Christian Gottfried Ehrenberg (1795–1876): the man and his legacy. An introduction

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"*Der Welten Klienes auch ist wunderbar und gross, Und aus dem Kleinen bauen sich die Welten*" (From the inscription on Ehrenberg's gravestone, Zölffel and Hausmann, 1990: 289; Corliss, 1996: 46).

"*Science progress rapidly, and soon many of them will be forgotten or have a mere historical interest; but Ehrenberg's name will always be connected with one of the most important scientific discoveries of the nineteenth century*" (Anonymous, 1876: 205).

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Abstract

Christian Gottfried Ehrenberg (1795–1876) is probably one of the most important of the early micropalaeontologists. During his early career Ehrenberg was a much respected scientist. Many of his contemporaries, like Charles Darwin, T.H. Huxley, Benjamin Silliman, J.D. Dana and J.W. Bailey, regarded him as the foremost expert in the identification of 'Infusoria'. The purpose of holding a meeting centred around the life and works of Ehrenberg was threefold. First, 1995 was the bicentenary of his birth and we were unaware of any major celebration of his life. Second, Ehrenberg has received scant attention in the history of science. Third, and perhaps most importantly, Ehrenberg left a large legacy to future science in the form of a massive collection of specimens.

INTRODUCTION

Christian Gottfried Ehrenberg (1795–1876) is probably one of the most important of the early micropalaeontologists, establishing the field of 'protozoology' (Jahn, 1995a; Corliss, 1996) by publishing the first review of all known 'Infusoria' (Ehrenberg, 1838: Figure 1). During his early career Ehrenberg was a much respected scientist corresponding with such notable scientists as Charles Darwin, T.H. Huxley, Benjamin Silliman, J.D. Dana and J.W. Bailey, all of whom regarded him as the foremost expert in the identification of 'Infusoria'.

The purpose of holding a meeting centred around the life and works of Ehrenberg was threefold. First, 1995 was the bicentenary of his birth and we were unaware of any major celebration of his life. Second, as far as we were aware, Ehrenberg has received scant attention in the history of science (two exceptions being Winsor, 1976 and Farley, 1982). Indeed, so little is known of Ehrenberg's life that only recently was the whereabouts of his grave discovered (Zölfell and Hausmann, 1990; for a photograph see p. 289) and the accuracy of some of his portraits questioned (see Corliss, 1989: 314, who included a portrait which turns out to be of Ehrenberg's brother, Carl August; Corliss and Jahn, *pers. comm.*). Lastly, and perhaps most importantly, Ehrenberg left a large legacy to future science in the form of a massive collection of specimens, many of which, with some collective effort, can once again be studied and applied to current scientific problems (Lazarus, This Volume).

Ehrenberg was considered by his contemporaries to be the authority on 'Infusoria'. Authority, in any guise, will always be a target for 'young turks' to challenge. At that time the 'young turks' included such notables as Charles Darwin and Thomas Henry Huxley. Neither Darwin nor Huxley seemed to have much respect for Ehrenberg's *ideas*. It appeared to be the normal state of affairs for Darwin to be concerned at Huxley's pointed and provocative comments regarding other scientists (for instance, see Darwin's letter to J.D. Hooker concerning Huxley's possible election to the Athenaeum in Burkhardt and Smith, 1990: 106). Darwin's concerns were perhaps well placed as Huxley was never a man to mince his words and shy away from a pointed critique (Desmond, 1992, 1997). Huxley made his views on Ehrenberg public in 1851 in a monograph on the radiolarian genus *Thalassiocollis*. Huxley described Ehrenberg's work as: " ... wonderful monuments of intense and unremitting labour, but at least as wonderful illustrations of what zoological and physiological reasoning should *not* be ..." (T.H. Huxley, 1851: 436). Ehrenberg was understandably upset.

