherit' each peak between 1865 and 1870 and display significantly lower values in the other two six-year spans. (For more details, see Table 20) For the concept of homology, the hits for the string 'archetyp' could be neglected; every article which mentioned 'archetyp', did also mention 'homolog'. Moreover, of the five references to Richard Owen's archetype concept, four are from Owen himself. (The other one comes from Mivart.)

It was checked whether the references for one of the concepts came predominantly from a small group of authors but no strong pattern appeared. While the concepts were indeed often used by their prominent supports – Owen for homology, Darwin, Bates, Bentham, Wallace for the Darwinian concepts – no small group accounted for anything close to a majority of the respective references. Interestingly, Owen's concept of homology was frequently employed by Darwinians, for instance by Bates, Wallace, Huxley, Hooker but also by Darwin himself. (Darwin 1862: 152; Darwin 1865: 190; Darwin 1867 [1865]: 48-117)

538 From cursory reading, I gained the impression that towards the end of the period, the latter two strings were not necessarily associated to the term 'natural selection' anymore. Thus, the number of references to the concept natural selection might be artificially high. To test this impression would require a more detailed study – If it is possible at all.

Overview Quantitative Analyis: Share of articles which mention concepts, frequency of references to the concepts

																					Sums & Averages				Median
		< 1858	1858	1859	1860	1861	1862	1863	1864	1865	1866	1867	1868	1869	1870	1871	1872	1873	1874	1875/6	59-64	65-70	71-75/6	59-76	59-76
	# of volumes	6	4	5	4	5	7	2	6	5	5	4	4	6	6	5	5	6	4	6	29	30	26	85	5
	# of articles	137	57	127	90	113	178	50	150	109	113	87	93	102	136	102	117	123	95	131	708	640	568	1.916	113
	# of pages	1511	1148	1615	1139	1622	1974	859	2159	1725	1898	1998	2179	2358	3337	2363	1868	2974	1898	2243	9.368	13.495	11.346	34.209	1.974
Concept natural selection	# of articles	0	0	3	4	5	9	0	4	9	10	7	3	5	6	3	3	9	4	4	25	40	23	88	4
	select*	0	0	2	2	1	7	0	3	6	6	3	2	3	5	3	1	5	4	2	15	25	15	55	3
	preserv*	0	0	2	0	3	3	0	0	2	5	4	1	1	3	0	1	4	2	1	8	16	8	32	2
	struggle*	0	0	3	2	3	5	0	2	3	4	3	1	2	1	1	1	5	1	1	15	14	9	38	2
	% of articles	0,00%	0,00%	2,36%	4,44%	4,42%	5,06%	0,00%	2,67%	8,26%	8,85%	8,05%	3,23%	4,90%	4,41%	2,94%	2,56%	7,32%	4,21%	3,05%	3,53%	6,25%	4,05%	4,59%	4,41%
	affirmative			3	3	4	5	0	4	7	7	7	2	4	5	3	2	8	2	2	19	32	17	68	4
	neutral			0	1	1	2	0	0	2	1	0	1	0	1	0	0	0	2	2	4	5	4	13	1
	negative			0	0	0	2	0	0	0	2	0	0	1	0	0	1	1	0	0	2	3	2	7	-
	# of hits	0	0	40	4	7	56	0	5	22	29	19	5	8	14	6	3	41	8	4	112	97	62	271	8
	select*	0	0	20	2	1	34	0	3	17	13	9	3	5	10	4	1	10	4	2	60	57	21	138	4
	preserv*	0	0	11	0	3	12	0	0	2	10	7	1	1	3	0	1	25	2	1	26	24	29	79	2
	struggle*	0	0	9	2	3	10	0	2	3	6	3	1	2	1	2	1	6	2	1	26	16	12	54	2
	1 hit per __ pages	n.a.	n.a.	40	285	232	35	n.a.	432	78	65	105	436	295	238	394	623	73	237	561	84	139	183	126	238
Concept evolution	# of articles	5	2	7	2	5	14	4	9	7	17	19	2	7	12	10	9	11	4	11	41	64	45	150	
	evol*	1	0	0	0	1	0	1	0	1	3	1	0	0	1	2	5	3	3	5	2	6	18	26	1
	transmut*	0	0	1	1	0	1	1	0	0	4	2	0	0	0	1	0	1	1	0	4	6	3	13	1
	inherit*	0	0	1	0	1	3	0	0	3	2	2	0	1	2	3	1	3	1	1	5	10	9	24	1
	fit*	0	0	1	0	1	1	0	0	1	1	2	0	0	1	0	1	2	1	1	3	5	5	13	1
	origin*	1	2	4	2	2	12	4	7	3	9	6	1	5	3	6	1	6	1	4	31	27	18	76	4
	ancest*	1	0	1	0	1	5	0	0	1	2	2	0	2	5	4	4	6	2	3	7	12	19	38	2
	progen*	3	0	3	0	2	4	0	1	2	1	10	2	1	2	2	2	2	1	1	10	18	8	36	2
	descen*	1	0	2	0	2	6	1	2	1	5	6	1	1	5	3	0	5	1	4	13	19	13	45	2
	% of articles	3,65%	3,51%	5,51%	2,22%	4,42%	7,87%	8,00%	6,00%	6,42%	15,04%	21,84%	2,15%	6,86%	8,82%	9,80%	7,69%	8,94%	4,21%	8,40%	5,79%	10,00%	7,92%	7,83%	7,69%
	affirmative			5	0	4	10	2	7	5	14	15	1	5	10	10	3	9	2	8	28	50	32	110	5
	neutral			2	2	1	4	2	2	2	3	4	1	0	2	0	5	1	2	3	13	12	11	36	2
	negative			0	0	0	0	0	0	0	0	0	0	2	0	0	1	1	0	0	-	2	2	4	-
	# of hits	13	4	33	3	35	95	10	13	23	67	55	4	34	24	34	17	73	35	25	189	207	184	580	33
	evol*	2	0	0	0	2	0	1	0	1	3	1	0	0	1	2	7	10	6	7	3	6	32	41	1
	transmut*	0	0	1	1	0	1	1	0	0	9	2	0	0	0	1	0	1	1	0	4	11	3	18	1
	inherit*	0	0	1	0	1	5	0	0	7	12	2	0	4	3	4	1	3	1	1	7	28	10	45	1
	fit*	0	0	1	0	1	1	0	0	1	3	3	0	0	1	0	1	5	1	1	3	8	8	19	1
	origin*	5	4	19	2	16	51	7	8	8	30	14	1	11	3	12	1	25	2	5	103	67	45	215	8
	ancest*	1	0	1	0	5	9	0	0	1	3	2	0	2	8	9	5	10	6	4	15	16	34	65	3
	progen*	4	0	8	0	2	5	0	1	4	1	20	2	1	2	2	2	2	7	3	16	30	16	62	2
	descen*	1	0	2	0	8	23	1	4	1	6	11	1	16	6	4	0	17	11	4	38	41	36	115	4
	1 hit per __ pages	116	287	49	380	46	21	86	166	75	28	36	545	69	139	70	110	41	54	90	50	65	62	59	70
concept: homology	# of articles	11	5	13	4	3	30	4	10	9	17	6	8	16	11	11	16	9	11	14	64	67	61	192	11
	homolog*	11	5	13	4	3	30	4	10	9	17	6	8	16	11	11	16	9	11	14	64	67	61	192	11
	archetyp*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1	1	0	0	1	-	4	5	-
	% of articles	8,03%	8,77%	10,24%	4,44%	2,65%	16,85%	8,00%	6,67%	8,26%	15,04%	6,90%	8,60%	15,69%	8,09%	10,78%	13,68%	7,32%	11,58%	10,69%	9,04%	10,47%	10,74%	10,02%	8,60%
	# of hits	27	8	100	10	13	112	16	19	26	101	54	48	43	57	58	75	37	93	58	270	329	321	920	54
	homolog*	27	8	100	10	13	111	16	19	26	101	54	48	43	57	56	74	36	93	58	269	329	317	915	54
	archetyp*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1	1	0	0	1	-	4	5	-
	1 hit per __ pages	56	144	16	114	125	18	54	114	66	19	37	45	55	59	41	25	80	20	39	35	41	35	37	45
	Darwin* (# of articles)	0	0	2	2	3	10	1	6	6	11	3	4	5	3	2	2	3	3	2	24	32	12	68	3
	Darwin* (# of hits)	0	0	1	5	3	56	1	7	17	22	11	9	5	23	3	2	6	5	2	73	87	18	178	5

Table 20: Overview quantitative analysis (1857/8-1875/6)

v. Distribution over journals

If one compares the six journals which certainly addressing the immediate scientific community of biology to the two borderline cases – the transactions of the Royal Societies – few marked differences appear. The Darwinian concepts are mentioned about equally often in the group of six as in the group of eight. The same is true regarding intensity. Homology, however, produces markedly stronger effects in the group of eight, i.e. it is less often mentioned in the journals of the Royal Societies. (See Table 21 for the comparison and Table 22 to Table 25 for the individual journals.)

	Aggregate values over all eight journals				**Aggregate values without Royal Societies**			
Sample size	# of volumes	# of articles	# of pages	# pages per article	# of volumes	# of articles	# of pages	# pages per article
	85	1.916	34.209	18	63	1.686	29.443	17
Natural Selection	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	88	4,59%	271	126	78	4,63%	229	129
select*	55	3%	138	248	48	3%	115	256
preserv*	32	2%	79	433	29	2%	71	415
struggle*	38	2%	54	634	32	2%	43	685
Utilization	total	positive	neutral	Negative	total	Positive	neutral	negative
Totals	88	68	13	7	78	63	11	4
in %	100%	77%	15%	8%	100%	81%	14%	5%
Evolution	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	150	7,93%	580	59	124	7,35%	427	69
evol*	26	1%	41	834	18	1%	31	950
transmut*	13	1%	18	1901	6	0%	11	2677
inherit*	24	1%	45	760	20	1%	30	981
fit*	13	1%	19	1800	9	1%	11	2677
origin*	76	4%	215	159	67	4%	173	170
ancest*	38	2%	65	526	26	2%	44	669
progen*	36	2%	62	552	32	2%	52	566
descen*	45	2%	115	297	36	2%	75	393
Utilization	total	positive	neutral	Negative	total	Positive	neutral	negative
Totals	150	110	36	4	124	93	27	4
in %	100%	73%	24%	3%	100%	75%	22%	3%
Homology	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	192	10,02%	915	37	116	6,88%	547	54
homolog*	192	10%	915	0	116	7%	547	0
archetyp*	5	0%	5	0	3	0%	3	0
Darwin*	68	4%	178	192	61	4%	126	234

Table 21: Quantitative analysis: Aggregate values for all eight journals and without Royal Societies

Of the 1.916 articles, more than half (53.18%) are contributed by the Royal Entomological Society and the British Ornithologists' Union (*Ibis*). They also account for nearly half of the pages (45.84%) and have, thus, a marked effect on the overall values. Unsurprisingly, least articles came from the Royal Societies, 100 from London and 130 from Edinburgh, which sum up to 12.00% of the overall number. The shortest papers come from the Edinburgh proceedings, which often only printed abstracts or titles of lectures; Edinburgh papers are on average less than 4 pages long and account for 1.40% of all pages. In turn, the longest papers are found in the London transactions, of which the

100 articles have an average length of 43 pages and account for 12.53% of all pages. The remaining journals oscillate between article lengths of 11 and 29 pages, relative close to the average of 17.

As a measure for the overall intensity of theoretical discourse, one may ask for how frequently *any* of the concepts was employed. Over all eight journals, one of the concepts is found every 19 pages. This number is significantly higher for the Royal Society of Edinburgh (4), the Zoological Society (8), the Royal Society of London (10), and the Transactions of the Linnean Society (12). All of these intensities are driven by the concept homology which has exceptionally strong showings in each of the journals.

	Transactions of the Linnean Society				**Linnean Society - Proceedings Botany**			
Sample size	# of volumes	# of articles	# of pages	# pages per article	# of volumes	# of articles	# of pages	# pages per article
	8	173	4.218	24	11	219	3.625	17
Natural Selection	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	10	5,78%	53	80	9	4,11%	34	107
select*	9	5%	39	108	4	2%	6	604
preserv*	3	2%	8	527	4	2%	23	158
struggle*	4	2%	6	703	4	2%	5	725
Utilization	total	positive	neutral	Negative	total	Positive	neutral	negative
Totals	10	9	-	1	9	8	1	-
in %	100%	90%	0%	10%	100%	89%	11%	0%
Evolution	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	22	12,72%	114	37	15	6,85%	77	47
evol*	4	2%	5	844	-	0%	-	n.a.
transmut*	1	1%	1	4218	-	0%	-	n.a.
inherit*	6	3%	10	422	4	2%	7	518
fit*	1	1%	1	4218	1	0%	1	3625
origin*	11	6%	48	88	12	5%	35	104
ancest*	9	5%	17	248	2	1%	2	1813
progen*	6	3%	13	324	3	1%	5	725
descen*	10	6%	19	222	4	2%	27	134
Utilization	total	positive	neutral	Negative	total	positive	neutral	negative
Totals	22	21	1	-	15	13	2	-
in %	100%	95%	5%	0%	100%	87%	13%	0%
Homology	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	43	24,86%	184	23	12	5,48%	31	117
homolog*	43	25%	184	23	12	5%	31	117
archetyp*	2	1%	2	2109	-	0%	-	
Darwin*	9	5%	22	192	4	2%	4	906

Table 22: Quantitative analysis: Linnean Society – Transactions & Proceedings Botany (1859-75/6)

The least intense theoretical discourse display *The Ibis* (96), the Royal Entomological Society (51) as well as the botany (26) and the zoology section (22) of the Linnean Society.[539] As the Ibis and the Transactions of the Royal Entomological Society constitute about half of the data set, their effect on the average is marked. With the exception of the Zoological Society, these frequencies correlate to the general character of the journals: the Transactions are the most abstract publication of the Linnean Society and the transactions of the Royal Societies are borderline cases between the broader and immediate scientific community anyway; they discuss more theoretical issues.

539 For the latter two, the frequency might have been lowered by bad scan quality.

	Linnean Society - Proceedings Zoology				Transactions of the Zoological Society			
Sample size	# of volumes	# of articles	# of pages	# pages per article	# of volumes	# of articles	# of pages	# pages per article
	10	191	3.450	18	5	84	2.469	29
Natural Selection	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	12	6,28%	59	58	6	7,14%	10	247
select*	6	3%	28	123	4	5%	7	353
preserv*	9	5%	20	173	2	2%	2	1235
struggle*	5	3%	11	314	1	1%	1	2469
Utilization	total	positive	neutral	negative	total	positive	neutral	negative
totals	12	9	3	-	6	2	1	3
in %	100%	75%	25%	0%	100%	33%	17%	50%
Evolution	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	14	7,33%	63	55	13	15,48%	36	69
evol*	3	2%	9	383	3	4%	3	823
transmut*	-	0%	-	n.a.	3	4%	8	309
inherit*	4	2%	5	690	1	1%	2	1235
fit*	2	1%	3	1150	1	1%	1	2469
origin*	10	5%	34	101	6	7%	17	145
ancest*	3	2%	3	1150	2	2%	3	823
progen*	2	1%	2	1725	-	0%	-	n.a.
descen*	6	3%	7	493	2	2%	2	1235
Utilization	total	positive	neutral	negative	total	positive	neutral	negative
totals	14	11	3	-	13	7	4	2
in %	100%	79%	21%	0%	100%	54%	31%	15%
Homology	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	14	7,33%	35	99	36	42,86%	271	9
homolog*	14	7%	35	99	36	43%	271	9
archetyp*	-	0%	-		1	1%	1	2469
Darwin*	7	4%	30	115	3	4%	5	494

Table 23: Quantitative analysis: Linnean Society – Zoology, Zoological Society (1859-75/6)

In a number of volumes, the concepts were not mentioned at all. For the Darwinian concepts this occurred in 18 of 85 volumes: in 7 of the 11 volumes of the botany section of the Linnean Society, 3 of the 10 volumes of the zoological section of the Linnean Society, 1 of the 8 volumes of the *Transactions of the Linnean Society*, 2 of the 5 volumes of the *Proceedings of the Royal Society of Edinburgh* and 5 of the 17 volumes of the *Philosophical Transactions of the Royal Society of London*.[540] Homology was not mentioned in 7 of the 11 volumes of the botany section of the Linnean Society, 4 of the 10 volumes of the zoological section of the Linnean Society, 1 of the 8 volumes of the *Transactions of the Linnean Society* and 14 of the 17 volumes of the Ibis.

The share of positive articles of all articles is lowest for the Zoological Society (33% for evolution, 54% for natural selection) and the Edinburgh proceedings (0% and 33%) as well as for the Entomological Society with respect to natural selection (66% positive articles). It is around the average for the zoology section of the Linnean Society (75% and 79%) as well as The Ibis (81% and 71%) and high for the transactions (90% and 95%) and the botany section of the Linnean Society (89% and 87%) as well as Royal Society of London (100% and 75%).

540 Remember, however, that the scan quality was bad for the botany section of the Linnean Society and mediocre for the zoology section.

	Transactions - Royal Entomological Society				The Ibis (British Ornithologists' Union)			
Sample size	# of volumes	# of articles	# of pages	# pages per article	# of volumes	# of articles	# of pages	# pages per article
	12	316	7.839	25	17	703	7.842	11
Natural Selection	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	20	6,33%	48	163	21	2,99%	25	314
select*	14	4%	23	341	11	2%	12	654
preserv*	9	3%	16	490	2	0%	2	3921
struggle*	7	2%	9	871	11	2%	11	713
Utilization	total	positive	neutral	negative	total	positive	neutral	negative
totals	20	18	2	-	21	17	4	-
in %	100%	90%	10%	0%	100%	81%	19%	0%
Evolution	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	29	9,18%	84	93	31	4,41%	53	148
evol*	6	2%	10	784	2	0%	4	1961
transmut*	2	1%	2	3920	-	0%	-	n.a.
inherit*	3	1%	4	1960	2	0%	2	3921
fit*	4	1%	5	1568	-	0%	-	n.a.
origin*	7	2%	8	980	21	3%	31	253
ancest*	7	2%	15	523	3	0%	4	1961
progen*	15	5%	26	302	6	1%	6	1307
descen*	8	3%	14	560	6	1%	6	1307
Utilization	total	positive	neutral	negative	total	positive	neutral	negative
totals	29	19	8	2	31	22	9	-
in %	100%	66%	28%	7%	100%	71%	29%	0%
Homology	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	7	2,22%	22	356	4	0,57%	4	1961
homolog*	7	2%	22	356	4	1%	4	1961
archetyp*	-	0%	-	n.a.	-	0%	-	n.a.
Darwin*	17	5%	33	238	21	3%	32	245

Table 24: Quantitative analysis: Royal Entomological Society, The Ibis (1859-75/6)

With respect to the single concepts, natural selection and evolution show a rather regular distribution. The median does not deviate much from the mean and the frequency increases and decreases with the general propensity of the journal to employ theoretical concepts. For evolution, however, the Royal Society of London and the Zoological Society display a large number of articles mentioning it 2.5 about times and about twice as often as on average. (The Zoological Society cites natural selection about 1.5 times as often as usual but of the 6 articles four are negative.)For homology, the deviations from its average (10.02%) are more marked. It is mentioned in 57.00% percent of articles of the London transactions, 42.86% of the articles of the Zoological society and in 24.86% of the articles in the Linnean Transactions. In return, the Ibis cites the concept only in 0.57% of its articles, the entomologists in 2.22%, the *Proceedings of the Linnean Society* for botany in 5.48% and for Zoology in 7.33% of the articles. Thus, homology shows a far more unequal distribution than the Darwinian concepts.

	Transactions - Royal Society of London				Transactions - Royal Society of Edinburgh			
Sample size	# of volumes	# of articles	# of pages	# pages per article	# of volumes	# of articles	# of pages	# pages per article
	17	100	4.288	43	5	130	478	3,68
Natural Selection	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	5	5,00%	9	476	5	3,85%	33	14
select*	2	2%	4	1072	5	4%	19	25
preserv*	1	1%	1	4288	2	2%	7	68
struggle*	3	3%	4	1072	3	2%	7	68
Utilization	total	positive	neutral	negative	total	positive	neutral	negative
totals	5	5	-	-	5	-	2	3
in %	100%	100%	0%	0%	100%	0%	40%	60%
Evolution	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	20	20,00%	94	45,62	6	4,62%	59	8
evol*	6	6%	8	536	2	2%	2	239
transmut*	5	5%	5	858	2	2%	2	239
inherit*	1	1%	1	4288	3	2%	14	34
fit*	3	3%	5	858	1	1%	3	159
origin*	5	5%	20	214	4	3%	22	22
ancest*	11	11%	20	214	1	1%	1	478
progen*	3	3%	9	476	1	1%	1	478
descen*	5	5%	26	165	4	3%	14	34
Utilization	total	positive	neutral	negative	total	positive	neutral	negative
totals	20	15	5	-	6	2	4	-
in %	100%	75%	25%	0%	100%	33%	67%	0%
Homology	# of articles	% of articles	# of hits	1 hit per … pages	# of articles	% of articles	# of hits	1 hit per … pages
Aggregates	57	57,00%	343	12,50	19	14,62%	25	19
homolog*	57	57%	343	13	19	15%	25	19
archetyp*	2	2%	2	2144	-	0%	-	n.a.
Darwin*	2	2%	3	1429	5	4%	49	10

Table 25: Quantitative analysis: Royal Societies in London & Edinburgh (1859-75/6)

vi. Conclusion

The general assessment among both Darwin's contemporaries and modern historians is, first, that the Darwinian revolution was achieved by ca. 1868 and, second, that many more biologists accepted evolution than did accept natural selection. Both assessments are confirmed by my analysis. Third, my analysis allows for estimating the overall impact of the Darwinian revolution on biology in Britain.

First, the peak of references to the Darwinian concepts clearly lies around the mid- to late 1860s, afterwards mentions faded. As my analysis did attributed articles to the publication year of the volume in which the articles appeared, the fading effect should even be delayed in my data. I can thus confirm the assessments of the time at which the revolution is achieved.

Second, the concept evolution was mentioned in much more articles and produced significantly more hits than natural selection. Moreover, the number of negative references to evolution is negligible while natural selection produced about 8% negative references. Furthermore, references to natural selection declined much stronger than references to evolution towards the end of the analyzed period, indicating that the concept enjoyed less sustainable success.

Third, the impact of both concepts on biological publications was small. In the sixteen years immediately after the publication of the Origin, less than 4.59% of the papers mentioned natural selection and 3.55% employed it or explicitly expressed support for it. Less 7.83 percent of papers mentioned evolution and less than 5.74% employed it or explicitly supported it. When one accounts for the overlap, i.e. papers which contain positive references to both concepts, only 7.52% of all papers employed or endorsed at least one of the concepts. Thus, only a fraction of the biological papers displayed an influence of Darwinian concepts on their presentation of descriptions of observations (data) and on their arguments.[541]

Moreover, the rise of both concepts was overshadowed by the parallel success of Richard Owen's homology concept. Homology is a classificatory concept (level 2 of my model) which Owen developed in the context of his archetype theory of the late 1840s. Between 1859 and 1875/6, homology produced more hits than the Darwinian concepts combined and was employed in exactly as many articles as both combined.[542] Moreover, its lasting effect on biological papers is much more sustainable throughout the analyzed period; hits increased towards the mid-1870s.

[541] Moreover, during the analysis I gained the impression that papers in the early and mid-1860s often employed the concepts in ornamental fashion or as a political statement. For instance, an area was described as dry and hot such that plants had to *struggle for their existence* there. The struggle metaphor obviously is not necessary here and serves as an ornament, although it formally counts as a use. I did not quantify this effect.

[542] Remember that homology was not theoretically contested. Therefore, I counted every reference as a use of the concept.

4.4 Synthesis

In this chapter I have distinguished four important groups of recipients of Darwin's evolution theory: (i) the *immediate scientific community* doing empirical work in Darwin's field, namely paleontologists, zoologists, botanists etc. (ii) professional and amateur scientists from other fields forming a *broader scientific community*, (iii) the *public* who followed the debate in newspapers and popular journals or more specialized magazines. My aim was to compare the reception of Darwin's theory among these groups in order to answer three questions: (i) Who received what information on Darwin's theory? (ii) By what criteria was the theory assessed? (iii) What elements of Darwin's theory were accepted and which rejected? The results of the analysis can be summarized as follows.

i. Reception depth and width

I have demonstrated that the three groups received increasing amounts of information on the theory and that the increase largely[543] followed the categories of my four-level model of scientific theories:

- The public received the theory mainly through its philosophical implications for their world-views, be it Man's alleged descent from the apes or its conflicts with the Victorian world views, notably the conception of a theist God. They received Darwin's explanation and classification only in their connotative component, i.e. they received Darwin's narration and interpretation but not his dynamic and static model.[544]
- The broader scientific community received the entire levels 2 to 4, although their reception of Darwin's static and dynamic model was usually somewhat limited.
- Only the immediate scientific community received and discussed all four levels.

Figure 29 summarizes the relation between these layers of reception depth and the different recipient groups.

<table>
<tr><th></th><th>Immediate scientific community: biologists</th><th>Broader scientific community: other scientists</th><th>Public: laymen</th></tr>
<tr><td>Level 4: Implications</td><td colspan="3">Implications for the Victorian world view</td></tr>
<tr><td rowspan="2">Level 3: Explanation</td><td colspan="3">Narration</td></tr>
<tr><td colspan="2">Dynamic Model</td><td></td></tr>
<tr><td rowspan="2">Level 2: Classification</td><td colspan="3">Interpretation</td></tr>
<tr><td colspan="2">Static Model</td><td></td></tr>
<tr><td>Level 1: Description</td><td>Descriptions of observations</td><td></td><td></td></tr>
</table>

Figure 29 : Recipient groups, depth of reception, types of biological knowledge

[543] This is a simplified representation, there exist exceptions to it. Some reviews for the public provided good explications of Darwin's static or dynamic model and a couple of reviews for the broader scientific community provided extensive descriptions of empirical evidence.

[544] Remember that this layer of information corresponds to the level of scientific knowledge which is easiest accessible to laymen; humans receive information, first and foremost, through metaphors and narratives. (cf. sections 2.1.2.i; 2.1.4.i, ii, particularly footnotes 80 and 81.)

Besides, it displays that the three recipient groups had three different kinds of knowledge of Darwin's evolution theory: The public's understanding was based on connotative meaning; it consisted in associations from the main metaphors in Darwin's narrative and in their linking to relevant metaphors of Victorian world-views. Thus, the public's knowledge of biology may be best called *associative knowledge*. The broader scientific community additionally possessed a *generic scientific knowledge* which allowed for understanding the main categories of Darwin's models and relating them in consistent statements. Only the immediate scientific community of working biologists possessed the *specialized* and *empirical scientific knowledge* to access the lowest layer of knowledge and to grasp the empirical meaning of the Darwinian theory.

Furthermore, the analysis revealed that the heated debate on Darwin did not take place in the biological journals. The number of extensive discussions in the journals for Darwin's immediate scientific community is very small, both compared to the overall number of biological papers and the number of reviews and extensive discussions in publications for the broader scientific community and the public. As only a small minority of biologists engaged in these more general debates, we can infer that the large majority of biologist did not engage in the debate. Moreover, this discrepancy suggests that much of the existing historical and philosophical reception of the Darwinian revolution focused on the public debate and debate among the broader scientific community as well as on a small group of biologists which engaged in these debates, notably Huxley, Owen, Darwin and Wallace.[545] This focus provides no representative image of the debate among biologists.

ii. Criteria for the assessment of the Darwinian theory: lines of criticism

Criticism followed the same pattern as reception depth: For lack of further knowledge, the general public judged the theory by the plausibility of Man's descent from the apes, notably the image of a deist God. The educated public focused on the possible political and moral implications conveyed by Darwin's narrative and judged its plausibility against the backdrop of Victorian Weltanschauung. The broader scientific community additionally looked for logical inconsistencies in the model and for the model's consistency with established models and meta-models, i.e. models from other disciplines and contemporary conceptions of scientific methods. The immediate scientific community discussed[546] aspects of all of the above but they also debated the empirical fit of Darwin's theory, for instance classifications or descriptions of experiments and observations relevant for assessing the theory.

The different criteria by which the recipient groups assessed the theory can be summarized in three categories: (i) plausibility: the fit with other ontologies, (ii) inner consistency: the logical consistency

545 In this respect it is interesting that The Origin itself be a book for the broader scientific community. The book that triggered the scientific revolution is itself a book with sparse and illustrative evidence; it is, in Darwin's words, "an essay" and its focus clearly lies on the presentation of the Darwinian model. The thorough empirical study was to follow in the "big book" Darwin promised but never published. Therefore, the revolution began and proceeded without a publication which would rigorously explain what empirics where presumed to support the novel model and how exactly the model related to the actual, thorough descriptions of empirics communicated within the immediate scientific community.

546 Remember that the immediate scientific community had access to the other debates and participated in them. Thus, even if ontological issues were not discussed in the biological journals, biologists could receive these debates – although many biologists might not have cared for the layman debate.

of Darwin's static and dynamic model, (iii) empirical fit: fit with the set of descriptions of observations which Darwin aimed to explain.[547] Table 26 summarizes these relations.

Audience	Criteria for assessing the theory
Public: laymen	Plausibility
Broader scientific community: scientists from outside biology	Plausibility – Inner consistency
Immediate scientific community: biologists	Plausibility – Inner Consistency – Empirical fit

Table 26: Audience and criteria for assessing the Darwinian theory

iii. Acceptance and rejection of elements of the theory

The lines of criticism allow for deducing what Darwin's theory changed in the minds and work of his contemporaries, i.e. what elements of the Darwinian theory were ultimately accepted by its recipients. Unsurprisingly, no audience accepted any of the information they had not received.[548] Therefore, the theory failed to revolutionize the world views of the general public which rejected all that it knew about the theory: Man's descent from the apes. It did modify the world views of the educated and interested public, however, who accepted the idea of the common descent of animals – albeit often blending it with their traditional idea of Divine Providence and Design. The educated public refused to apply *Evolution* to man – at least to his moral and mental faculties. The broader scientific community followed this refusal. Moreover, they would accept Darwin's model only if it was supplemented by elements of Design, by explicit reference to a First Causes or by a Vital Force which steered the critical variations.

Trends for the immediate scientific community resembled those of the broader; many biologists accepted evolution and few criticized Darwin's static model and its interpretation. Natural selection encountered much more opposition, was employed less frequently and criticized more often; biologists clearly were divided on topic. Towards the end of the studied period, it seems that the term was mostly avoided and biologist preferred the more neutral concept of preservation.[549]

However, neither concept had a large impact on biological work in Britain. In Darwin's home country and arena of the heated public debates, only 3.55% and 5.85% percent of papers employed or explicitly supported the concepts natural selection and evolution. This seems like a weak effect, particularly when compared with Richard Owen' concept of homology which was employed in 10.02% of the papers, produced more hits than natural selection and evolution combined and

[547] Note that Darwin's theory was challenged by empirical evidence from other debates or, more precisely, by models based on such evidence. In the debate on the age of the earth, Thomson did provide data from physical observations and challenged Darwin's theory by his interpretation of this data. As this is conflict of explanations, not of the underlying data, I do not count Thomson as assessing the empirical fit of Darwin's theory.

[548] As it was no result of an informed decision, I hesitate to call this lack of acceptance 'rejection'.

[549] In Darwin's model preservation is a sub-concept of natural selection, however, connotatively it has less anthropocentric overtones and less immediately suggests an agency than selection.

showed a more sustainable long term effect than the Darwinian concepts for which the references decrease in the 1870s.[550]

iv. Synthesis

My analysis provides a classification of reception depths during the Darwinian revolution in Victorian Britain[551]; it demonstrates that different audiences received Darwin's theory to different depths and that these depths largely follow the abstraction levels and the two kinds of meaning which I have distinguished in my model of scientific theories.

Moreover, this classification of reception explains the criteria by which the recipient groups judged the theory and the elements they considered[552] for acceptance.[553] Thus, it explains why the debates on the Darwinian theory differed between the three recipient groups and why there existed little shared debate: the recipient groups generally discussed different topics and where topics overlapped they differed in the depth in which they were discussed.[554]

Finally, the reception analysis reveals to which point the acceptance of the Darwinian theory was a selective matter. Recipients did not accept the theory as a whole; they did not even accept all the elements they received. Rather, they deliberately chose single elements of Darwin's classification, explanation and ontology and combined it with elements of other theories or their established world-views – no matter how Darwin had intended his theory to work. This independence between the text of the Origin and its effect on the Victorian Britain highlights the difference between a theory as a linguistic entity – a meaningful text – and a social entity – a collection of cluttered and incoherent interpretations of and projections on the text. – In its reception, Darwin's theory led a life of its own.

550 It is evidently possible that references increase again in the 1880s and later but such an effect needs is not known; moreover, it would require demonstration that the effect is still due to Darwin. Regarding the mid-20th century modern synthesis of genetics and evolution theory, such a relation would be dubious.

551 In order to assess whether my results translate to other contexts – to different periods or geographical areas or to other scientific revolutions – requires additional research.

552 It does not, however, explain which elements were ultimately accepted; this might be possible through additional explaining phenomena, for instance a specification of the Situation Type in which the reception took place: the cultural context of the reception.

553 In other words, there is a dynamic model in which the reception depths figure as Input and the criteria for the theory choice and elements of theory figure as Output.

554 For instance, the debate on the descent of Man in the broader scientific community was way more complex then within the general public; it included references to the model of Natural Selection and the Evolution of animals and plants. Within the immediate scientific community, it also had an empirical dimension, including references anatomical studies and field observations. Hence, although often employing the same concept names, the three recipient groups did not speak about the same piece of denotative content, i.e. the same set of empirics.

5 Conclusion

My dissertation pursued a triple project, partly historical-epistemological, partly philosophical and partly sociological. In section 2.1, I have developed a novel model for the analysis of scientific theories which distinguishes four abstraction levels and two kinds of meaning within scientific theories. I applied this model in the analysis of a group of theories of evolution in the first half of the 19th century. (Chapter 3) As a complementary perspective, I have developed a novel framework for the analysis of the reception of scientific theories with heterogeneous audiences (section 0) and I have studied the reception of the Darwinian theory with its help. After distinguishing three groups of recipients – biologists, other scientists and the public – I have analyzed which parts of the theory were received by its different recipients, by which criteria different recipients judged the theory and which elements they accepted or dismissed. (Chapter 0)

Now let me interpret and explain these results and let me demonstrate how they improve our understanding of both the Darwinian and scientific revolutions in general. I will begin by a historical-epistemological reconstruction of Darwin's contribution to the debate on evolution, continue with an assessment of Darwin's impact on 19th century biology and conclude by discussing possible generalizations from the Darwinian to other theoretical revolutions in science.

5.1 Historical-epistemological conclusion: What reorganization of biological knowledge and what revolution of biological beliefs did Darwin suggest and achieve?

No unifying theory of biological phenomena existed at the beginning of the 19th century, only fragments and fading older beliefs. First, on the level of interpretations (level 2), the idea of a *scala naturae* was continuously losing supporters. Buffon had publicly dismissed any such notions and had considered taxonomic classifications to be useful tools, no more. More importantly, however, each newly identified species made it more and more difficult to cling to an ideal order of organisms. In order to organize the known organisms in a regular static scheme, more and more complex models were needed and they were less and less intuitive. Second, on the level of explanations (level 3), the British and Cuvier stuck to the trail of natural theology, studying nature in order to reveal divine greatness. On the continent, theistic explanations were a thing of the past. De Maillet, Buffon or the German idealists had expressed tentative deistic explanations. Yet, no full-fledged naturalistic (mechanistic) explanation was available. In terms of ontological implications (level 4), Man's place at the pinnacle of nature was still intact, both in Britain and on the continent. In the British context, God continued to intervene in nature, studiously taking care of each of his beings. On the continent, God rather took back-stage, acting through laws and secondary agencies.

At the end of the 1860s, these different levels of biological beliefs had undergone revolution and biology displayed two dominant models and a unifying theory: the static model of the common descent-tree and the dynamic model of natural selection, both embedded in a deistic framework of law-like divine actions. – How much of this revolutionary change can be explained in the framework of shared knowledge and shared beliefs? What role did shared challenging objects and mental models play? And how much of the change was actually an individual achievement of Charles Darwin, after whom we name this revolution?

i. *Fossils and foreign organism: the challenging objects of early 19th century biology*

The challenging objects of the Darwinian revolution were produced by two biological sub-disciplines which had emerged in the late 18th century: biogeography and paleontology.[555] The first biogeographic studies can be traced back to Buffon in the 1770s, but it were systematic studies like those of Alexander von Humboldt and Aimé Bonpland (1799-1804), Charles Darwin (1831-1836), or Alfred Russel Wallace and Henry Bates (1848-1852), which discovered (i) the wealth of novel species and (ii) the remarkable biogeographical regularities which challenged the established understanding of biology.

In the 1830s and 1840s, specimens "flooded into museums, as collectors plundered Nature at home and abroad", displaying manifold subtle differences and challenging taxonomists to classify them. (England 1997: 270) Thus, the question of the origin of species partly emerged from the sheer need to develop new classification systematics in order to cope with the more and more complex taxonomic classifications:

> "What constituted a good species, and what was merely a local variety (hardly a new problem to taxonomy), became a common source of dispute and concern among naturalists. Species "splitters" insisted that slight differences often marked a distinct species, while species "lumpers" claimed that this approach needlessly multiplied species and confused them with mere varieties." (England 1997: 270)

Among the most spectacular and most philosophically challenging new species were the apes; Owen's important papers on orangutans, gorillas, and chimpanzees all appeared between 1837 and 1859.[556]

Paleontology posed further problems. Mollusk fossil series had led Lamarck to adopt evolutionary views as early as 1800. Cuvier had denied that the fossil record supported any such views up to his death in 1832. Yet, while such views could still be considered to be reasonable skepticism in the 1830s, this became increasingly difficult. Geoffroy converted in the mid-1830s because of a series of reptiles. Moreover, each decade complemented the geological record and pointed towards the same conclusion: species evolved. Such, in the horse genus, the Hipparion fossils of 1855 and 1859 formed a link between Cuvier's extinct Paleotherium and the modern Equus.

Thus, in 1868, Owen concluded that the fossil record allowed for no other interpretation than that evolutionary change had indeed occurred:

> "The progress of Palaeontology since 1830 has brought to light many missing links unknown to the founder of the science. My own share in the labour led me, after a few years' research, to discern what I believed, and still hold, to be a tendency to a

[555] In cultural-sociological terms, these challenging objects emerged because of the commercial expansion (expeditions, trade) and the industrial revolution (construction of channels and railroads).

[556] Important discoveries of prehistoric human species were made in the same period, with the Engis skull being discovered in 1829, the Neanderthal skull in 1856. Yet, these skulls were interpreted as stemming from prehistoric humans only much later.

> more generalised, or less specialised, organization as species recede in date of existence from the present time. Even instances which to some have appeared to oppose the rule, really exemplify it." (Owen 1868: 790)

Furthermore, biogeographers reported remarkable specifications of Buffon's law, i.e. the fact that species did not simply correlate to climate zones; instead many regions display distinct animals and plants despite quite similar physical conditions. Thus, organisms were not merely adapted and designed for their "conditions of existence". – There had to be more. Wallace, in his 1855 paper, summarized the regularities of biogeography and paleontology best, stating that

> "Every species has come into existence coincident both in space and time with a pre-existing closely allied species." (Wallace 1870a [1855]: 5)

Everybody in the biological community was aware of these challenges, indeed some made for veritable sensations, as the first gorilla in 1837 or the Archaeopteryx in 1861. [557] Thus, these objects were not only known to the biologists of the early 19th century, it was also clear in what way they challenged established beliefs. This becomes clear when one studies the impact of these challenging objects on the shared knowledge and shared research topics.

ii. Evolution as a shared research topic of 19th century biology

First and foremost, by undermining the static view of a *scala naturae*, the challenging objects hoisted evolution onto the biological research agenda of the early 19th century. To de Maillet and Buffon, long term change of large groups of organisms had been an intriguing idea and a worth-wile topic of speculation. With Lamarck's analysis of the mollusk series, however, evolution began to move into the realm of the empirically accessible.[558] This move could be denied for another decade or two, as Cuvier did, but the evidence kept piling up. In the mid-1830s, when Geoffroy converted after studying a series of reptile fossils, the tides were clearly turning.

Therefore, it is no surprise to find evolution on the research agendas of all, Geoffroy, Owen, Wallace and Darwin, not mentioning Chambers or the diverse debate in Germany. In England, John Herschel referred to it as the "mystery of mysteries". Hence, it is clear that evolution was not a topic which Darwin or Wallace identified by themselves and which they studied in opposition to everybody else. Instead, evolution was one of the "hot" topics in biology, fostered by the challenging objects of biogeography and paleontology.

Moreover, by the 1830s at least, it was clear that both the environment and inherited features (structure) had to play a role in the explanation of evolution. In their famous debate at the *Académie Royale des Sciences* in Paris, Cuvier and Geoffroy had advocated both sides as unique explanations of the taxonomic relations. Cuvier was considered the winner of this particular battle, but none had

557 There was a third class of challenging regularities, namely regularities in the growth of organisms within their life-span. (ontogeny, embryology) Yet, these did not trigger the Darwinian revolution nor were they explained by Darwin and Wallace.