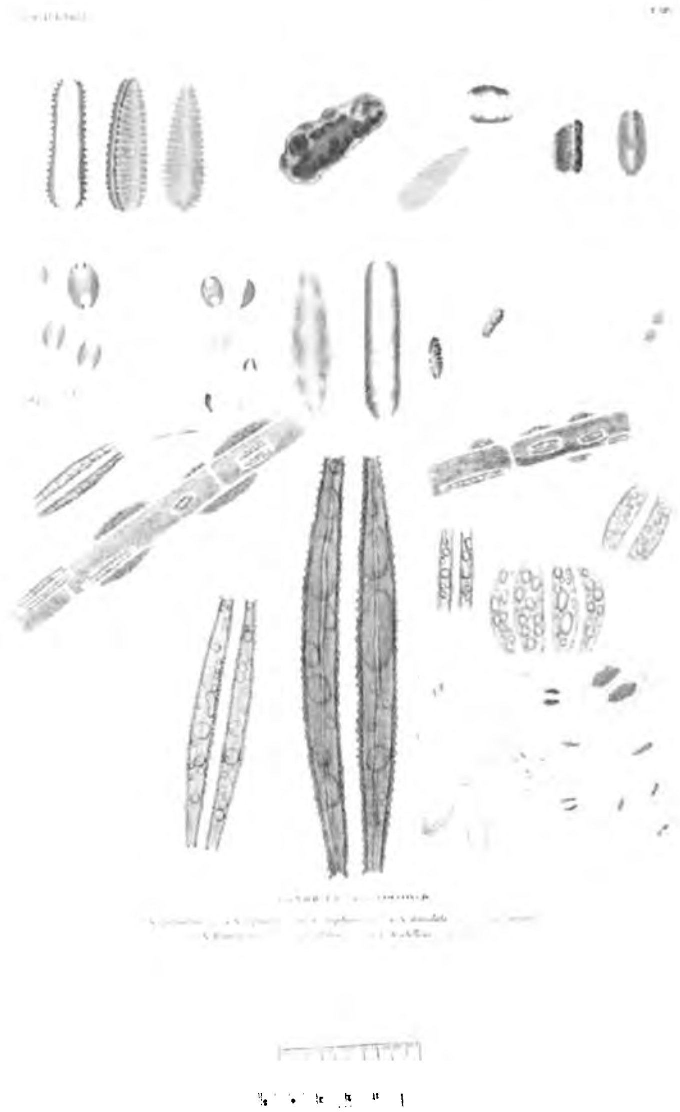

Figure 1. Reproduction of Taf. XIV from Ehrenberg's *Die Infusionthierchen als vollkommende Organismen* (1838). It is worth noting that Ehrenberg's illustrations included cell contents, as did perhaps those of all early diatomists. The decline of such detail may be worth considering (see Mann, This Volume).

Nevertheless, harsh criticism sometimes has a habit of rebounding and, in spite of perceived faults in Ehrenberg's 'zoological and physiological reasoning', he was an acute observer. Later, in 1868, Huxley announced the discovery of microscopic organisms from the North Atlantic bottom sediments he called *Bathybius haeckelii* (T.H. Huxley, 1868). *Bathybius* was "simultaneously a candidate for the lowest form of protozoological life, the elemental unit of cytology, the evolutionary precursor of all higher organisms, the first organic form in the fossil record, a major constituent of modern marine sediments, and a source of food for higher life forms in the otherwise nutrient-poor deep oceans" (Rehbock, 1975: 505). It turned out to be nothing but calcium sulphate crystals precipitated from sea-water by the use of alcohol to preserve specimens. Huxley was a little red-faced: "I have just had a long letter from Wyville Thomson. The *Challenger* inclines to think that *Bathybius* is a mineral precipitate! in which case some enemy will probably say that it is a product of my precipitation. So mind, I was the first to make that 'goak'. Old Ehrenberg suggested something of the kind to me, but I have not his letter here." (L. Huxley, 1913: 182; Desmond, 1997: 45). Ehrenberg's doubts concerning *Bathybius* appeared in print in 1872 (Ehrenberg 1872: 376). According to Rehbock (1975: 529), there is a letter from Ehrenberg to Huxley in Imperial College requesting a sample of *Bathybius* to examine (Rehbock 1975: 529; no date for Ehrenberg's letter is given and it is not included in L. Huxley, 1913).