558 I believe it reasonable to draw the line between evolutionary speculations and the first model of evolution (in a qualitative sense) here: Buffon and de Maillet had no empirical evidence on which to test their ideas, thus they speculated. Lamarck, meanwhile, developed the first (scientific) model of evolution using actual empirical evidence (albeit a very limited set). Thus, Lamarck modeled actual regularities between features of empirical objects. As for the question whether Buffon's and de Maillet's speculations might be referred to as 'theories', see section 6 vi, vii.

won the war; neither the "conditions of existence" nor the "unity of type" alone made sense of the paleontological and biogeographical record. This, too, was shared knowledge among the biologist of the time. Consequently, we find references to both the environment and to structure in the later works of Geoffroy, as well as in Chambers, Owen, Wallace and Darwin.

iii. Different pathways of coping with the challenging objects

The respective individual contributions consisted, first, in specific organizations of the shared knowledge in static and dynamic models and, second, in the beliefs by which these models were interpreted or embedded in narrative structures.

I cannot identify any major differences in aggregation pathways (strategies). Several of the considered biologists achieved important improvements of existing classifications, for instance Lamarck, Cuvier and Owen. Moreover, taxonomic discussions seemed a regular phenomenon in the immediate community of biologists. However, these technical questions never provoked such heated debates as evolution and, more importantly, they produced no lasting divides in the biological community.

The interpretation of classifications was another matter. Lamarck, based on his very limited empirical knowledge, interpreted them as evidence for transformations of lower into higher organisms, but not for extinctions. To Cuvier, they did not suggest evolution, only extinctions and successive new creations, to Chambers, a regular and orderly progression to higher types. Owen interpreted taxonomic relations as oriented on archetypal form. To Darwin and Wallace classifications were irregular branching trees, evidence of common descent but no teleological or ideal order.

In dynamic modeling, distinct pathways can be distinguished. Lamarck and Geoffroy were both willing to link evolution (Output) to environmental changes (Input), but ignored individual variations as triggers of evolution and an important part of environmental changes. Chambers followed this assignment fully, Owen only with respect to extinctions; he traced sustainable alterations of structure to "laws of development" instead. Darwin and Wallace, by stressing the importance of individual variation for both a species and its competitors and predators/prey, introduced a new Input to dynamic models of evolution, thus creating new aggregate statements. The inspiration to this probably came from their shared interest in field work[559] and was outside the research focus of a lab researcher like Richard Owen.[560]

559 Both seem to have gained this inspiration in the field and on living organisms. It probably could not have been gathered on paleontological evidence for this evidence was too sparse and did not display the minute differences. (Only a small number of fossils were available per species.) It could not have been gathered in the dissecting room for anatomy focused on types and saw too little exemplars of each species. Both had carried out extensive field work early in their career – even before their expeditions to Latin Americas and South-East Asia. Wallace had worked as a land surveyor during the railway boom and the well-off Darwin had gone on long walks with the botanist and friend John Stevens Henslow (1796-1861) while in Cambridge. In their theoretical work, they established something like a micro-biogeography as opposed to the macro-approach of Buffon and others.

560 As an anatomist, Owen spent his time in the dissecting room and marveled in the description of single organisms which he considered to be representatives of the species; he focused much more on similarities than differences.

Both, Lamarck and Geoffroy, introduced Connectors which conveyed the idea of an altered behavior of the organisms.[561] Chambers and Owen did not specify a Connector nor a fully developed dynamic model. Wallace has a very developed model; only a Connector is missing. The most complete model is Darwin's. In a metábasis[562] (category shift), he introduced a Connector which draws an analogy to artificial selection (breeding) and paves the way for portraying Nature as the principal Agent of evolution.[563]

The most marked differences seem to have existed in the narratives by which evolution was told and in the ontological implications of these narratives. Chambers and Owen told in a deist narrative, explaining their static models by divine laws. This was already a controversial move in Britain as these narratives limited God's role to that of a distant observer who controlled biological life but did not intervene directly. Lamarck, Geoffroy and Darwin developed mechanistic (non-divine) narratives which complemented their dynamic models. These narratives championed novel Agents and pushed God still further to the back of biology. Moreover, with the distance to God increased controversial ontological implications regarding God's relation to Man, Man's place in Nature and social stability.

In sum, different pathways of knowledge reorganizations are rather found in dynamic models than static models; they concerned synthetic empirical regularities, much less the analytic empirical regularities on which classifications were founded. However, much of these different pathways can be explained by the growth of biological knowledge in the first half of the 19th century: Wallace's independent development of Darwin's dynamic model reveals that the relation of individual variation to evolution was not merely a product of Darwin's brilliant mind but suggested by the empirical evidence of field researchers.[564]

With respect to beliefs, the image is much more diverse. Biologists differed greatly on how to interpret taxonomic relations, on how to tell evolutionary change and what this telling implied about the world. Here, individual and distinct pathways become visible.

iv. From interpretation to explanation: the switch from static to dynamic models

One remarkable aspect about biology in the first half of the 19th century is its shift from interpretation (level 2) to explanation (level 3), from static modeling to dynamic modeling[565]. From my point of view, this shift had at least three important dimensions.

First, the shift in modeling was preceded by a shift in empirical knowledge. With the advent of biogeography and paleontology, biology shifted from analytic empirical regularities to synthetic[566] ones: it shifted from regularities on the same objects, independent of space and time, to regularities in space and time. The first kind of knowledge is best represented by Linnaeus and Cuvier who

561 This does not imply that both considered the organisms to be Agents of evolution. (see below)

562 A category shift consists in employing an established concept name in a new context to denote a new concept. Darwin borrowed a term which was well-established in the context of breeding and denoted a clear concept. He then transferred it to another context, wild-life, where it had not previously been used, thus bestowing much of the connotation of the original use onto the new context.

563 Wallace dismissed breeding as evidence on the question of evolution while Darwin extensively drew on the knowledge of breeders. (See sections 3.3.3, 3.3.4)

564 This does not imply that it was an obvious correlation; in the end, only Wallace and Darwin suggested it.

565 Historian of science Michel Morange calls this shift a move from encyclopedic knowledge to explanatory knowledge. (Morange 1998)

566 For the distinction, see section 6 ii.

studied which features of one organism were correlated to which other feature of the same organism. The second kind is embodied by Buffon, Wallace, or Darwin, who studied how organisms changed in space, geographical zones, and time, geological strata.

Second, the shift in modeling devalued static modeling. While static models like the *scala* or the *archetype* dominated the works biologists up the Linnaeus, they are still central to Owen's work and some of his contemporaries, for instance the early Geoffroy's *type*. In the later works of Geoffroy, but also in Lamarck, Wallace and Darwin, the static modeling becomes less and less sophisticated. Moreover, Darwin and Wallace devalued their own static modeling by emphasizing how arbitrarily species were defined, the units of their static model (the tree).[567] Conversely, these authors developed the first sophisticated dynamic models of evolution (around their simpler static ones).

Third, the shift in modeling anticipated, probably even initiated a shift from object knowledge to event knowledge. In Darwin's and Wallace's models, but also in Geoffroy's and Lamarck's, the terms employed to denote the Input and Output denote regularities of features of objects, for instance different properties of geological strata or of single living organisms. Yet, in their connotations, terms like 'variation' or 'evolution' conveyed the impression that biologists had observed the events which had produced these features in the first place. This terminological transgression may have served as a powerful heuristic, anticipating experimental biology and the real-time observations of evolution which would be possible only much later.

v. Filling the space between fact and tale: what explanations implied about the world

In his foreword to Matthias Schemmel's study of Thomas Harriot, Jürgen Renn remarked with respect to early 16th century-physics that "It was only after the growing body of mechanical knowledge became a vital resource of early modern societies that mechanical knowledge within its own conceptual systematizations started to compete with natural philosophy by constructing its own worldviews." In biology, this moment should probably be dated to the period here analyzed: the first half of the 18th century, when biologists expressed the first explanations (dynamic models) of biological phenomena. The shift from static to dynamic models implied the suggestion of novel narratives which were not centered around God. These narratives conflicted with established worldviews and eventually required biologists to construct their own, competing world-views.

In Britain, this meant loosening the grip of theology on the biology in the first place. While physics had separated its models from clerical judgment more than a century earlier, British biologists still faced adversity when promoting deistic explanations of natural phenomena. On the continent, this was mostly a question of the past, Cuvier again being a notable exception.

Beyond, the big issue was what secondary agents one could introduce between God and his natural subjects. Lamarck was the first to give it a try by ascribing some enigmatic agency to the plants and animals and he failed to convince. Geoffroy alluded to God and nature but stuck with the safe choice. Chambers and Owen remained in the traditional framework and introduced no secondary agent. Wallace's two articles of 1855 and 1858 contained no clues about secondary agents. It was Darwin

567 This does not imply that static models or their components would not matter anymore. For instance, for Ernst Mayr they are not merely morphologically similar individuals, but a reproductive group which does not (hardly) breed with non-members.

who dared most and won big in installing Mother Nature as an Agent next to God, thus shifting God more to the background of organic life.[568]

It seems to me that science has always told stories. Moreover, even before there was empirical access to biological phenomena, philosophers and poets were telling stories about how organic life was organized; the bible, one of the most widely received stories, has much to say about the origin of life.[569] Such, my point here is not that Darwin or Lamarck were the first to tell stories about nature. Nor is it the point that someone expressed a narrative which contradicted Scripture.

The remarkable point here is Jürgen Renn's from above: the scientists dared to express their own world-views for the first time and these ontologies were *based on observations*. Thus, in the conflict with the then-dominant reading of the bible they were not as easily dismissible as earlier "unfounded" speculation; the biologists had accumulated an impressive body of knowledge, one which was accessible, notably in public museums. Thus, the facts seemed to support their heterodoxy.

In sum, the first half of the 19th century was the period in which biologists accumulated the body of knowledge which allowed them to fill the space between observable biological facts and tales about biology. This allowed them to start telling their own tales: their own world-views.

vi. Three mental models of the Darwinian revolution: the tree, the "Struggle for Life" and "Natural Selection"

I see three crucial mental models[570] which shaped the Darwinian revolution, i.e. mental representations by which Darwin and Wallace organized their thoughts and through which they communicated their explanation of evolution.[571]

On level 2 of my model, both Darwin and Wallace employed the image of a tree to describe their static model. This is a rather basal model, yet, it implies a couple of important characteristics of

[568] As modern debates with creationists demonstrate, most scientists now prefer to completely exclude god from their tales, although quite some of them profess Christian faith. One can believe in god without referring to him in scientific explanations. (cf. Miller 2007)

[569] Today's majority opinion among scientists and theologians is that the bible's account and scientific narratives do not compete with one another. In some parts of the USA and in Victorian Britain this is and was disputed.

[570] Based on (Renn and Damerow 2007), I have described mental models as mental representations of basal belief structures and/or shared knowledge, often practical knowledge. Mental models support and guide inferences in default logic. When confronted with aberrant or contradictory experience (challenging objects and events), mental models may be modified or extended in order. In such inferences, mental models do not give up their basic structure; they are characterized by a remarkable longevity. Such, novel interpretations or explanations, which arise in reorganizations of knowledge systems, can often be described as modifications of old mental models. (See section 1.1)

[571] Remember that my use of mental models here differs slightly from the typical use within Historical Epistemology. I am not considering mental models to shape shared beliefs but rather scientists to employ mental models in their formulation of shared beliefs. This, however, is a difference in narrative only. Both explanations are based on the observation that specific mental models appear, first, in the history of a discipline and, second, (in modified form) in novel scientific theories. I construct this correlation as a human action to employ a certain model, whether this action stems from conscious choice or not. Historical Epistemology would rather construct it as a mental model shaping a knowledge-reorganization. My explanation employs more of a social science narrative, the historical-epistemological one more of a natural science narrative.

evolution. First, a tree has a common trunk from which all its branches and twigs originate, and, conversely, to which they can be traced back: a single origin.[572] Second, the image of the tree implied common points to relate different twigs and branches: the famous "intermediate forms", which were immediately claimed by the opponents of evolution. Third, the "tree"-metaphor might have been understood as implying disorderly yet opportunistic growth, an idea which easily accommodates the disorderly stream of new species which continued to flow to European museums.

On the third level, the most popular metaphor of the Darwinian revolution can be found, the Struggle for Life or Struggle for Existence.[573] As a mental model it implies that somebody is fighting for something, possibly by certain means. As specified by Darwin and Wallace, the struggle conveys the image of two or more parties fighting for a common goal, namely life / existence. Thus, the concept of the struggle put a teleological imprint on nature, conveying the idea of a common goal towards which all organisms are oriented. When asking for the means by which the parties lead their struggle, one evokes the question of what constitutes an advantage in survival, a key element of Darwin's narrative.

Both of these mental models were easily accessible to the biological community and the public. The idea of a tree easily related to the metaphors of biologist, who had been speaking of branches or embranchements for some time. A number of historians have attempted to identify *the* one author who inspired Darwin's and Wallace's[574] metaphor of the struggle for life.[575] Most of these sources are legitimate, yet, the whole enterprise appears futile. The idea of a struggle in nature is probably as old as biological thought, it simply is a very basal mental model[576], which Darwin and Wallace modified and linked to modern thought. Thus, if they created a powerful metaphor which was intuitive to both scientists and the public, it was because he drew upon a powerful mental model, a belief structure which was already shared by his contemporaries.

The truly innovative mental model of the Darwinian revolution came from Darwin himself and is found on level 3 of my model. The category shift (metábasis) from artificial selection to "natural" selection may be the masterpiece of his theory, its rhetorical hinge joint. It takes up the old idea of Nature as an Agent and combines it with an analogy from breeding, the selective action of the breeder. Hence, the mental model of selection suggests the two core elements of Darwin's narrative: the Agent and his Purpose; selecting requires someone to select and a goal for which one is selecting.

572 This implication of the metaphor was somewhat weakened by both, Darwin's diagram in the Origin, of which the "trunk" displayed more than one line, and by his enigmatic statement about "a few forms" into which the Creator might have breathed life, instead of just one.

573 Ellegård reports that 'struggle' is the metaphor which was popularized the fastest. (Ellegård 1958: 43)

574 Allusions to it can be found in all three parts of the joint paper as well as in the Origin.

575 Desmond and Moore, among others, attempt to trace the concept of Darwin's struggle back to the Swiss botanist Augustin-Pyrame de Candolle (1778-1841), who, in his *Organographie végétale* (1826), mentioned Nature's war for space and resources and spoke of plants as being "at war one with another". (Desmond and Moore 1995: 323) Darwin himself would point to Lyell, Herbert and de Candolle (Darwin 1858b [1857]: 51) Owen claimed the honour for himself. (Owen 1868: 799-800) In my historical introduction, I referred to Aristotle, Linnaeus, and Geoffroy. (0 x) Other supposed sources are Robert Malthus or 19th century economic theory. (cf. Bowler 1976) – In sum, I suppose that if one looks closely enough, one can identify at least one author per decade to employ this mental model between the 1770s (Buffon) and the 1850s (Darwin).

576 This is not surprising at all when one considers how fundamental a thought the ideas of ecological niches and specialization is; a child realizes that species do not occupy all of nature but are found in specific limited spaces in which they outperform competitors. Thus, the acknowledgement of ecological niches already suggests the idea of a competition in nature.

By evoking the image of a benevolent Nature which selected for "the betterment" of species, Darwin related to an established belief about Nature as an Agent. He thus created one of the most influential narratives, which preserved some elements of the design and teleology, all the while loosening the link between God and life. Much of Darwin's success in both science and the public sphere can be explained from the intuitive appeal of this mental model.

vii. The first modern biologist? – How much was Darwin still rooted in his time?

Keeping these gaps in Darwin's résumé in mind, one might wonder in what aspects of his work Darwin transcended his contemporaries and in what aspects he remained firmly rooted in his historical context.

On one hand, Darwin was an innovator on different levels of biological knowledge. With respect to empirics (level 1), he and Wallace and were pioneers of biogeography and extended it by focusing on individual variations and other organisms as ecological factors. Again with Wallace, he abandoned static modeling in the sense of Linnaeus or Owen and lessened the role of static models. (level 2) In terms of explanation, he excluded the origin of life (spontaneous generation) from his model and in his narrative, he moved from theistic to deistic narratives.

On the other hand, Darwin's work remained within the context of his time. He did not integrate the developmental aspects of Geoffroy's and Owen's work in his theory and he did not anticipate genetics, a biological discipline founded by his contemporary Gregor Mendel (1822-1884). In terms of explanations and ontologies, Darwin did not transcend the deistic framework already dominant in France or Germany; God clearly played a role in his narrative.[577]

Thus, not surprisingly, the picture is a mixed one. In some aspects of his work Darwin was innovative and pointed the way to the future of biology. In other aspects, however, Darwin remained firmly rooted in his time and his theory obstructs the view on other, more innovative strands of research.

viii. His and only his? – What are Darwin's truly individual achievements?

Another interesting question is how much of the Darwinian revolution actually is Darwin's individual achievement. In terms of description (level 1), Darwin's innovative empirical methods were reproduced, at least, by Wallace and foreseen by Geoffroy. Wallace independently came to the same conclusion as Darwin in terms of interpretation, suggesting an irregularly branching tree. (level 2) Darwin's and Wallace's models were equivalent, as one would expect from their equivalent empirical innovations, and display close resemblance to Geoffroy's works of the mid-1830s. Moreover, in their modeling, the all drew largely on shared knowledge. (level 3) Finally, Darwin's important ontological innovations, the deistic world-views, had been anticipated in Germany and France a century earlier and, still decades earlier, by Chambers and Owen in Britain.[578]

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[577] This is particularly remarkable when one considers how Darwin is today portrayed in the debate on creationism. While Darwin clearly opposed the kind of theistic explanations favored by design theorists like Michael Behe (Behe 2000, 2004), he also did not take an atheist position in the *Origin of Species* as, prominently, Richard Dawkins is taking today.

[578] This concurs with Ernst Mayr's judgment that "…the publication of the Origin in 1859 was the mid-point of the so-called Darwinian revolution rather than its beginning. Stirrings of evolutionary thinking preceded the Origin by more than 100 years, reaching an earlier peak in Lamarck's *Philosophie Zoologique* in 1809. The

In sum, the only part of Darwin's theory which was exclusively his seems to be his narrative: the manner in which Darwin told the story of variation, selection and evolution. For every other part it is true what the contemporary historian and biologist Edmond Perrier said: "Before the appearance of Darwin's book, all the information needed to construct this theory of the individuality of species was already known to science. There is not one of his chapters that some naturalist could not at some stage have formulated in his mind. But all the facts were widely scattered ..." (Perrier 2009 [1884]: 198) In sum, Darwin was the one who assembled the facts and told people how to make sense of them.[579]

I do not say this to belittle Darwin. Rather, the results of my historical-epistemological reconstruction display what is true of other theoretical revolutions: they are group achievements. Darwin was not a single hero of science among blind contemporaries but one in a series of excellent biologists, a series which linked Lamarck, the later Geoffroy, Wallace and Darwin on one side as well as Cuvier, the earlier Geoffroy and Owen on the other side. The continuity in biological works, however, becomes visible only in close analysis. The more we focus on the person of Darwin, the less we see the continuity between his work and the work of other excellent biologists of the time. Only to Duhem's "superficial observer"[580] does the theoretical revolution in 19th century biology appear as the individual achievement of Charles Darwin.

5.2 Sociological conclusion: How was the Darwinian revolution received and what effect did it have on biology?

My analysis has focused on two sociological dimensions of the Darwinian revolution: the reception of the Darwinian theory and its effects on scientific practice. Let me recapitulate my results on four key points here: (i) the public reception of Darwin, (ii) the reception within the community of biologists,

final breakthrough in 1859 was the climax in a long process of erosion which was not fully completed until 1883 when Weismann rejected the possibility of an inheritance of acquired characters [or, even later, the modern synthesis of the first half of the 20th century, when most biologists would finally accept natural selection]." (op. cit. Mayr 1990b: 86-7)

579 I am unsure of whether to concur with Peter J. Bowler's argument that the Darwinian revolution is erroneously called "Darwinian" because (i) his theory shared many of its elements with previous or competing theories and (ii) because Natural Selection was accepted but by a minority of biologists and the public. (Bowler 1992 [1988]: 1-6) I agree with his historical assessment but it seems to me that two reasons support the current denomination. First, a relevant group of Darwin's contemporaries identified the revolution with Darwin and historically linked it to his name – and not to Lamarck's, Geoffroy's or Wallace's. Second, much what we consider today the crucial elements of evolution theory do indeed stem from Darwin. (cf. Ruse 2009) Beyond this, one can obviously dismiss the label "Darwinian". In this case, however, probably no theoretical revolution in science should be named by the name of a single scientist. For a more extensive discussion of the topic see (Ruse 2009).

580 Remember my introductory quotation: "When the progress of experimental physics goes counter to a theory and compels it to be modified or transformed, the purely representative part enters nearly whole in the new theory, bringing to it the inheritance of all the valuable possessions of the old theory, whereas the explanatory part falls out in order to give way to another explanation. Thus, by virtue of a continuous tradition, each theory passes on to the one that follows it a share of the natural classification it was able to construct, as in certain ancient games each runner handed on the lighted torch to the courier ahead of him and this continuous tradition assures a perpetuity of life and progress for science. This continuity of tradition is not visible to the superficial observer [sic!] due to the constant breaking-out of explanations which arise only to be quelled." (Duhem 1962 [1906]: 32-3)

(iii) the effects of this latter reception on supporters of the Darwinian theory and (iv) on competing research strands.

i. Why did Darwin become the star of early 19th century biology?

If the Darwinian revolution, for the greater part, is the common work of the biological community of the 19th century, how come we identify it so much with Charles Darwin – and so little with Lamarck, Geoffroy, Wallace or Owen? Why did his British contemporaries considered Darwin one of the, if not *the* outstanding scientist of the Victorian age, granting him a grave next to Newton and Herschel in Westminster Abbey? A combination of several factors provide for an explanation.

First, Victorian Britain experienced the advent of popular culture, including a popular interest in scientific issues. Major technical improvements in printing led to a massive decrease in printing costs and an unprecedented dissemination of books, magazines and journals. In combination with the liberal British press laws, this development made content accessible to ever-increasing audiences, particularly hot and controversial topics, among them some scientific issues.[581]

Second, the debate on evolution touched some important social and political issues of the time, notably the debate on deism. The advance of deist positions from the continent had been brought to a halt by the political restoration after the French Revolution. Yet, the first half of the 19th century revealed that the proponents of liberal religious could not be held in check much longer. The immense reception of the *Bridgewater Treatises* (1830s) on one hand and *Essays and Reviews* (1860) on the other hand, exemplifies the importance of the debate.[582] Moreover, the debate on evolution touched more down-to-earth topics like slavery or the separation of social classes in Britain. The public interest in these questions directed attention towards the topic of evolution.

Third, it is around the Darwinian revolution that biology emerged as a discipline and gained public relevance. The emergence was fueled by both biology's professionalization and its unification. The professionalization is exemplified by the advent of the first generation of professional biologists, scientists who made their living of biology[583] but also by the formation of many important biological journals[584]. Moreover, with the Darwinian revolution, British biologists began to refer to their discipline as 'biology' and considered paleontology, anatomy or physiology as sub-disciplines of this unified life science. To this development, Darwin's unifying theory made an important contribution; he was one of the founding fathers of biology.

Moreover, by the 1850s, biologists had acquired a body of knowledge which allowed them to suggest their own world-views and to challenge not only established religious dogmas but also the dominant science of the age: physics. It is for these world-views that the works of Lamarck, Chambers or Darwin were discussed in the public sphere and that such a heated debate as the one on the age of the earth could take place. (See sections 4.1.2, v) The respectability to which biology rose in these

[581] Both Darwin's Origin and Chambers' Vestiges experienced remarkable public reception.

[582] The reception of *Essays and Reviews* overshadowed the *Origin* in the 1860s.

[583] Huxley and Hooker but also Owen belonged to this group. Darwin was a gentlemen-naturalist, i.e. an amateur of independent means. The majority of the biological journals which I analyzed in the reception analysis came into being in the 1840s and 1850s.

[584] The large majority of the journals which were analyzed in the quantitative part of the reception analysis were formed in the 1840s and 1850s.

debates is probably best exemplified by the fact that geology and biology were granted their own museum in 1881.[585]

Fourth, it seems to me that Darwin's fame was further fueled by the need for an ambassador of the newly unified, emerging biology. Physics and chemistry had produced their share of heroes but, in the mid-19th century, biologists were still struggling for respect and public attention. In this struggle, important biologists championed Darwin as the face of their discipline, popularizing his name and referring to themselves as Darwinians. Huxley and even Wallace did associate their work with Darwin's name.[586]

Fifth, Darwin's truly individual contribution to the evolution debate is to be found on the abstraction layer of biological knowledge which is accessible to the public. Thus, Darwin was visible far beyond biology and, while his model earned him the respect of his fellow-biologists, it was his ingenious narrative which reached the masses. The story of variation, selection and evolution seemingly rendered complicated biological questions accessible to the laymen. The impact of Darwin's narrative shaped both the public reception and the reception among the broader scientific community. Even today, few social scientists, few philosophers, physicists or engineers know anything precise about evolutionary biology beyond Darwin's narrative and, for some, his model. To the uneducated public, Darwin might be the only biologist they ever heard of.

In sum, Darwin was received because his book was available to a wide public, his theory touched topics which were already hotly debated, he was championed as the public face of an emerging discipline and he formulated the part of the theory of evolution which was best accessible to the public. Thus, most of public Darwin's fame stems from him becoming a figure of popular culture. In this, Darwin's fame resembles the fame of fellow "pop-star scientists" as Einstein, Galileo or Freud.[587] (see below)

ii. Selective adherence: What did it mean that biologists accepted the Darwinian theory?

Within biology itself, the picture becomes much more diverse. First, few if any scientists adhered to all of components of the Darwinian theory. Even the self-proclaimed Darwinians made partial choices: Wallace refused to explain Man's mental and moral faculties as evolutionary products and Huxley considered natural selection as part of the Connector but not as the entire solution.

Second, as my reception analysis reveals, the more one approaches a specific research field (sub-discipline) within biology, the less important is Darwin.[588] I suppose that a similar quantitative analysis of today's biological journals as I have carried out for the period from 1859 to 1874 would reveal similar results with respect to theoretical terminology. Most empirical papers do not mention abstract theoretical vocabulary – and those which do usually employ it as mere ornament or political statement. Moreover, the work of the large majority of scientists displays no sign of commitment to

585 Remember that it was Richard Owen who had lobbied for an autonomous museum for decades and that he became its first superintendent.

586 Wallace published his own retrospective on the revolution in a tome named 'Darwinism', Huxley published a collection of papers und the title 'Darwinia'.

587 Again, I do not aim to belittle Darwin's achievements, which are undisputedly remarkable.

588 This should be true for all empirical disciplines. Such communities share a large part of their objects/events of interest and much of their observational/experimental methodology (instruments, boundary conditions of measurements). By my non-representative estimate, these communities comprise ca. 150-300 people.

the Darwinian theory or the denial of it. This can clearly not be explained by the ignorance of scientists for Darwin clearly made the headlines in both science and the public sphere. Rather it is an indicator of how much biological theorizing and empirical biology were disconnected. Whether or not one referred to the Darwinian theory in one's empirical work seems not to have mattered much. Both, a competing theoretician like Richard Owen or a theory-abhorrent scientist could go through the Darwinian revolution unfazed.[589]

Thus, Darwin developed a model and an intriguing narrative applicable to most biological sub-disciplines and flexible enough to adapt to the extensions of biological knowledge throughout the 19th and 20th century, notably in the modern synthesis. This does not imply, however, that these sub-disciplines all needed evolution theory to guide their work or make sense of their empirical findings. Dobzhansky's famous word[590] that nothing in biology makes sense expect in the light of evolution is at least imprecise. One by one, probably most biological regularities can be made sense of without evolution. Only if we require a covering explanation for different the fields within biology, Darwin's is the only explanation so far which we deem acceptable. However, for the utmost part of science, no such covering explanation is needed.

iii. Discontinuity in explanations & implications, continuity in description & classification

Considering the selective adherence to Darwin's theory and its limited effect on empirical work in biology, it is not surprising that the Darwinian revolution did not trigger discontinuous breaks throughout the entire body of biological knowledge.

Darwin had partial success in establishing his explanation and its ontological implications. He succeeded in establishing a novel (static) model of the objects of biology, interpreting the contemporary animals and plants as descendants of extinct progenitors. This made sense to the public and broader scientific community and it allowed biologists to interpret their established taxonomic knowledge in a more intuitive way. Darwin's explanation of the steps which lead from a progenitor to its descendent, i.e. his (dynamic) model and its narrative around natural selection, was considered part of the solution. However, the narrative's ontological implications did not comply with the Victorian world views and philosophy of science. Additionally, it suffered from Darwin's incapacity to explain the causes of variation. In sum, Darwin achieved a considerable change on the upper layers of biological knowledge.

On level 2 of my model, classification, one might suppose that the acceptance of 'common descent' as the organizing principle of taxonomic relations and the devaluation of the species concept might yield a novel taxonomy, i.e. a reorganization of the taxonomic system established by Linnaeus. However, the Darwinian revolution did not lead to any substantial changes here, only further specifications; the Linnaean system is still in use today.[591] Moreover, the acceptance of evolution

[589] Whether the lack of positioning towards the rising theory had any drawbacks would be an interesting empirical question.

[590] It is a phrase which biologist Theodosius Dobzhansky (1900-1975) expressed in a 1964 article on evolution and employed as the title of a 1973 essay. (Dobzhansky 1964; Dobzhansky 1973)

[591] Ernst Mayr reports that zoological classifications underwent some minor changes but not botanical ones. This is not surprising if one considers that similarity, the criterion on which classifications had formerly been based, was a pretty good approximation of common descent and Darwin himself had provided few empirical criteria for further refinement. (Mayr 1984: 173-7) For a more details on this, see below.

theory did not even trigger a debate on taxonomy.[592] Lastly there are no traces of an explicit dismissal of established knowledge; I cannot find any papers that devaluate previous taxonomic work with reference to Darwin.

There is one remarkable change on this level, however: the dissemination of the concept 'homology'. The concept was introduced by Richard Owen in 1843. Its acceptance as a classificatory term for the description of organisms falls right in the analyzed period. Between 1859 and 1874 its use increased steadily, moreover, although it stemmed from Richard Owen and was originally introduced together with his archetype concept, the concept of homology was employed by Darwinians as T.H. Huxley, J.D. Hooker, Asa Gray and by Darwin himself. Once the Darwinian revolution was accomplished, there even existed a suggestion to change the name of Owen's concept, i.e. its connotation.[593] (See section 2.1.2 i) Yet, no such thing happened; the concept is still in use today under its original name.

On level 1, one might suppose that Darwin altered the research questions of biology, that it changed the way biology would describe their objects and events of interest. Such suppositions are hardest to operationalize and therefore hardest to verify or falsify. However, I do not observe any such change. Papers from 1859 hardly differ from papers in 1874 and where they do, this change is not linked to the concepts of evolution or natural selection. Second, one could suppose that the Darwinian theory led to the introduction of novel concepts in the practice of observation and experiments and that, in return, these novel concepts would change the manner in which empirics were described. Particularly, one could suppose that biologists would stress the influence of the environment and of other organisms as selective forces. There are some instances of such influence but they remain restricted to a small fraction of papers.

In sum, the theoretical debate hardly touched the lower layer of biological knowledge: Darwin suggested a new interpretation of existing empirics, but no new manner of doing empirics. The Darwinian revolution remains a theoretical revolution: it revolutionized theory, i.e. models and their ontological implications; it did not revolutionize the description and classification of empirics below the models and ontological implications.

Moreover, as my comparative analysis reveals, some of this discontinuous break should not be dated to 1859 or the years past and should not be identified solely with Darwin. Darwin's Origin was the culmination point of developments which had begun in the late 18th century: The rise of biogeography and geology and their production of challenging objects slowly led to changes on more abstract layers of knowledge, sometimes in discontinuous breaks.[594] Such, the first half of the 19th century saw important specifications in classifications and, in the 1840s and 1850s, the dissemination of Owen's concept of homology as a device for taxonomic classification. Based on a remarkable series of fossil mollusks, Lamarck suggested the first explanation of evolution in 1809 – a visionary and somewhat precocious move. The 1820s to 1840s saw important debates on the interpretation of the changing classifications, among them Owen's archetype concept and the famous debate between Cuvier and Geoffroy in 1832. In parallel, the public discourse in Britain and Chambers' *Vestiges* paved the way for deism. Figure 30 provides an overview over these successive breaks.

592 While a number of papers address taxonomic questions none refers to Darwin's theory for justification.
593 Remember that Lankester did not intend to change the concept's denotation, only its connotation. (Rupke 1994: 217)
594 The next major theoretical change in biology, the modern synthetis, would also be triggered by empirical, not by theoretical work: genetics.

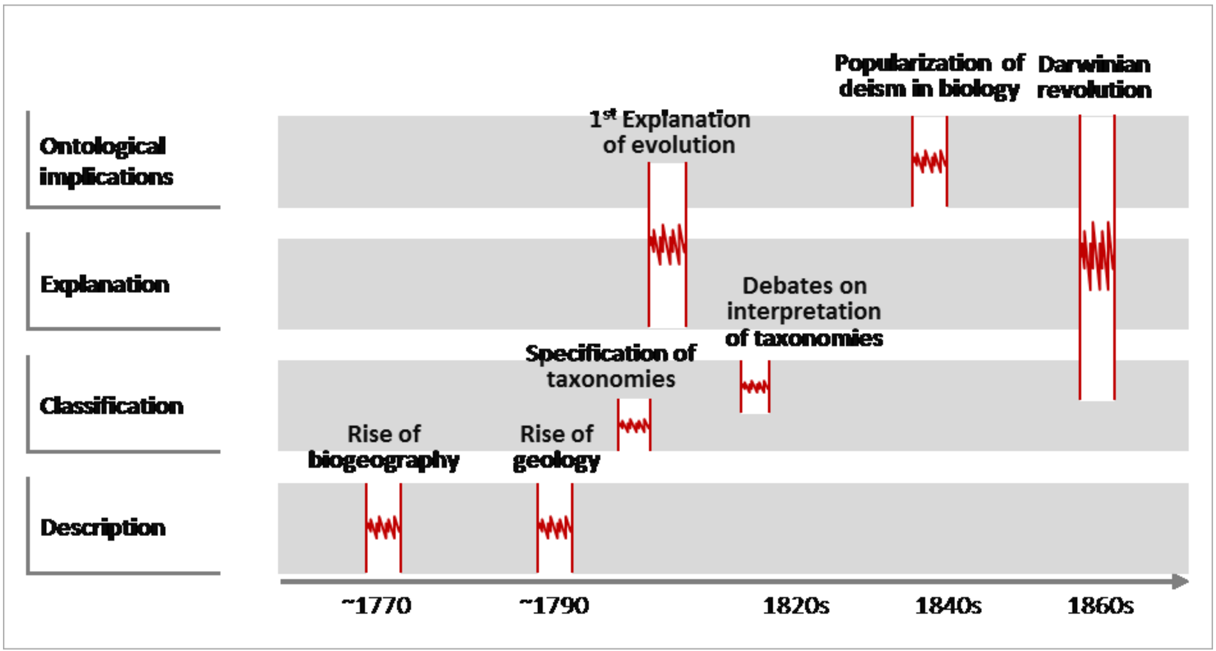

Figure 30: Continuity and discontinuity on different layers of biological knowledge in the prelude to the Origin

iv. Delaying evo-devo? – How the Darwinian revolution overshadowed the work of Geoffroy and Owen on structural similarities

I have argued above that the Darwinian revolution was fueled by empirical regularities from paleontology and biogeography. The models of Darwin and Wallace successfully linked these novel regularities with the existing body of biological knowledge and integrated several disciplines into a unified discipline of biology. However, there were some challenging regularities which Darwin did not contribute to the Darwinian revolution and which could not be explained by either Darwin or Wallace.

These regularities encompass, first, the morphological regularities which Owen summed up by the term 'serial homology' and which were completely ignored by Darwin.[595] Thus, Rupke remarks that,

> "In the secondary literature it is unquestioningly assumed that the Darwinian incorporation of Owen's homological work purified and enriched it; and to some extent this assumption is true. It should be noted though that the Darwinian reinterpretation also impoverished a certain segment of the homological programme, notably that concerned with serial homology [i.e. the similarity of repeated elements in an individual body, for instance between the ribs of a rib cage]. Both, special and general homology, were instantly translatable into phylogenetic terms, but not the similarities of an arm to a leg of a left to a right extremity and of one vertebra to the next in the same spinal column. Vertical, lateral and serial homologies represented morphological similarities which had no direct bearing on descent, and seemed to suggest 'genetic' rather than an environmental control over organic structure.[596]" (Rupke 1994: 218-9)

595 I know of no publication in which Wallace would have addressed this topic.

596 Rupke's quote continues like this: "Mivart [in 1871] lucidly perceived this weakness in the Darwinian programme: 'The facts of serial homology seem to hardly have excited the amount of interest they

Today, Owen is considered as an early predecessor by proponents of the research strand 'evolutionary developmental biology' or 'evolution of development' or, short, 'evo-devo'. (Hall 1999: 73-5, 96; cf. Bowler 2008)[597] This research strand studies developmental processes, not only to determine the ancestral relationship between them, but also to understand how developmental processes evolved. Darwin's success overshadowed this research program and probably delayed it by doing focusing the attention and resources of many biologists to the impact of ecological changes and away from developmental processes. In the terminology of an earlier debate, evolutionary biology focused on how 'conditions of existence' altered structure and moved away from how 'unity of type' preserved it.[598]

Second, Darwin was unable to explain heredity, as he openly admitted. Thus, he provided an interpretation for mutations – referring to them as 'accidental variations' – but did not attempt to explain them. Moreover, the first laws of inheritance were described by Gregor Mendel in 1865 and 1866, i.e. during the Darwinian revolution, but they were not linked to evolution until the turn of the century.

Third, even his own research program in macrotaxonomy faded relatively soon. While Darwinians such as Ernst Haeckel set out to reorganize classifications in the Darwinian sense and reveal ever larger parts of Darwin's and Wallace's tree, they soon faced disappointment. In most cases, similarity, the criterion on which classifications had hitherto been based, was a pretty good approximation of common descent and Darwin himself had provided few empirical criteria for further refinement.[599] Thus, progress in macrotaxonomy was relatively modest and the program lost much of its appeal by the turn of the century.[600] (Mayr 1984: 175-7)

In sum, Darwin did not solve all contemporary problems of biology; he merely suggested a solution for its most renowned problem. By doing so, he defined a research program which diverted attention and resources away from other promising fields. Thus, some strands of biological research profited from the Darwinian revolution, others suffered.

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certainly merit.' […] That Owen and Mivart were on the right track in this surmise was later shown by the discovery of chromosomes and genes. Also, the study of the molecular basis of life has led to a renewed interest in serial homology and in its early espousal by Owen." (Rupke 1994: 218-9)

597 Sometimes, this research program is also referred to as the "extended modern synthesis", i.e. a developed of the modern synthesis of evolution and genetics.

598 Even one of the Bridgewater treatises discussed it favourably. (Amundson 2007: xix)

599 This problem was already clear to Darwin's contemporaries. In a paper at the 15th anniversary of the *Origin of Species* in December 1874, Huxley regretted that "that we have so little real knowledge of the phylogeny even of small groups, while of that of the larger groups of animals we are absolutely ignorant." (Huxley 1876 [1874]: 200). Brady, Parker and Jones, mentioned the same problem still four years earlier, in 1870. (Brady, Parker, and Jones 1871: 198)

600 As Ernst Mayr reports, at that time, many young biologists were choosing the experimental fields over evolutionary biology, for instance zytology, physiology, biochemistry, genetics. By the 1950s, macrotaxonomy was somewhat marginalized. (Mayr 1984: 176)

5.3 Possible generalizations about scientific theories and theoretical revolutions in science

Much of today's thought on scientific revolutions remains inspired by a 1960s debate, notably by Thomas Kuhn's *Structure of Scientific Revolutions* (1962). This is unfortunate, at least for two reasons: First, Kuhn himself has modified many of his early positions in later work and has taken more nuanced and more informed stands. (cf. Hoyningen-Huene 1993; Kuhn 2000) Thus, most of today's reception and criticism of Kuhn as well as the work of many self-proclaimed Kuhnians refer to a short period of Kuhn's work only and do ignore the later work. While one could reasonably assume that Kuhn's later work would never have attracted the attention of *Structure*, one should at least be aware that most of today's debate on Kuhn focuses on stands which Kuhn himself has long cleared.

Second, Kuhn's *Structure* continues to outshine many more deserving works on the history of science – at least outside of the History of Science. Kuhn's work is an essay of less than 180 pages which covers several theoretical revolutions on a couple of pages each and never cites a primary source. The debate of the 1960s on has shown that Kuhn's terminology is sloppy and that his central statements vague. In the neutral sense of the word, *The Structure of Scientific Revolutions* is a very superficial book. Still, it is cited much more often than more informed and more sophisticated works on the history and sociology of science, for instance by Edmonde Perrier (2009 [1884]), Pierre Duhem (1962 [1906]), Ludwik Fleck (1980 [1935]), Alvar Ellegård (1958), Karin Knorr-Cetina (1981, 1999), Richard Whitley (1984) or Ernst Mayr (1984 ; 1991), to name a few.