Still, taking advantage of authority figures is nevertheless appealing (and probably still as popular). Darwin sent Ehrenberg material he collected during the *Beagle* voyage: dust blown from Africa which fell on the ship near the Cape Verde Islands, volcanic tuff from Ascension Island, chalk and mud from South America, and clay from Tierra del Fuego used by the natives for face paints.

To give one example, Darwin wrote to Henslow on the 25th July 1844: "My more immediate object, however, in writing now, is to ask you to send me, if you can find quite easily the specimens, some bits of Peat (with their country marked) for Ehrenberg. I am going to send another parcel to him. The specimens might be so small, that you could send them by post. – Did I give you a ball of white paint, with which the Fuegians colour themselves? If you can find it easily (*& it is* **quite unimportant** *if you cannot*) please send me a little bit for the same end." After examination, Ehrenberg declared that "[Y]our face paint from Tierra del Fuego was also very interesting to me. It also consists of infusoria, the first fossil deposit that has come from there. Thus far I have determined 18 species of which none is new but all are exclusively freshwater forms" (Burkhardt & Smith, 1987: 388, a translation of the original letter in German on p. 155; Ehrenberg's account was published in 1845: 63-4). Darwin used Ehrenberg's studies as part of the account of the Beagle voyage. Of the Fuegian face paint, Darwin wrote: "... this is a beautiful example of the results obtainable through Professor Ehrenberg's microscopic researches ... It is, moreover, a striking fact in the geographic distribution of infusoria, which are known to have very wide ranges, that all species in this substance, although brought from the extreme southern point of Tierra del Fuego, are old, known forms" (Darwin, 1870: 221, footnote).