Nonetheless, Kuhn's book remains a major reference point in the debate on scientific theories. Thus, I will address several key claims of the 1960s Kuhn about scientific revolutions and I will demonstrate that most of them fail to fit the historic record. (Thus, in the remainder of this book 'Kuhn' refers to the Kuhn of the *Structure of Scientific Revolutions*.)

Obviously, my empirical basis for such criticism is limited. I have analyzed but one scientific revolution in detail and there is no guarantee that these results transfer to other revolutions. However, two sorts of indicators point towards such transferability. First, I know of no single revolution for which the specialists would claim that it fits the Kuhnian account. Significantly, one could make that case even for Kuhn's own study of the Copernican revolution; Kuhn's account of this revolution in the *Structure of Scientific Revolutions* does not fit the record which he himself had given five years earlier.[601] (Kuhn 1957; Kuhn 1970 [1962]: 68-9) Thus, it rather seems that the Kuhnian claims are plausible with respect to a "general view" of scientific revolutions but fit none in particular. Poignantly, the less one knows of actual scientific revolutions, the more plausible appears the Kuhnian record.

Second, this perception asymmetry complies well with a structural problem which I see in the Kuhnian record of scientific revolution. Kuhn and many who followed him look at scientific revolutions and scientific progress with the eyes of theoreticians; their work focuses on the upper layers and the connotative components of my framework: Kuhnian study interpretations, narrative

[601] This argument was pursued by Friedel Weinert in his April 2012 talk at the conference on Scientific Progress in Tilburg, Netherlands. He pointed out that the 1962 Kuhn identifies the Copernican revolution fully with Copernicus while, only five years earlier, he had neatly separated the contribution of Copernicus from those by Tycho Brahe or Johannes Kepler. (cf. Weinert 2009: 37-47)

explanations and their implications but virtually ignore how these link to dynamic models, static models and to descriptions. As a result, they look at scientific revolutions as "outsiders" – in the same way the physicists or mathematicians or the public of Victorian Britain looked at the Darwinian revolution.[602] (see Table 27) Consequently, to Kuhnians, science looks much more homogenous, much more theory-driven and much more discontinuous than to closer observers.

<table>
<tr><th></th><th>Immediate scientific community: biologists</th><th>Broader scientific community: other scientists</th><th>Public: laymen</th></tr>
<tr><td>Level 4: Implications</td><td colspan="3">Implications for the Victorian world view</td></tr>
<tr><td rowspan="2">Level 3: Explanation</td><td colspan="3">Narration</td></tr>
<tr><td colspan="2">Dynamic Model</td><td></td></tr>
<tr><td rowspan="2">Level 2: Classification</td><td colspan="3">Interpretation</td></tr>
<tr><td colspan="2">Static Model</td><td></td></tr>
<tr><td>Level 1: Description</td><td>Descriptions of observations</td><td></td><td></td></tr>
<tr><td>Criteria for assessing the theory</td><td>Plausibility,
Consistency,
Empirical fit</td><td>Plausibility,
Consistency</td><td>Plausibility</td></tr>
</table>

Table 27: Perception asymmetry: the perception of scientific change depends on the previous knowledge

In my study, I believe to have avoided this perception asymmetry by thoroughly studying the denotative components of scientific theories and by analyzing theories before the background of the empirics which they aim to interpret and explain. Thus, I am confident that many of the following considerations apply to more scientific revolutions than one.[603]

i. *Theory and empirics are only loosely connected: there is no incommensurability, nor normal science*

My first and most fundamental dissent with the Kuhnian position concerns his emphasis of the role theories for science. My reception analysis indicates that

- Only a fraction of the scientific literature addresses theoretical questions at all
- Even were theoretical questions are addressed, these discussions hardly discuss all-encompassing theories, but single aspects of theorizing
- The adherence to novel theories is selective, hardly anyone commits to entire theories[604]
- The immediate impact of novel theories on scientific practice is very limited

[602] Albeit being a deeper and more thorough study than *The Structure of Scientific Revolutions*, one can make this case for Kuhn's study of the Copernican Revolution, too.

[603] Contradictory evidence is obviously welcome. Actually, it would be interesting to see to which cases which elements of Kuhn's account do actually apply.

[604] This is not surprising if one identifies the challenge of theoretical scientific innovation as linking the new in an original way to the old, to reframe the shared knowledge in an innovative and fruitful manner while, at the same time, relating to established beliefs, e.g. through the modification of mental models.

- Proponents of competing theories can discuss their different interpretations and explanations in the language of description; there is no widespread incommensurability

Thus, theory seems to matter much less to science than theoreticians like Kuhn may want us to believe; both are only loosely connected. This interpretation would be consistent with other results of my study, but also with the results findings of important studies in the science studies.

With respect to epistemic changes, my comparative analysis of biological theories has shown that Darwin's theory did not revolutionize all layers of biological knowledge but selected elements of single layers; most elements of his theory were already part of the theoretical debate before the publication of the *Origin*.[605] It is, therefore, not to be expected that these partly innovations would mainly be discussed in an all-encompassing manner or that they would require adherence to all elements of the theory in which they were presented, e.g. Darwins.

Moreover, Nancy Cartwright has demonstrated how loosely only theories relate to more concrete knowledge layers and how little one knows of the body of empirical knowledge if one knows but theoretical laws. (Cartwright 1983) She famously and polemically interpreted this relation as the theoretical laws of physics "lying" about the world. Before the background of my comparative analysis, however, her findings can also be interpreted as an indicator of how loosely empirical knowledge is connected to theory.[606]

With respect to the impact of theory on scientific practice, sociologist of science Richard Whitley analyzed specialization and the emergence of sub-disciplines in science in his *The Intellectual and Social Organization of the Sciences* (1984). His findings demonstrate that sub-disciplines and smaller research communities define their problems and agendas autonomously and quite independent from overruling theories. Therefore, the existence and persistence of a general theory does not imply that less abstract knowledge layers remain unchanged. Instead, for scientists in a discipline with such a theory

> "Establishing new sub-fields [is] easier than attempting to radically alter dominant perspectives, and so intellectual change in these fields is likely to take the form of differentiation and specialization rather than revolutionary overthrows of established doctrines." (Whitley 1984: 28-9)[607]

In turn, the independence of lower levels of theorizing from general theories would concur well with my findings on the alleged incommensurability between competing research programs. (Kuhn 1970 [1962]: 159-165, 198-204) Kuhn claimed that scientists of such competing programs cannot

605 Similar results were found for the revolution in pre-classical mechanics (Galilei) by (Schemmel 2008; Büttner, Damerow, and Renn 2001; Büttner et al. 2003; Valleriani 2010) and for the revolution in astronomy (Copernicus) by (Weinert 2009: 30-87)

606 This, in turn, might fit with her account of a dappled world, a patchwork of laws. (Cartwright 1999) (With respect to terminology, I would consider laws to denote general statements in my dynamic model.)

607 Similar conclusions can, for instance, be drawn from Andrew Abbott's work on sociology: There are no overruling subjects and research agendas but specific ones in specific sub-disciplines. Thus, the impact of paradigmatic theories for scientific practice and collaboration is very limited. (Abbott 2001)

> "…resort to a neutral language, which both use in the same way and which is adequate to the statement of both their theories or even of both those theories' empirical consequences." (Kuhn 1970 [1962]: 201)[608]

I observe no lack of such a neutral language. Proponents of the Darwinian theory and Owen's theory of the archetype did agree on the description of fossils and organisms; I do not find a single case in which the descriptions of such fossils or organisms was called in question – particularly in the debate on the *hippocampus minor*. (Section v) In debates on interpretation and explanation, like the classification of Man in the *hippocampus*-debate or the *Archaeopteryx* the differences in interpretation were addressed and the respective merits could be discussed with reference to the descriptions of these specimen.

Moreover, Lankesters' 1870 suggestion of changing the name of Owen's concept of homology for its Platonic overtones shows that proponents of one theory were very well able to grasp the connotations conveyed by concepts of competing research programs and could separate them from the denotative part.[609] (Rupke 1994: 217; see 4.3.2)

In sum, it seems that Kuhn, but also Russel Norwood Hanson in his *Pattern of Discovery*, fell prey to the perception asymmetry sketched above. (Hanson 1972 [1958]) Seemingly, they did not know their subjects profoundly enough to grasp the denotative meaning of its core concepts; to them, scientific concepts were mere metaphors.[610] If one takes into account the layer of empirical knowledge which I term 'description' and distinguishes between connotative and denotative meaning, this problem disappears: As long as the communicating scientists share a body of empirical knowledge which they know and to which they can refer, the can formulate their differences in interpretation or explanation.

Let me summarize by attempting a metaphor: Complex belief systems like scientific theories are ephemeral structures on top of a constantly changing body of knowledge. They may be compared to a film of oil on the surface of moving water. The film forms some thicker accumulations of oil on the water (peaks of theorizing), large area of thin film (low-level theorizing), but also oil-free parts (theory-free areas) and, not to forget, many single oil droplets are mingled in the moving water (ad-hoc or provisional theoretical ideas).

ii. There is scientific progress underneath the models: knowledge accumulation despite belief reorganizations

Figure 31 might illustrate the relation of knowledge production and belief production in biology around the Darwinian revolution. From bottom to top it displays the production of knowledge and beliefs on the four levels of my model of scientific theories. From left to right it depicts the

[608] In the postscript to the 1970 edition, Kuhn clarified that he did not intend to say that scientists who work under different research programs cannot communicate at all. Rather, he stressed, when discussing different research programs, there is no neutral language in which scientists can compare how well their theories perform. Thus, there is no fully objective criterion for choosing between theories.(Kuhn 1970 [1962]: 198-9) I suppose I agree with Kuhn's latter claim (his vocabulary is typically vague) but not with his former on the neutral language. (Criteria for theory choice might still be less arbitrary than he claims, see section 5.3 iv)

[609] Remember that Owen's concept is still in use in modern biology.

[610] While both sometimes vaguely point to the empirical referent of scientific concepts, it is remarkable that neither Hanson nor Kuhn cite a single primary source in their books.

progression of time with the two highest peaks marking the publication of Lamarck's and Darwin's theories of evolution, which both received popular reception.[611] From the back to the front it displays different biological sub-disciplines.

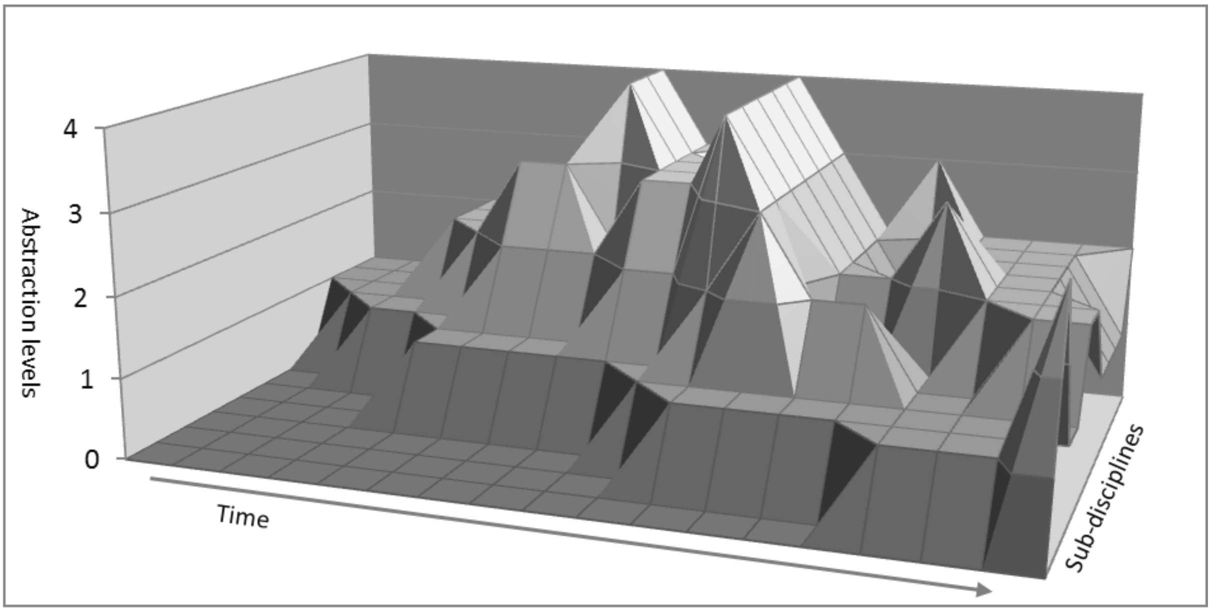

Figure 31: An epistemic landscape – knowledge and belief production in biology around Darwin

The figure is obviously schematic and much simplifying and many of its data points are not backed up by empirical material[612], yet, it might illustrate a number of trends and interdependencies in the scientific production of knowledge and beliefs. First, there was a remarkable increase in number of such disciplines from the times of Buffon and Linnaeus to the turn of the 20th century; thus, biology did not only produce new evidence in established fields but tapped fully novel sources of knowledge. (level 1) Second, lower-level theorizing like static modeling develops quite constantly and may change regularly. (level 2) Novel explanations, i.e. models and narratives, are rare (and many are not approved by the community). Still, they remain usually invisible to the public. (level 3) Theories with important and controversial ontological implications are solitary events. (level 4)

Considering the perception asymmetry, this epistemic landscape looks quite differently to different recipients. Particularly, with the Kuhnian "outsider" look on science, i.e. the sole consideration of higher theoretical layers and connotative meaning, this heterogeneous and multi-layered development becomes quite homogeneous and linear. It boils down to some ground-work and the unsuccessful theorizing of Lamarck until biology finally transitions to the state of mature science with Darwin. His contribution leads to a deep epistemic break and post-*Origin* biology does not look anything like pre-Origin biology. The diverse research strands after the 1860s may then appear as post-paradigmatic problem-solving. – If all one knows of science is theories then theoretical change makes one believe that all of science is changing.

611 However, only one of them gained public support in Britain; public reception alone does not suffice for a revolution.

612 Particularly on the lower abstraction levels, an exact description of the knowledge and belief production would require much better data and much more sophisticated tools than I had at hand.

Obviously, to such outside observers, most of the scientific production of knowledge and beliefs remains invisible. In my opinion, however, the indicator of scientific progress should be empirical[613], i.e. science's capacity[614] to describe, predict and produce[615]. If one does not include the lower levels of scientific knowledge in one's analysis of scientific developments, one simply overlooks the progress in science. However, theoretical shifts leave the broad stream of empirical knowledge untouched.[616] Or, as French biologist Jean Rostand (1894-1977) put it: "Theories pass. The frog remains."[617]

iii. Popularity does not equal scientific excellence

Theoretical revolutions in science are famous for their ontological implications: Darwin and Einstein were first-rate modelers[618], but they are famous for their story-telling, for what their narrative explanations implied about the world. It is for this reason that popular-science accounts of science – like the Kuhnian of the 1960s – focuses so much on individuals and so little on collectives and underlying structures. It tells science as a sequence of heroic achievements by a few pop-star scientists.[619]

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613 Some philosophers fancy the idea of theoretical progress. I know of no such concept which would be applicable to the history of science and I do not know whether it makes sense to look for one – once one understands how limited the role of large theories is for science. For philosophy of science with a focus on empirics and material culture, see e.g. (Rheinberger 1997).

614 Such orientation towards application is sometimes criticized by defenders of "pure" scientific reasoning. However, as Heather Douglas argues, the distinction between applied and pure science is a very recent one and also very vague. It obscures that science is and was oriented towards social plus value. (Douglas 2012)

615 I distinguish the capacity to describe, to predict and to produce. The first one is ex post knowledge, the latter two constitute ex ante knowledge. Description comprises the description of single events (e.g. lightning), or event sequences (a seaquake leading to a tsunami), object features (length of the bone of a fossil) and regularities of such object features (only herbivores bear hooves). Prediction and production refer only to event sequences or object features; in prediction we cannot control the outcome, in production we can. The three concepts are overlapping: what we can produce, we can predict and what we can produce or predict, we can describe.

616 I find Lakatos' metaphor of an intact theoretical core of a research program inadequate and I would not know how it fits with my results; particularly I do not know how to interpret theory as the core of scientific work. (Lakatos 1999 [1978]:48-9) In any case, my model provides a much more detailed framework for the distinction of continuous and discontinuous elements in theories.

617 In return, the focus on empirical knowledge means that science does not progress without losses. Empirical knowledge is tied to the objects of inquiry and the instruments by which these are observed. If either one vanishes, the knowledge becomes a non-testable report only. Thus, historic reports of extinct races (in biology) or rare planetary constellations (in physics) or of political attitudes in the early 20th century (in sociology) describe phenomena and objects which are not accessible anymore. Likewise, observations which were made on historic instruments are often not reproducible because the instruments are lost and cannot (or are not) reproduced. In both cases, one can convincingly argue that the described findings do not constitute scientific knowledge anymore because they are not reproducible. Such, science constantly loses some of its knowledge and some frogs disappear. In the case of instruments, however, there seems to be a consensus that the historic knowledge has been replaced by a superior one, gathered on more precise and more powerful instruments and thus more complete and much richer than its predecessor.

618 In the case of the Copernican revolution, the case is still more complex. Most of the model of planetary motions which is today considered Copernican was developed by Kepler. Its philosophical implications, however, were still told by others, notably Giordano Bruno.

619 The case is a different one for achievements in applied science. The names of the great engineers and inventors have reached popular culture as well. Overlooked by outside observers seem to be contribution to the intermediate layers of science (static modeling, interpretation, dynamic modeling) and the basic research which may eventually lead to application.

History and philosophy of science, however, should not follow this example. We should not mistake popular fame for scientific quality or consider contributions beneath the threshold of popularity as inferior, shortsighted or immature. These are no low-hanging fruits! Rather, most excellent and influential scientists have never reached popular culture; they remain invisible to the public. This does not diminish their role in and for science. With respect to their scientific achievements, the likes of Geoffroy, Owen or Cuvier are clearly on par with Darwin or Lamarck.

iv. Epistemic criteria and theory choices: classifying criteria for the assessment of theories

With respect to the acceptance or rejection of the Darwinian theory or its elements, my reception analysis does not allow for a detailed description or classification of the criteria by which the Darwin's theory has been assessed by its contemporaries (or by later generations). However, the perception asymmetry which I identified (see above) as well as the distinction of different levels of abstraction within my model provide some clues how such questions may be pursued and allow for a classifications of the criteria by which scientific theories may be judged: a classification of epistemic criteria.

In a 1977 book, Kuhn mentioned five major criteria by which theories may be judged and these seem to still dominate the philosophical debate. (Kuhn 1977a: 321-2[620]; Oberheim and Hoyningen-Huene 2012):

- Accuracy: the "consequences deducible from a theory should be in demonstrated agreement with the results of existing experiments and observations"
- Scope: "a theory's consequences should extend far beyond the particular observations, laws, or sub-theories it was initially designed to explain"
- Consistency: a theory should not contradict either itself or other currently accepted theories
- Simplicity: a theory should bring "order to phenomena that in its absence would be individually isolated, and, as a set, confused."
- Fruitfulness: a theory should "disclose new phenomena or previously unnoted relationships among those already known"

Based on my model, I suggest specifying and systematizing these criteria, organized according to two kinds of distinctions. First, I wish to distinguish the different levels of my model of scientific theories, i.e. the abstraction levels which organized my comparative analysis of theories and my reception analysis: description, classification, explanation and ontological implications. Second, it is organized on what I would call 'epistemic goals', i.e. goals which are pursued in the formulation of theories. I see three such goals:

- the *organization* of empirical evidence (data): theories should order data in a manner which allows for easy orientation and navigation
- the *communication* of empirical evidence (data): theories should present data in manner which allows for efficient procession and dissemination[621]
- the *inspiration* for new research: theories should serve as fruitful heuristics for further research, systematically evoking new research problems and fields

[620] All quotes in the following two paragraphs and the list are from this book.
[621] This relates closely to the conversational implicatures described by psycholinguistics. (See footnote 80)

To these three epistemic goals of theorizing, I add the quality and quantity of the empirical evidence (data), which the theory may organize, communicate, or, with respect to which it may inspire new research. The opposition of my four levels to these epistemic goals results in a matrix. (See Table 28) In this matrix, epistemic goals are not identified with single levels of abstraction, but may apply to several such levels.[622] Hence, the organization of data (column 2) concerns both levels 2 and 3 and it has both a (denotative) logical component: inner consistency, simplicity of static and dynamic models, as well as a literary (connotative) one: simplicity of interpretative principles and of narratives. For communication (column 3) and a theory's heuristic function (column 4), the connotative elements matter most. It is the interpretation, the narrative and the ontology of a theory which allows for its dissemination and procession without complete knowledge of the underlying data[623], allows for consistency checks with other interpretations, narrative explanations and ontologies and for its integration in a world-view. Finally, it is the interpretation, the narrative and the ontology of a theory which point out very different kinds of research fields, evoking questions about the existence of (directly observable) objects and events (as well as their features), about regularities between them and, finally, about abstract entities and relations between such entities.

Thus, my classification covers all of Kuhn's criteria and it introduces a number of further distinctions which, I believe, supplement and clarify some of them: In column 1, my epistemic criteria correspond to accuracy and scope. I would, furthermore, add the ability to predict and produce for we consider a theory more powerful if it allows for predicting or influencing future events. (see above) In column 2, my distinction of denotative and connotative simplicity specifies the demand for simplicity, namely that a theory should bring "order to phenomena that in its absence would be individually isolated, and, as a set, confused."[624] Equally, my classification accommodates the first part of consistency, namely that a theory should not contradict itself. The second part is accommodated by column 3 which demands that a theory complies with other theories in order for it to be compatible to existing interpretations, narratives and ontologies. Furthermore, column three demands that a theory be convincing either in its interpretation, explanation and ontology, thus catering to human intuition and providing humans the impression of (better) understanding the data through the interpretations, explanations and ontologies provided by the theory. Finally, column 4 specifies what Kuhn calls 'fruitfulness', namely that a theory should "disclose new phenomena or previously unnoted relationships among those already known". It could point out gaps in either, classifications, explanations, ontologies or in combinations of them.

622 The exceptions are level 1 and column 1 because the other three epistemic goals – organization, communication, inspiration – do not add to the quality and quantity of data and because the theoretical abstraction levels of my model – classification, explanation, implications – do not apply to level 1.

623 In this sense, however, knowing a theory's interpretation, narrative or ontology does not imply that one knows the entire theory. Actually, in this sense, knowing the entire theory becomes quite daunting a task.

624 System theorist and complexity specialist Niklas Luhmann claimed that to organize knowledge is to reduce complexity. This corresponds to my impression that a good theory is a like a good file cabinet; it closely follows a carefully designed order and employs intuitive and unequivocal labels.

	Epistemic goals			
Level of Abstraction	**Quality & quantity of data**	**Organization of data**	**Communication of data**	**Inspiration for new research (heuristic)**
Level 4: Ontological Implications			▪ Ontological power: making sense of the world ▪ Consistency with other Ontologies	▪ Gaps in ontologies: entities, relations between entities
Level 3: Explanation		▪ Logical (inner) Consistency of dynamic models ▪ Simplicity of dynamic models ▪ Simplicity of narratives	▪ Explanatory power: making sense of dynamic models ▪ Consistency of narratives with other narratives	▪ Gaps in modeled processes (laws): regularities between objects, events
Level 2: Classification		▪ Logical (Inner) Consistency of static models ▪ Simplicity of static models ▪ Simplicity of interpretative principles	▪ Interpretative power: making sense of classifications ▪ Consistency of interpretations with other interpretations	▪ Gaps in static models: objects, object features, events, event features
Level 1: Description	▪ Data accuracy ▪ Data scope ▪ Possibility to predict and/or produce			

Table 28: A categorization of epistemic criteria by abstraction levels and four epistemic goals

Moreover and interestingly, my classification complies perfectly with what Darwin described as the added value of his theory on the last pages of the *Origin*. In the first paragraph of this lengthy passage, he suggests that his theory simplifies static modeling and interpretation (1.1.) as well as dynamic modeling[625] (1.2.). In the second paragraph, Darwin discusses communicative virtues, namely interpretation (2.1.) and narrative explanation (2.2.). Finally, in the third paragraph he addresses the heuristic value of his theory:

> „When the views advanced by me in this volume, and by Mr Wallace in the Linnean Journal., or when analogous views on the origin of species are generally admitted, we can dimly foresee that there will be a considerable revolution in natural history. [1] Systematists will be able to pursue their labours as at present; [1.1.] but they will not be incessantly haunted by the shadowy doubt whether this or that form be in essence a species. This I feel sure, and I speak after experience, will be no slight relief

[625] For narration, his text does not support my classification nor does it stand it in conflict it. In any case, I do not suppose that Darwin was a aware of the organizational value of a simple narrative, which seems to be rather new psycholinguistic insight.

The endless disputes whether or not some fifty species of British brambles are true species will cease. Systematists will have only to decide (not that this will be easy) whether any form be sufficiently constant and distinct from other forms, to be capable of definition; and if definable whether the differences be sufficiently important to deserve a specific name. This latter point will become a far more essential consideration than it is at present; for differences, however slight, between any two forms, if not blended by intermediate gradations, are looked at by most naturalists as sufficient to raise both forms to the rank of species. [1.2.] Hereafter we shall be compelled to acknowledge that the only distinction between species and well-marked varieties is, that the latter are known, or believed, to be connected at the present day by intermediate gradations, whereas species were formerly thus connected. […] In short, we shall have to treat species in the same manner as those naturalists treat genera, who admit that genera are merely artificial combinations made for convenience. This may not be a cheering prospect; but we shall at least be freed from the vain search for the undiscovered and undiscoverable essence of the term species.

[2] The other and more general departments of natural history will rise greatly in interest. [2.1.] The terms used by naturalists of affinity, relationship, community of type, paternity, morphology, adaptive characters, rudimentary and aborted organs, etc., will cease to be metaphorical, and will have a plain signification. When we no longer look at an organic being as a savage looks at a ship, as at something wholly beyond his comprehension; [2.2.] when we regard every production of nature as one which has had a history; when we contemplate every complex structure and instinct as the summing up of many contrivances, each useful to the possessor, nearly in the same way as when we look at any great mechanical invention as the summing up of the labour, the experience, the reason, and even the blunders of numerous workmen; when we thus view each organic being, how far more interesting, I speak from experience, will the study of natural history become!

[3] A grand and almost untrodden field of inquiry will be opened, on the causes and laws of variation; on correlation of growth, on the effects of use and disuse, on the direct action of external conditions, and so forth. The study of domestic productions will rise immensely in value. A new variety raised by man will be a more important and interesting subject for study than one more species added to the infinitude of already recorded species. Our classifications will come to be, as far as they can be so made, genealogies; and will then truly give what may be called the plan of creation. The rules for classifying will no doubt become simpler when we have a definite object in view. We possess no pedigrees or armorial bearings; and we have to discover and trace the many diverging lines of descent in our natural genealogies, by characters of any kind which have long been inherited. Rudimentary organs will speak infallibly with respect to the nature of long-lost structures. Species and groups of species, which are called aberrant, and which may fancifully be called living fossils, will aid us in forming a picture of the ancient forms of life. Embryology will reveal to us the structure, in some degree obscured of the prototypes of each great class." (Darwin 1860: 484-487)

In sum, I believe that my classification may clarify to some degree what kinds of epistemic criteria one might distinguish, how these criteria relate to different components of scientific theories, to different epistemic goals and to each other.[626] It also suggests that theory choice might be an even more complex matter than Kuhn suggested. It does not imply however, that theory choice is an irrational or arbitrary choice. Rather, in the perspective of my earlier arguments that empirics and theories are only loosely connected and that adherence to general theories is selective, it suggests that elements of different theories might serve different purposes on different occasions. It makes no sense to ask whether one theory is better than another, when one does not specify the epistemic position of the person supposed to adopt one of them and the communicative situation in which it is supposed to be employed, e.g. in modeling, as a heuristic device or in communication and in what communicative situation, for instance among colleagues of the same small research community, colleagues from the same discipline, scientists from other disciplines, an educated and interested public or a general public.[627] All these situations demand different theoretical virtues and might thus favor elements of different theories. This is particularly true for theoretical structures below general theories as models; one model might provide an intuitive explanation, another one an elegant logical structure, a third the most accurate representation of data.[628]

v. Judging Kuhn's account of scientific revolutions requires more than a plausibility check

No in-depth study has ever confirmed the Kuhnian claims. Historians and philosophers alike have heavily criticized *The Structure of Scientific Revolutions* and even Kuhn did clear most of his 1960s positions in the decades before his death in 1996. (cf. Hoyningen-Huene 1989; Kuhn 2000; Kuhn 1977b; Kuhn 1977a; Wray 2011; Wray 2012) Yet, why does his account of scientific history continue to fascinate? Why do so many scientists and non-scientists find it a plausible and intuitive account of science?

I believe the answer to these questions lies in a point which I have discussed during the presentation of my model, in the section on narration (section 2.1.4): Kuhn's is the case of a narrative fallacy. In the *Structure of Scientific Revolutions*, he tells a story about science which complies with one of the most fundamental narrative patterns of human experience: Kuhn tells the story of a white knight, a noble and ingenious hero who overcomes extraordinary difficulties by pursuing the right goals and who ultimately succeeds. This narrative pattern appears plausible and intuitive because it is extremely simple and very familiar.

However, underneath Kuhn's narrative lies neither a valid model nor the empirical findings to back one up. Table 29 shows that his story, albeit intuitive, clearly does not fit the empirical record. [629] As

[626] Therefore, this classification might be useful for the design of empirical studies of theory choices, providing an static model within a dynamic model of such choices.

[627] Communicative considerations matter a lot for science politics. Thus, the framing of research questions and results is an important marketing tool both within science and with respect to the public.

[628] How such criteria interact as factors of theory, is a question for sociologists.

[629] To be clear, the problem with Kuhn is not that he omits certain aspect of the history of science; any theorizing is abstraction and, therefore, omission. Kuhn, however, is founding his argument on such omissions. (I do not imply that he consciously did so; I do not know this.)

soon as one goes beyond checking whether Kuhn's story is intuitive one remarks that it is inconsistent and empirically wrong.[630]

Narrative elements	The Kuhnian story	A more realistic account of science (and still a simplified one)
Scene (Where?)	In a discipline in crisis, unable to solve problems posed by empirics (anomalies)…	Large scientific disciplines are never integrated into a single theoretical framework. There are always different sub-disciplines with particular empirical problems. Crisis is constant – or absent.
Agent (Who?)	…a single hero scientist[631] with a touch of genius…	The supposed hero scientist is usually part of a network of excellent collaborators and competitors and draws on shared challenging objects, shared research topics and a shared heritage of beliefs about his discipline
Agency (How?)	…formulates a brilliant novel theory…	The novel theory usually shares many elements of competing theories and integrates historical shared beliefs. Its brilliance consists mostly in the integration of many existing parts in a single, consistent framework which conveys controversial ontological implications to the public.
Act (What?)	…which then beats out its competitors, becomes accepted by the scientific community and defines the new "normal science"…	Theories are not accepted as units; rather scientists accept some aspects and dismiss others. Moreover, their effect on empirical work is limited; particularly sub-disciplines avoid theoretical positioning or employ theory only in communication to outsiders. Elements[632] of "loser" theories are preserved or recycled in new theories.
Reason (Why?)	…because it best solves the existing problems.	There are manifold reasons for accepting or rejecting elements of a theory beyond its fit with data. Scientists may accept a theory for its ability to organize empirical knowledge, for its appeal as a communicative device, or because it promises to be a powerful heuristic. Such choices may be momentarily and may change with the epistemic position (previous knowledge, depth of understanding) and with the purpose for which the theory is employed, e.g. the communicative situation in which it is employed.

Table 29: The Kuhnian narrative and its more realistic counterpart

630 Unfortunately, of the three criteria – plausibility, consistency, empirical fit – checking plausibility is the easiest and requires the least resources. Therefore, it often is the only criterion by which scientific statements are judged – notably in the humanities.

631 Unlike in later works, Kuhn did not adequately represent the role of collectives in the development of theories in *The Structure of Scientific Revolutions*. (Kuhn 1970 [1962]) On page 18 of *Structure*, Kuhn mentions the possibility that a group may develop a novel theory. On page 21, he mentions a collective of scientists who developed the theoretical foundation for electrics. On page 3, Galileo is mentioned as being embedded in a group of scientists, yet, this is not Kuhn's own statement but a reception. In the remainder of the book, he identifies theoretical advances with single scientists, for instance Einstein, Galileo, Copernicus, Darwin, Lavoisier. Groups figure predominantly as recipients of theories or as the performers of normal science. (cf. Kuhn 1977a: 321)

632 The program of Historical Epistemology identifies mental models as such preserved/recycled elements.

In sum, all the spectacular and incendiary elements of Kuhn's account of scientific revolutions – the elements for which he and his book became famous – turn out to be wrong. He overestimated the role of theories for science thus exaggerating the notion of crisis. He focused on individuals and neglected the role of collectives[633] and the knowledge and beliefs they share. He oversimplified the process of reception and theory choice by taking the position of a particular recipient group and neglecting that other groups receive the theory to different depths and assess it by different standards. Finally, Kuhn overlooked how very selective theories are accepted or rejected; scientists and the public deliberately choose single elements of a theory and ignore or dismiss others; the received theory is a very different thing from the one which find in a written text like the Origin of Species. Thus, Kuhn's spectacular theoretical scientific revolutions – these seemingly disruptive breaks in scientific practice – reorganize the body of scientific knowledge but they do not interrupt the accumulation of knowledge.

5.4 Synthesis

In this dissertation, I have achieved three projects: (i) I have developed a complex model of scientific theories which distinguishes different abstraction levels and two kinds of meaning – logical and literal – within theories. It allows for describing scientific knowledge systems in a novel degree of rigor and precision. (ii) I have applied this model in a historical-epistemological analysis of the Darwinian revolution, thus putting Darwin's contribution to the debate on evolution in the context of his discipline and his predecessors and competitors and identifying his truly individual contribution to 19th century biology. (iii) I have developed a novel type of reception analysis which distinguishes different audiences, in Darwin's case with biologists, scientists from other disciplines and the public. I have demonstrated that these audiences received the theory to different depths and that these differences in reception depth influenced the criteria by which they judged the theory as which elements of the theory were accepted or rejected. Furthermore, I have carried out the first large-scale quantitative analysis of the reception of Darwin's evolution theory among biologists.

In this work, I see four important contributions to existing research on Darwin, scientific theories and scientific revolutions: (i) The model of scientific theories which I have developed promises to be an efficient and flexible tool for both historians and philosophers of science. The model allows for precise and systematic descriptions and comparisons of different theories as well as the description of their transformations. (ii) I developed a novel framework for analyzing the reception of scientific theories among heterogeneous audiences, particularly audiences which comprise scientists and non-scientists. My framework allows for the classification of different reception depths as well as the explanation of correlated phenomena like the criteria by which a theory is judged. (iii) I have provided a comprehensive description of the transformation of the body of biological knowledge in the first half of the 19th century, which is significantly more precise and systematic than existing accounts. (iv) I have developed a general framework in which theoretical scientific revolutions can be described and explained.

Finally, my combination of philosophical, historical and sociological methods has revealed an image of scientific revolutions which is more precise, more systematic and more realistic than previous

[633] I am not even speaking about modern research groups here but about colleagues and competitors with independent research agendas who worked on similar problems in different places.

accounts. It portrays scientific revolutions as large-scale knowledge reorganizations rather than disruptive breaks in the scientific knowledge production and does thus avoid the misrepresentations and fallacies of earlier works on the topic.

THE END

6 Annex: Philosophical-systematic appraisal of my model of scientific theories

Similarly as for the generalizations on scientific revolutions, the empirical basis for an appraisal of my model is rather slim. I have demonstrated that it holds well for four theories and parts of other theories in 19th century biology. Also, I have sketched its application to theories in two other disciplines in my description of my model. (See section 2.1) From this, it seems to me that the model reveals a number of aspects about specific theories and theories in general which have hitherto gone unnoticed or have been mingled. Particularly, it allows for clearly distinguishing the connotative parts of a theory from its denotative parts; thus separating a concept from the meaning of its concept name, a static model from its interpretation, a dynamic model from its narrative and both from the narrative's ontological implications. In other words, my model separates different kinds of beliefs about science from different forms of scientific knowledge. (See Figure 32) Such, it may serve as a useful static model (a classification) in future research in both the History and the Philosophy of Science.[634]

Beyond its usefulness as an analytic tool, my model relates to a couple of problems in 20th century philosophy of science, solving[635] two, clarifying and attenuating others.

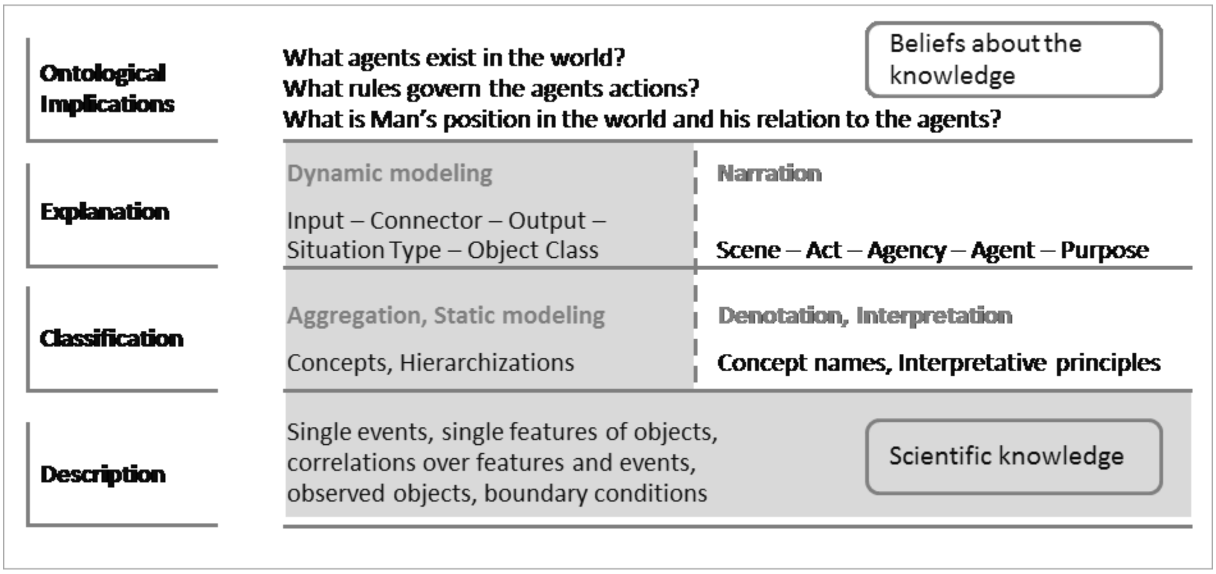

Figure 32: Scientific knowledge (grey shade) vs. beliefs about science (white) in my model of scientific theories

634 Applications, however, should treat my model (or any similar framework) not as an ontology or ideal model but as a tool box, an extendable one with it. For instance, it could be enriched by mathematical formulae or by more advanced tools for the analysis of metaphors and other stylistic devices.

635 I consider the solution of a philosophical problem either of these possibilities: (i) clarifying terminology to the point that the problem disappears or (ii) clarifying terminology to the point that the problem becomes an empirical, i.e. a scientific one. This, however, feels like a minority position in Philosophy of Science.

i. Realism with respect to beliefs; empiricism with respect to knowledge

It is common sense that scientific theories are more than mere aggregations of facts, somehow they mingle facts knowledge with hypotheses and it is eminently difficult to separate one from the other. Paul Feyerabend, in a sarcastic response to Karl Popper[636], famously went to the point of claiming that "anything goes" in science, that there was no methodology and that scientific theorizing, fundamentally, did not differ from religion or ideology. All were producing beliefs and none was more justified than the other. (Feyerabend 1975) By clarifying the line between beliefs and knowledge in scientific theories as the line between connotative and denotative meaning, my model should demonstrate that science is not just producing beliefs, not just telling stories. Scientific knowledge, in its theoretical form, is woven into a network of metaphors, stories and story sketches but it is not identical with this network. Its core is the logical aggregation and ordering of descriptions of empirical observations.

Beyond this body of empirical knowledge, however, science offers little more than a clutter of beliefs, some explicit and well-formulated, most implicit and in fragments – like mental models. A theory like Darwin's is the rare exception; few succeed in creating a coherent belief system around a body of empirical knowledge and fill all four levels of my model: description, interpretation, explanation and explicitly addressed philosophical implications. Yet, even these ideal theories are no coherent belief system in scientific practice; they are open to interpretation to the point that they might mean something different to any two recipients. Moreover, these differences in reception grow with the cultural differences. In this, scientific theories are not unlike poems, speeches or films: they are different cultural products in different times.

Like prominent empiricist philosophers, I cannot reasonably refer to this cluttered, subjective and constantly shifting network of beliefs as 'knowledge'; the term[637] just seems inappropriate.[638] This dismissal, however, comes with two important qualifications. First, beliefs can become knowledge and connotative meaning can be transformed into denotative meaning. Scientists do this all the time when, based on their beliefs about objects or phenomena of inquiry, they make predictions (ex ante) or describe novel observations (ex post). Thus, some debates on interpretation, explanation or ontology can and could be settled by novel experiments and/or observations.[639] The debate on evolution is a case in point.

However, such operationalization of beliefs is never fully possible. At any given moment, theories contain beliefs which have not yet been operationalized and may not be operationalizable in the foreseeable future. Thus, an important part of the beliefs incorporated in scientific theories remains

[636] I am indebted to Paul Hoyningen-Huene for clarifying the historical context of Feyerabend's book to me.

[637] I am making this meta-argument in the terminology of my model: After aggregating different parts of theories in different sets, I am discussing how these different sets should be named. I suppose to name the set of connotative elements 'beliefs' and the set of denotative elements 'knowledge'.

[638] One could make a reasonable case that mental models incorporate, to a large part, implicit and practical knowledge. This, however, is not the realist argument.

[639] Such operationalizations of beliefs, however, are frequently subject to heated debate. It is not evident, in what way one the existence of theoretical entities like agents, or ontological rules of interactions like forces can be tested empirically. Also, such operationalizations would have to produce notable differences to previous results (at least outside the interval of tolerated deviation) under the same boundary conditions, notably on the same instruments. I am not sure, that all cases of famous predictions qualify here; therefore, a systematic study of famous predictions might be an interesting historical project.

inaccessible to empirical test and thus does not have a determinate truth value. This part can either be believed or not believed.

Second, with respect to such beliefs, scientists seem in a somewhat schizophrenic position, a position which should be taken into consideration in philosophical debates. In the context of discovery[640], i.e. during research, scientists often seem driven by specific beliefs, i.e. specific interpretations, specific narratives, specific ontologies. When asked, they might justify their research with reference to these beliefs. However, in the context of justification, i.e. when presenting their results to their peers, scientists appear much more cautious with respect to these beliefs; they rarely claim to have proven their beliefs or even demonstrated that, given the available belief sets, they best fit the data. Holding beliefs beyond the established body of empirical knowledge empirics is a different thing than pretending these beliefs have been proved!

In sum, I would side with realist philosophers in that scientific theories do say more about the world than the data they accommodate and predict: Indeed, to many scientists and to many others they claim the truth of their interpretations, narratives and ontologies.[641] However, with respect to the truth of this "more", I would side with empiricist philosophers; we have no means of assessing it and therefore cannot consider it to be (intersubjective) knowledge. Therefore, the only possibility of settling issues of the realist-antirealist debate seems to be the scientific one: empirical study.[642]

ii. Analytic vs. synthetic statements[643] in the empirical sciences[644]: regularities within one set of objects/events and regularities between non-overlapping sets of objects/events

Beyond the distinction of beliefs and knowledge, the logical part of my model allows for solving a pair of technical[645] problems which have plagued the syntactic (linguistic) view of scientific theories: (i) the distinction of analytic and synthetic statements and (ii) the explanation of confirmation holism, the so-called Duhem-Quine hypothesis. (see next section)

Immanuel Kant apparently was the first to explicitly highlight a distinction between analytic and synthetic statements. (Kant 1787: B10) He describes the difference as such:

640 The distinction of a context of discovery and a context of justification is sometimes considered old-fashioned. However, it is often useful in distinguishing different phases of knowledge production and it is well operationalizable by distinguishing the work prior to a publication and the debate after a publication.

641 Theo Kuipers (Kuipers 2000: 9) provides a systematic overview over beliefs held by different kinds of realists. For a defense of structural realism, see (Engler 2008).

642 I do not imply that empirical study may solve all debates about reality.

643 This section and the following ones are abbreviated and non-formal versions of a forthcoming article on analytic and synthetic statements in scientific theories. (Zacharias forthcoming)

644 I will not discuss natural language examples like "All bachelors are unmarried.". While such sentences may express analytic statements, their terms are not sufficiently specified in terms of truth-values to allow for logical analysis. In my opinion, it makes no sense to discuss whether statements are analytic, if the predicates of these statements are not clearly defined. – Moreover, I will not discuss the statements of the non-empirical sciences (mathematics, geometry, logic) although many of them are analytic. For a discussion, see (Zacharias forthcoming).

645 I will discuss both, analyticity and holism, as logical problems, i.e. in terms of denotative (extensional) meaning. While there exist discussions of the problem as one of connotative meaning (e.g. Putnam 1962), in the original debate, both problems have been formulated as a logical problems by Willard van Orman Quine and Morton G. White: both demanded an extensional (denotative) definition of analyticity. (Quine 1951; Quine 1961; White 1950) Moreover, I do not see why or how one would discuss a logical problem in terms of connotations. As a problem of linguistic intuitions ("All bachelors are unmarried."), analyticity is a topic of linguistics or psychology and I do not see what value philosophers might add to empirical research.

> (i) "In all judgments in which the relation of a subject to the predicate is thought (if I only consider affirmative judgments, since the application to negative ones is easy) this relation is possible in two different ways. Either the predicate *B* belongs to the subject *A* as something that is (covertly) contained in this concept *A*; or *B* lies entirely outside the concept *A*, though to be sure it stands in connection with it. In the first case, I call the judgment analytic, in the second synthetic."
>
> (ii) The analytic statement cannot be denied without logical contradiction.

I read these two conditions as two formulations of the same relation, once in terms of set theory, once in terms of logical statements, namely (i) that there exist two sets A and B of which A contains B and (ii) that to deny that something satisfies predicate A without claiming that something satisfies predicate B leads to a wrong statement.[646] Kant calls statements which link A and B in this manner 'analytic' and statements which rather link non-overlapping sets or predicates 'synthetic'.

The key to distinguishing analytic and synthetic statements in science is the distinction of two kinds of regularities which I have separated throughout my study[647]: regularities between the same kinds of objects and regularities between different kinds of objects or, more generally and more precisely formulated, regularities within one set of object or event features and regularities between non-overlapping sets of such objects or features. Let me illustrate.

Until the end of the 18th century, biologists produced classificatory knowledge, i.e. they described the features of plants and animals and discovered that these descriptions allowed for the systematic classifications of organisms in groups of which the members shared certain features. For instance, all vertebrates display a spinal cord and, as Cuvier highlighted, all animals with hooves are herbivores. Within such classifications, each taxonomic group is defined by a set of features which its members share.[648] The more general the group, the less features its members share.

Now, if one describes the relations between a general group and one of its subgroups, one describes a relation as described by Kant in statement (i). For instance, the taxonomic group 'humans' is a subset of the group 'biped mammals' as well as the group 'mammals'. Also the group 'mammals' contains the group 'biped mammals'. Therefore, one cannot deny the existence of mammals without denying the existence of biped mammals: if there exists one biped mammal there also exists at least one mammal.[649] This corresponds to Kant's statement (ii). Hence, statements which clarify the

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646 In modern logic, Kant's statements can be expressed more precisely in a set-theoretical formulation and in predicate logic. Be A and Be two sets, each element of set B an element of set A but at least one element of B no element of A. (I exclude identity because analyticity is not identity and mixing both may distract from the actual problem.) Furthermore, be Ax and Bx two predicates, with Ax denoting „x is an element of the set A" and Bx denoting „x is an element of the set B". The statements (i) and (ii) two can then be expressed like this: (i') $\mathrm{B} \subset \mathrm{A}$ and (i'') $\forall \mathrm{x}(\mathrm{Bx} \rightarrow \mathrm{Ax})$.

647 Hence, my solution to the problem is simple and low-tech; it is based on an empirical distinction and requires no complex formal apparatus.

648 These relations can be expressed in biconditional statements, e.g. $\forall \mathrm{x}(\mathrm{Ax} \leftrightarrow \mathrm{Bx} \vee \mathrm{Cx})$, with Bx and Cx denoting subsets of Ax.

649 In more formal terms, the following three statements cannot be true simultaneously: (i) $\forall \mathrm{x}(\mathrm{Ax} \leftrightarrow \mathrm{Bx} \vee \mathrm{Cx})$ (ii) $\exists \mathrm{x}\mathrm{Cx}$ (iii) $\neg\exists \mathrm{x}\mathrm{Ax}$. Note that this contradiction exists only if there is a definition which defines Ax as implying Cx. As this is not the case in normal language, one cannot discuss analyticity there. (See above)

relations of a taxonomic group to a more general group, by specifying elements of the definitions of such groups (relations within static models), are analytic.[650]

With the advent of biogeography, paleontology and experimental biology, biologists began to supplement analytic statements with synthetic ones, i.e. statements which describe relations between non-overlapping sets. For instance, certain groups of fossils were restricted to certain geological strata (which were interpreted as representing different periods of time), certain groups of living organisms were restricted to certain geographical areas, and certain micro-organisms were linked to chicken broth which had first been boiled and then left standing open.[651]

Such statements do not specify relations within a static model (classification). Instead, they relate groups of organisms not to subgroups or more general groups of organisms but to non-overlapping groups[652] like sets of geological strata or geographical areas or events as boiling.[653] It seems to me that synthetic statements are rather found in dynamic models, i.e. models which describe changes in space and time. Thus, the Input-Output relations of the dynamic models are all synthetic statements.

iii. Underdetermination of concepts, models, ontologies & confirmation holism

The distinction of analytic and synthetic statements, in turn, allows for clarifying another problem, the so-called (confirmation) holism, the observation that scientific models and theories can be immunized against divergent empirical evidence by restricting concepts which figure in the explanation of this evidence. (Duhem 1962 [1909]: 187) A case in point is the term ‘perfect market’. It denotes the Situation space in which Rational Choice models and much of macroeconomics apply: hardly any such regularity applies outside perfect markets. Consequently, when predictions fail, macroeconomics can always blame the market and claim that it was not perfect, thus immunizing their model from contradictory evidence.[654]

The observation of holism has then been developed to the general thesis that theories are underdetermined by the evidence they aim to interpret and explain, i.e. that data provides no unambiguous criterion for the choice between theories. (Quine 1975)[655] Finally, the thesis of

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650 Note that this is why such statements are called ‘analytic’; they analyze (dissect) complex definitions. Therefore, I find it a trifle misleading to claim that analytic statements represent a priori knowledge, i.e. that one knows them beforehand. One only does, if (i) one knows all definitions of a given classification and (ii) understands these definitions. This often is not the case. Therefore, analytic statements can be informative although they merely specify one part of a (complex) definition.

651 In the first and second example, objects are linked to objects; in the third events are linked to events. However, in models, the objects of the second example were interpreted as displaying the result of events, i.e. the emergence of certain species. The same is possible in the first example, the geographical distribution could display the result of migrations.

652 As I did discuss it in section 2.1.2, these objects and events may, themselves, be classified in classifications of events or other objects, for instance in geological or geographical correlations. However, such classifications would be independent of the classifications of groups of organisms.

653 In formal terms, such relations can be expressed in statements like the following: $\forall x(Ax \rightarrow \exists y Cy)$ where Ax and Cy are logically independent predicates (the sets A and C do not overlap). The difference to analytic statements is visible in the logical form of the statements already: The universal quantifier of an analytic statement binds both the antecedens and the consequens of the conditional in the bracket. Contrarily, in a synthetic statement, it binds but the antecedens.

654 The same is true for the ‘homo oeconomicus’ as a denotative term of the object class; contradictory evidence can always be blamed on humans acting irrationally.

655 A mix of these two statements is also referred to as the Duhem-Quine-hypothesis.

underdetermination has been used to challenge the self-image of science as a rational enterprise. (Stanford 2009) Before I address the latter two points, let me describe what kinds of underdetermination are accommodated by my model and how it specifies accounts of holism and underdetermination.

First, from level 1 to 2 of my model, descriptions of observations are aggregated, denoted, hierarchized and interpreted in classifications. These choices are not entirely dictated by the evidence and human perception of it; humans differ in them. Thus, any particular classification may be underdetermined with respect to the way it aggregates descriptions of observations in sets and denotes these sets, hierarchizes sets and provides interpretative principles for these hierarchies.

A famous example for the aggregation and denotation is Karl Popper's black swan. In his seminal *Logik der Forschung*, Popper argued that until the discovery of a black swan the statement "All swans are white." was true, yet, with the discovery of the black swan it became falsified. (Popper 1995[1935]: 3) With respect to science and scientific practice, Popper's argument is wrong. If one assumes that 'white' was a defining attribute of the set with the name 'swan'[656], then the animal found in Australia was no swan and its inclusion in the set 'swan' would have required modifying the definition of the set named 'swan', namely the dropping of 'white' as defining attribute.[657] In either case, the statement was not falsified. Equally, when Owen described the Archaeopteryx in 1862, he classified it as a bird, not as the intermediate between birds and reptiles as which it is classified today. Thus, the discovery of the Archaeopteryx did not refute or contradict Owen's archetypal classificatory system; rather, if (and only if) one classified the Archaeopteryx as an intermediate form between reptiles and birds, it did not fit Owen's classificatory system – and this is no refutation or logical contradiction, merely a reduction of a model's scope.[658] Moreover, such underdetermination exists not with respect to the evidence but also with respect to other models. In the debate on the age of the earth (section v), both physicists and geologists identified their respective, non-overlapping evidence in timescales of quite different magnitudes. To side with one party and not with the other was a matter of classificatory choice, not one of evidence or its perception.

Such choices consist in two options, both of which are closely related to the aforementioned analytic statements, i.e. statements which describe relations between sets. One can either restrict a set to exclude the aberrant evidence or divide the set in order to integrate it: One can either allow for black swans or not consider the black swan a swan. One can either drop the distinctions between archetypes or classify the Archaeopteryx as a reptile or a bird – but nothing between. One can either accept two different timescales of the age of the earth or dismiss one of them. Each of these choices implies modifying the definition of sets and, thus, changing relations within a static model. These changes become visible in novel analytic statements, i.e. statements which specify the novel attributes in the modified definitions.

[656] This seems dubious; colors as defining attributes would probably only be used if they were needed to distinguish between organisms which resemble each other in all but their color, for instance black and white swans.

[657] My argument does not hold with undefined terms and intuitive concepts, e.g. in natural languages. Thus, without a definition of the predicate 'is a swan', Popper's argument is quite intuitive.

[658] Philosophers often argue that a theory logically entails evidence. (cf. Laudan 1990: 269) Aside from the fact that linguistic entities can only entail linguistic entities, e.g. theories descriptions of observations, such a view works only with respect to denotations, not connotations, e.g. not in natural languages. Connotations are no logical entities and do not entail anything logically.

On level 3, within dynamic models, the phenomenon of underdetermination becomes more complex. As I explained in the introduction of my model, dynamic models summarize aggregate statements over sets of boundary conditions (in the Situation Types), sets of observed objects (in the Object Class), sets of events or object features (in Inputs, Outputs) sets of assignments of events or object features (in the Connector). When evidence does not comply with a dynamic model, each of these sets may be restricted or divided as on level 2. This renders the empirical test of dynamic models such a complex[659] matter and it is probably what Pierre Duhem meant in the following statement – one simply has to read 'hypothesis' as 'definition':

> "the physicist can never subject an isolated hypothesis to experimental test, but only a whole group of hypotheses; when the experiment is in disagreement with his predictions, what he learns is that at least one of the hypotheses constituting this group is unacceptable and ought to be modified; but the experiment does not designate which one should be changed." (Duhem 1962 [1906]: 187)

It seems to me that scientific disciplines have developed certain traditions with respect to which sets of their dynamic models they uphold and which they protect. Such, a physicist would rather doubt the existence of a field or vacuum (Situation Types, operationalizable in boundary conditions) than doubt the working of the basic physical forces (Connectors). A macroeconomist working on financial markets would rather doubt the existence of perfect information at the stock market, i.e. the existence of a perfect market (Situation Type), than the ideal of rational decisions (Connector) by rational agents (Object Class). Darwin did rather postulate some sort of ecological drift (an unnamed Connector) rather than interpreting the fluctuations of polymorphic species as evolution (Output).[660]

On level 4, the third and most abstract kind of underdetermination can be found: underdetermination of ontologies. It consists of the fact that the available empirical evidence allows for telling different narratives about nature and that, in turn, these narratives may convey different ontologies of the world, i.e. different tales about which entities do interact how in the world. As the discussion of my model highlighted (see 2.1.5) and as the reception analysis as well as my discussion above revealed (see 3.1 – 3.5, 5.3.i), these ontologies are only very loosely connected to empirics and the subjective interpretation is still more marked in ontologies than in classifications (interpretation, denotation) and explanations (narratives).

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[659] One might grasp the complexity of this operation like: An empirical regularity is a statement with a set of properties which may or may not satisfy a specific Situation Type, Object Class, Input, Output. (The Connector is but a name for a set of such configurations.) An empirical regularity is covered by a dynamic model if it satisfies each of these four elements. (In this case it also satisfies the Connector.) By specifying any of the elements one restricts the number of possible statements which may satisfy the dynamic model and, usually, the number of statements which do satisfy it.
One of the problems of modeling in the social sciences is the lack of distinction for its Situation Types and Object Classes. By classifying different sets of boundary conditions as different Situation Types, one could distinguish different sets of regularities by the Situations in which they apply. If no such distinctions are introduced, the regularities either apply to a very large space of situations or very few situations. Usually, the latter is the case for few, in any case, empirical regularity apply to large classes of objects and/or situations. Thus, the focus single Situation Types and/or single Object Classes, strictly limits the available empirical knowledge.

[660] The flip-side of such immunization, however, is a strongly limited scope of their models. Therefore, rather than focusing on perfect markets or perfectly rational agents, economists might wish to study actual behavior in actual situations and develop more complex concepts of both, its Object Class and Situation Type. (See (North 1977) for a similar point and (Callon 1998) for an argument against such increased complexity which is based but on ontological considerations.)

As ontologies are attempts to describe the reality behind the observed reality, they are not surprising; the access to such a reality is a highly subjective matter. Therefore, it is not surprising that many of the most controversial topics in science are ontological ones. When concept names like Natural Selection, electricity or gravity, the homo oeconomicus or the age of the earth are not considered mere metaphors or useful scientific fictions but as having true existence beyond the observable (in the realist sense), then they become questions of world-view and therefore highly debatable.[661]

I believe that it is this underdetermination of ontologies which Quine described when he discussed whether "systems of the world" are underdetermined by the totality of known evidence. (Quine 1975) Thus, "empirically equivalent" models or theories are underdetermined with respect to their narratives and ontological implications. However, unlike Duhem's, Quine's underdetermination is no logical phenomenon. As my analysis has shown, neither narratives nor their implications are denotative entities; they exist only in the realm of connotations, i.e. outside the reach of logic. Therefore, empirically equivalent theories do not contradict one another in the logical sense of 'contradiction'. Rather, their narratives and ontologies might be judged as *intuitively* incompatible by a specific subjective recipient from a specific cultural context.[662] Such judgments and their criteria, however, are no topic of logical but of psychology or sociology. [663]

With respect to all these three forms of underdetermination, it makes no sense to ask whether a theory is true: A theory does not model, interpret, or tell evidence in the single true way but in one of several ways, forming different sets, naming them differently, arranging these concepts in

661 Moreover, they strongly depend on cultural context; philosophical implications can fade over time or increase in importance. For instance, today, the mention of God's in the *Origin*, would rather be read before the background of a debate between atheists and believers than between deists and theists as in the Darwinian time.

662 Thus, Quine's question whether a "reconstrual of predicates" would transform one empirical theory into the other in terms of truth values (Quine 1975: 327) can be answered in the affirmative: Quinean underdetermination is no logical phenomenon and empirically equivalent theories do not contradict each other logically. Changing the concepts and concept names, transforms one theory into the other in terms of truth values. However, such reconstrual would erase all connotative meaning of the concerned theory and thus the interpretative, explanatory and ontological component of a theory. (Feyerabend 1962: 28-9) expresses the same point, with less distinctions: "a complete replacement of the ontology (and perhaps even of the formalism [dynamic model]) of T' by the ontology (and the formalism) of T and a corresponding change of the meanings of the descriptive elements [classification] of the formalism of T' (provided these elements and this formalism are still used)."

663 This may explain why the reduction of scientific theories to descriptions of evidence is such an unappealing idea: it deprives a theory of its sense. (cf. Bridgman 1927; Bridgman 1951a; Bridgman 1951c; Bridgman 1951b)

I do not support the idea of theory-reduction between different theories, notably theories from different disciplines. Kenneth Schaffner identifies Nagel (1947, 1961) as the standard view on such theory reduction and characterizes it like that: "Nagel envisaged reduction as a relation between theories in science. A theory in biology, say, was reducibly to a theory in chemistry, if and only if (1) all the non-logical terms appearing in the biological theory were connectable with those in the chemical theory, e.g., gene had to be connected with DNA, and (2) with the aid of these connectability assumptions, the biological theory could be derived, essentially as in the Hempelian explanation …, from the chemical theory (with the additional aid of general logical principles)." (Schaffner 1996: 31) – To me, the idea of such a theory-reduction is absurd. One may seek to unify theories in connotative terms, within a single and coherent terminology, although this can be daunting linguistic task. However, one cannot deduce denotations from different denotations, for instance the observations of biology from those of physics. Such ideas make sense only if one ignores the empirical content (the referents) of scientific theories and reduces them to systems of metaphors.

different narrative structures, conveying different ontologies.[664] None of these ways is wrong; rather they represent specific manners of humans making sense of scientific knowledge.

iv. The theory-ladenness of observations and incommensurability

Like the debate on holism and the analytic-synthetic distinction, the debate on theory-ladenness and incommensurability was a reaction to the logical empiricist project of the Vienna Circle, and its attempt to model scientific theories as logical-linguistic entities. Part of this project had been the postulation of some basic kind of objective observation statements which could be distinguished from theoretical statements and would thus form an undisputed basis for theorizing. In the late 1950s and in the 1960s this assumption was attacked by Norwood Russel Hanson, Paul Feyerabend and Thomas S. Kuhn, among others. (Hanson 1972 [1958]: 4-30, Feyerabend 1962; Kuhn 1970 [1962]: 149-165, 198-200) These philosophers claimed that any observation implies theorizing and that, therefore, any description of observations has at least some theoretical component. From this alleged theory-ladenness they concluded that there exists no undisputable basis for theorizing and that, therefore, no common measure by which to compare two theories: theories are "incommensurable".

I have not worked on acts of observation and cannot speak about whether they are theory-laden or in what way. However, based on my model, I can say something about the relation between descriptions of observations and different kinds theorizing, i.e. classification, explanation, ontological implications. My model as well as my study suggest that accounts of theory-ladenness and incommensurability are exaggerated and/or without empirical basis.

First, if descriptions of observations are supposed to be theory-laden, then one has to demonstrate this theory-ladenness on these descriptions and not on interpretations, explanations or ontologies of such descriptions. The original proponents of the thesis of theory-ladenness have failed to do so; their demonstrations of theory-ladenness are limited to what in my model are interpretations, explanations or ontologies.[665] They do thus fall prey to the same perception asymmetry as Kuhn in his analysis of scientific revolutions (see above); they analyze science from the perspective of outsiders and draw conclusions which are biased by this perspective.

Second, identifying theory-ladenness requires more than pointing out single terms in descriptions and claiming that they *might* be interpreted in *some* theoretical context, particularly from a different historical context or from outside science.[666] Instead, one would have to demonstrate that terms in descriptions are systematically linked to a theory which covers these very descriptions in a specific

[664] Thus, underdetermination is not only a logical problem, it consists of denotative (logical) and connotative (literary) choices.

[665] Neither (Feyerabend 1962) nor Kuhn (1970 [1962]) nor (Hanson 1972 [1958]) cite a primary source. Their presentation of scientific theories is sketchy and limited to models and their narratives, sometimes classifications are mentioned. Moreover, most discussions of theory-ladenness focus on the textbooks or theoretical overviews, not on the descriptive part of empirical papers, as they should.

[666] Thus, it is not sufficient to claim theory-ladenness in a general understanding of theory, in the sense of some more or less specific world-view. Moreover, when identifying supposedly theoretical terms, one has to pay close attention whether these terms where in use as theoretical terms in the historical context in which they were employed. The use and the reference of terms (their denotative and connotative meaning) is subject to profound changes.

historical context of science. (Otherwise, the alleged theory-ladenness remains but an a posteriori projection.) I know of no empirical study which would thus support claims of theory-ladenness.

Third, even if such systematic relations were identified, one still would have to demonstrate their impact on scientific practice, particularly on research methodologies or the assessment of new models or theories. I do not know any such demonstration.[667]

As far as I see, none of these conditions is fulfilled. Furthermore, my study of theoretical developments in 19th century biology suggests that descriptions of observations, while probably not theory-free, are *theory-neutral*[668], i.e. compatible with different, possibly opposing theories. Hence, Proponents of the Darwinian theory and Owen's theory of the archetype build their theories on the same set of descriptions, many of which had been produced by Owen. I do not find a single case in which such descriptions were called in question – not even in the debate on the hippocampus minor. Instead, the heated debates on classifications, explanations and ontologies were led before the background of and with reference to a common and undisputed body of scientific knowledge, these namely descriptions of observations.[669]

Moreover, this common body of descriptions allowed for discussing different components of the competing theories and for assessing how they performed with respect to this body. Thus, the majority of biologists accepted Darwin's classification but held reservations with respect to his explanation and its ontological implications; they accepted some elements of his theory and dismissed others.[670] This selective adherence suggests that scientists were able to assess theories from without these theories and make their judgments without adhering to any alternative. They were able to assess what theory added to empirical descriptions and, in return, what these descriptions where independently from their theories.

A point in case is Lankesters' 1870 suggestion of changing the name of Owen's concept of homology because it still held Platonic overtones. (Rupke 1994: 217; see section 4.3.3) While his suggestion was not adopted[671], it shows that proponents of one theory were very well able to grasp the connotations conveyed by theoretical concepts and could separate them from the denotative part. In other words, they could make judgments about theories in which they separated descriptions of observations from their theoretical superstructure, i.e. classification, explanation and ontological implications.

In my understanding, this clearly contradicts accounts of theory-ladenness and it suggests that criteria for theory choice can very well be explicated from without theories in question. This does not imply, however, that such choices are evident or objective. As I have sketched above, criteria for theory-choice are manifold and non-exclusive. Thus, it may be possible to assess that one theory fares better in area X while the other does better in area Y without it being clear which theory one should choose. One might still lack a "common measure" by which to choose between them. However, unless the existence of theory-ladenness is demonstrated with respect to the three

667 I do not doubt here, that scientists hold ontologies which influence their research agendas and theoretical choices. Yet, theory-ladenness should be observable in the writings of scientists, namely in their descriptions of observations, and not in their opinions or verbal statements.

668 I owe this term to Fynn Ole Engler and Hans Jürgen Wendel from the Institute of Philosophy at the University of Rostock.

669 This does not imply that this body of knowledge may not grow or be corrected. However, such growth or corrections are justified with respect to observations or experiments, not from theoretical justifications.

670 This again underlines that theories are not accepted in their entirety and should not be treated thus.

671 Remember that Owen's concept is still in use in modern biology.

conditions above, this lack of a common measure cannot be read in the sense of traditional claims of "incommensurability".

v. A new approach to scientific explanations?[672]

Since Carl Gustav Hempel's first ambitious model of scientific explanations, the covering law-model or deductive nomological model (D-N model), several alternatives or complements have been advanced for explanations in the natural sciences. (cf. Salmon 1989) In a recent article, Heather Douglas distinguished four influential contemporary views: covering law explanations (D-N-explanations), causal explanations, explanations through unification and mechanistic explanations.[673] (Douglas 2009: 455-6) Outside the natural sciences, one may add teleological explanations, i.e. explanations which do not answer why something happened or emerged but what for.[674]

In discussing these different types of explanations, there seem two philosophically relevant questions, a normative and a descriptive one. On one hand, one may ask which of them qualify as good explanations and what characterizes a good scientific explanation. On the other hand, one may ask what distinguishes these different kinds of explanations, how they may be described and compared. My model provides clues to both questions.

First, one may discuss the epistemic value of different explanations and define what a good explanation should provide. I agree with Douglas that good explanations should be more than good stories (narratives); they should also be adequate dynamic models of empirically observed regularities.[675] This reflects the three criteria for theory-assessment which I identified in the reception analysis (section 0): (i) *empirical adequacy*: a good explanation should allow for describing, predicting[676] and/or producing empirical regularities[677], (ii) *consistency*: it should model these

[672] I do not discuss classifications here although they might be regarded as 'explanatory' in a larger sense of the word.

[673] For the classic account of covering law explanations, i.e. deductive-nomological (D-N) explanations, see (Hempel and Oppenheim 1948) and (Hempel 1962). For causal explanations, see for instance (Salmon 1998). For explanation through unification, see (Kitcher 1981). For mechanistic explanations with a focus on biology, see (Schaffner 1996) or, with reference to "laws" instead of 'mechanisms', (Mitchell 2000).

[674] Teleological explanations are frequent in the social sciences and humanities, although there exist other forms of explanation. Many social scientists interpret events as human actions and explain them as results of human decisions, for instance rational decisions. In the humanities, many scholars explain objects (text, film, artefacts) or events (theater pieces, interactions) as products of intentional decisions. Such explanations might be mixed with causal or mechanistic explanations, though. (One might also speak of products of mindful acts which relates to the German term Geisteswissenschaften for the humanities; Geisteswissenschaften study products of human minds.)

[675] However, unlike Douglas, I do not see a "philosophical relationship" between prediction and explanation. (Douglas 2009: 450) I simply believe that a good explanation should comprise both elements of level 3 of my model of scientific theories, i.e. a dynamic model and a narrative.

[676] Douglas mentions an explanation's ability to produce novel predictions, too. Her understanding of the term 'prediction', however, is rather loose and mixes two epistemic functions of an explanation: organization and inspiration (heuristic value). (For the distinction of epistemic functions, see Table 28) Thus, Douglas's notion of 'prediction' covers not only precise predictions of specific events – for instance predictions of the tides or projections of economic growth – but the general idea that explanations may yield novel and interesting results when applied outside their original domain or to formerly unknown objects or events in this domain. (A case in point for prediction in this large sense would be the discovery of Neptune. Before the planet had been observed, it had been predicted by French astronomer and mathematician Urbain Le Verrier (1811-1877) from theoretical reasoning. Another one is Kurt Lewin's application of physical models to psychology which resulted in a number of empirical breakthroughs. (See Perlina forthcoming)

regularities in a logically consistent manner, (iii) *plausibility*: it should provide a compelling narrative which makes sense of the described observations and experiments.

Logically, this requirement results in a more detailed version of the D-N-scheme, i.e. the demand that explanations comprise empirically adequate dynamic models as described by level three of my model of scientific theories. (This should be the necessary condition for a scientific explanation.) Beyond logic, however, my model allows for a pluralism of explanations and also for the selective use of explanations which can be observed in scientific practice. (This is the sufficient condition.) One explanation may provide the best organization of data, another might be more useful as a communicative tool in teaching, a third one might turn out to be the most fruitful heuristic. Moreover, scientists in the same field may pursue different narratives in their research all the while accepting the same model or two logically equivalent models of the established body of knowledge.[678] Thus, cooperation is possible and fruitful even where scientists disagrees about what is an acceptable explanation, i.e. one they consider "intuitively" explanatory. (Kitcher 1981: 508)

Second, by specifying the logical form of static and dynamic models (denotative meaning) and by distinguishing them from interpretations and narratives (connotative meaning), my model provides analytic tools for the analysis of different types of explanations. For instance, it clarifies that the covering law model (D-N-model) and unification focus on *logical aspects of explanation*, while causal, mechanistic and teleological explanations focus, first and foremost, on *narrative aspects*.

Thus, covering law explanations are statements which link an Input to and Output in a general statement, possibly via a Connector. Unification might apply to all elements of a dynamic model: one might unify Situation Types, Object Classes, Inputs, Outputs and Connectors; the most relevant elements for explanations are probably the latter three.[679] For instance, Darwin unifies the phenomena of paleontology, biogeography, anatomy and morphology under a single Output named 'evolution'. Newton unifies different phenomena of the physical world – celestial motions, the tides, falls of bodies on earth – under the term 'motion', which figures in both his Input and Output. Rational Choice summarizes numerous sets of empirical regularities under a single Connector: 'rational decisions'. Consequently, most covering law-explanations involve some degree of unification, too. In causal explanations, the terms for the Input or the Connector of a dynamic model are employed as Agents in the narrative explanation. For instance, a moving body (Object, Input) may alter (Agency) the motion (Output) of another body (Object) because gravitational forces act between them (Reason). Compared to full-fledged causal explanations, mechanistic explanations are narrative sketches only. They focus on the Connector, too, but present it as an Agency (means) rather than an Agent (cause), thus providing no reason/purpose for the process they describe. For instance, an effect (Input, Output) is achieved via a Mechanism (Connector), although the underlying cause

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Thus, prediction in this large sense includes what I would call the heuristic dimension of a narrative. This, however, like its communicative function, is nothing I would tie to dynamic models in explanations. A narrative might be a useful narrative tool or a good heuristics although it is not linked to a good dynamic model and, therefore, not part of a good explanation. Therefore, the symmetry thesis, i.e. the idea that prediction and explanation are mutually depended, is wrong in both ways. There exist good scientific explanations which yield no interesting predictions and bad or un-scientific explanations which turn out great heuristics.

677 When predictable and/or controllable, such regularities are often called 'effects'.

678 I am aware that such clear cut cases do probably not occur in practice.

679 Generally, Kitcher's unification account focuses on what I call 'static modeling'. It addresses level 2 of my model, not level 3. Thus, one could argue that it addresses a prerequisite of scientific explanations rather than scientific explanations themselves.

(Agent) is still unknown. In teleological explanations in the social sciences, the members of the Object Class are interpreted as Agents which are motivated by the term for the Input, e.g. preferences, and pursue (Purpose) the Output (Act) via the Connector (Agency), e.g. rational decisions.

As the latter three modes – causal, mechanistic, teleological explanations – specify narrative aspects of explanations and the former two – covering law and unifying explanations – describe logical aspects, they are not mutually exclusive. Rather, an explanation which satisfies one of the narrative modes may also satisfy one or both of the logical modes and an explanation which satisfies one of the logical modes may also fulfill one of the narratives modes.[680] Thus, a causal explanation based on an empirically adequate dynamic model fulfills the conditions of a dynamic model and, indeed, most causal explanations in the natural sciences are covering law explanation as well. Moreover, causal explanations unify Connectors, i.e. the names of covering laws (sets of regularities under general statements). Mechanistic explanations do the same but to a lesser degree; compared to causal explanations, their Connector unifies smaller sets of empirical regularities. These sets of regularities, in turn, often fulfill the conditions of covering law-explanations such that the Mechanism (Connector) of a mechanistic explanation equally is the name of a covering law. The case of teleological explanations is equivalent: A Connector like 'rational decision' does the same for sociological explanations as a Mechanism does for a biological explanation. Likewise, the elements of a prototypical Rational Choice explanation unify large sets of possible Inputs, Outputs and Connectors; thus, 'rational decision' denotes an entire set of empirical regularities in the social sciences.[681]

I cannot go beyond sketching possible applications of my model here. Still, I am confident that the distinction between the logical and the literary component of explanations as well as the four levels of my model might allow for more informed and more informative comparisons of explanatory practice and traditions in different branches of science.[682] Possibly, it might also allow for more theoretical pluralism, i.e. the acceptance of different, competing interpretations, narratives and ontologies over the same (similar) data sets.[683]

vi. Criticizing models, theories & modeling and theoretical choices for the right reasons

Such pluralism could go hand in hand with more specific criteria for the assessment of theories and models. My impression[684] is that such assessments are often quite one-dimensional and focus too

680 Covering law-explanations and unifying explanations are not mutually exclusive either. However, the three narrative modes seem to exclude each other in that the same explanation is never perceived as both teleological and causal or causal and mechanistic or mechanistic and teleological.

681 Therefore, there are explanations in the humanities and social sciences which fulfill the same logical criteria as explanations in the natural sciences – although their narrative form differs. Danto 1965 and Frings 2008 describe such explanations in History.

682 An interesting case is Darwin himself: In his explanation, Darwin made the move from putting the main explanatory metaphor on the Connector instead of the input. Thus, he switched from the explanatory mode of the humanities to the mode of physics.

683 Moreover, it might allow for developing operational criteria for narratives in scientific explanations. One might specify what aspects should the underlying model or the studied objects and event need to exemplify for a narrative to be applicable.

684 Naturally, I might be falling prey to the aforementioned perception asymmetry in that I am aware only of the prominent (popular) critical accounts, i.e. those which focus on levels 3 and 4 of my model.

much on the upper levels of my model, i.e. ontologies, narratives.[685] Modeling choices are less often addressed, questions of empirical scope and data accuracy[686] still less.

This trend shows very markedly in economics where the criticism of the Rational Choice theory focuses mostly on the world-views of the theory, i.e. what it implies about humans and their behavior.[687] Laymen critics argue that economists would not take into account the entirety of human motives; for instance they would ignore morals and altruism in human decisions. Psychologists like Amos Tversky and Daniel Kahneman or Gerd Gigerenzer focus on decision-making processes and argue that empirical evidence in psychology goes counter to Rational Choice ontologies of how humans decide. (Tversky and Kahneman 1981; Gigerenzer and Todd 1999; Gigerenzer 2001; Gigerenzer 2008; Gigerenzer and Brighton 2009)[688]

While it is a perfectly legitimate ambition to criticize the ontology of a theory, I cannot avoid the impression that such criticism diverts the attention from what seem to be the more urgent problems of macroeconomics, for instance the lack of empirical foundation for much of economic forecasting or the lack of distinctions in its Situation Type and Object Class (see footnote 659) or the question whether the organization of economic regularities in the form of fundamental laws reminiscent of physics does actually increase the heuristic value of these models.

Therefore, I would argue for multi-dimensional criteria for theory choice and a stronger focus on the empirical merit of theories and models. Table 28 (page 313) specifies a list of possible criteria, organized by abstraction level and epistemic goals.

vii. Demarcating science from non-science and explaining the success of science

According to my model, scientific theorizing implies description and modeling but also interpretation, narration and the explication of ontological implications; in other words, it implies logical aggregation and organization of scientific knowledge as well as attempts to make sense of this knowledge, to relate it to views of the world. The sheer existence of such sense-making led Paul Feyerabend to the conclusion that science is in no privileged epistemic position towards ideology, religion or myth. According to him, science tells stories and constructs worldviews (ontologies) just like its competitors; it merely happens to enjoy more social prestige than them. (Feyerabend 1986[1975]: 385-97)

My distinction of denotative (logical) and connotative (literary) meaning within scientific theories clarifies the fallacy by which Feyerabend and his successors are taken in: While scientific theories do

685 The focus on narratives and ontologies might partly stem from on narrative traditions. Generally speaking, natural scientists regard their objects as unintentional – outside of biology and medicine even as inanimate – and explain events as results of natural laws. Social scientists construct their objects of study, humans, as intentional and conscious agents. In the humanities, many researchers, attempt to explain their objects of study – film, text, images, artifacts – as products of intentional actions.

686 I am not speaking of single case studies, here, but of systematic studies of the empirical record of a specific model or theory: how much does it describe, predict, produce.

687 The debate on Kuhn is another example in that Kuhn could have and should have been criticized for suggesting a crudely misrepresenting model, which lacked any substantial empirical support. However, most of the debate focused on the ontological implications of his work, i.e. what it implied about scientists and science.

688 Gigerenzer and his colleagues studied decision making processes and demonstrated that humans usually do not make conscious decisions but subconsciously follow “fast and frugal heuristics”.

contain literary (connotative, rhetorical) elements, they cannot be reduced to them. The (much) larger part of the scientific work consists in empirical descriptions as well as in static and dynamic modeling, both of which are non-metaphorical and non-narrative enterprises.[689]

Moreover, the descriptive and logical work clearly and unequivocally distinguishes science from other ontology-/world-view-producing systems like ideologies, religions or myths. Hence, it appears that it provides as a simple and clear criterion for distinguishing science from non-science: science requires empirical descriptions[690] and their logical aggregation while non-science does not.[691]

Finally, it provides a simple explanation for the (empirical) success of science, i.e. the ability to describe, predict and produce. [692] Precise descriptions and their aggregation in semi-formal languages (definitions, nomenclatures) allow, first, for efficient organization and communication of empirical knowledge and, second, an effective division of cognitive labor between independent research groups. (Kitcher 1990) Thus, they allow for modern science as we know it: a network of loosely connected research groups which discover empirical facts and regularities, describe them, model them and make sense of them through interpretation, narration and their respective ontological implications.

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689 I have a hard time attributing Feyerabend's fallacy to the perception asymmetry which I identified in Kuhn's argument on scientific revolutions. Feyerabend's complete ignorance of the denotative part of science is just absurd.

690 First, if one wishes to include the non-empirical disciplines, i.e. mathematics and logic, only logical aggregations (transformations) are required. Second, according to this definition not all disciplines at contemporary universities are sciences. This does not imply that these disciplines may not be worth academic activities.

691 Note that, within the empirical science, both conditions need to be fulfilled. Particularly, it is not sufficient for a model to be logically consistent in order to be considered scientific; it has to be empirically adequate as well. (This relates to the three criteria for the assessment of theories which I have identified in the reception analysis, i.e. plausibility, consistency and empirical adequacy. (see section 0) Non-scientific explanations/interpretations/models/theories can pass for science only if one does not check for all three of them.) The so-called "Intelligent Design" model is an example of a model which is logically consistent but does not comply with empirics; it merely pretends to do. (For a discussion, see Zacharias and Schulz forthcoming.)

692 In compliance with my understanding of scientific progress as empirical progress, I do not include theorizing in this success, although it is a relevant part of scientific practice. However, I do not know whether science is superior to other systems in its interpretation and explanation or with respect to the ontologies it conveys. Thus, I seek to explain "less" success than realists like (Engler 2008).

7 Figures, Tables, Index, Bibliography

7.1 Figures

7.2 Tables

7.3 Index

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7.4 Bibliography

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