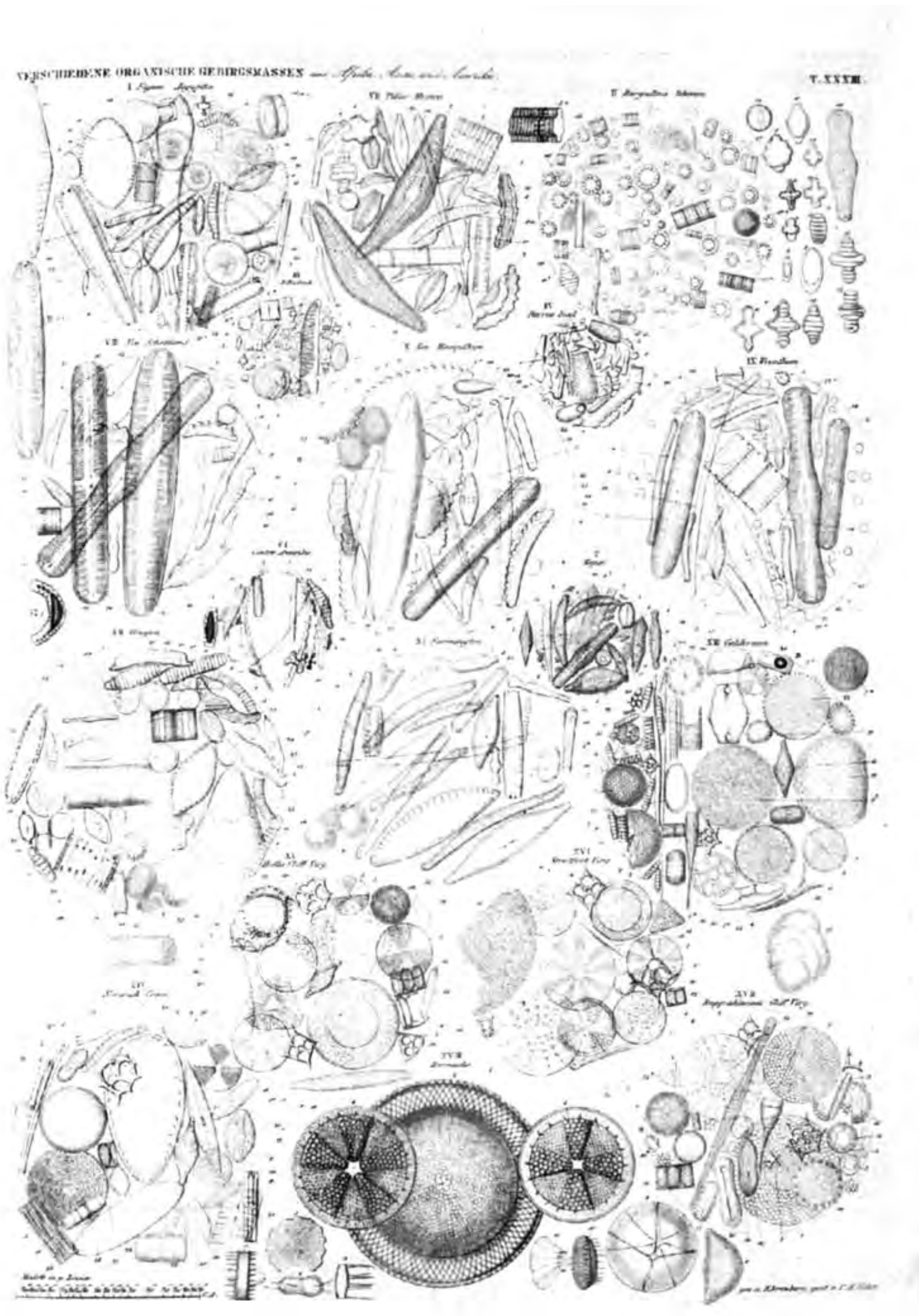

Figure 2. Reproduction of Taf. XXXIII from Ehrenberg's *Mikrogeologie. Das Erden und felsen schaffende Wirken des unsichtbar kleinen selbständigen lebens auf der Erde* (1854).
Details from this plate are given in Williams *et al.*, This Volume.

It is perhaps significant that Darwin and others considered the geographical distribution of organisms among the most compelling evidence for evolution (see, for instance, Wallace, 1876; Browne, 1983). Perhaps inadvertently, Darwin may have helped promote the notion that 'Infusoria' "have very wide ranges". Of course, the idea of what a 'very wide range' exactly is, is open to interpretation, especially when considering the various 'Infusoria' (Williams, 1994). What were Ehrenberg's thoughts on biogeography? At one level he considered it problematic to explain the distribution of fossil 'Infusoria' distributed around Pacific rim regions (Ehrenberg, 1849; 1850). In this respect, Ehrenberg's genus *Biblarium* Ehrenb. is of significance. The genus, now correctly called *Tetracyclus* Ralfs (Williams, 1987, 1989), is composed largely of extinct, freshwater species many of which have been and continue to be used as stratigraphic markers for several continents, under the assumption that they are relatively widespread and confined to precise geological epochs. This perception seems to be incorrect and the key to further understanding resides among Ehrenberg's preserved specimens. In total, Ehrenberg described 19 species of *Biblarium*, of which five he considered unique to a Siberian fossil deposit, six unique to an Oregon fossil deposit, and six shared between both the Siberian and Oregon deposits (Figure 2, Ehrenberg, 1843; 1845; details from this paper are given in Williams, Huxley & Ross, This Volume). Of the remaining two species, one occurs in Chile, *Biblarium chilense* Ehrenb.[1], and the other, *Biblarium emarginatum*, in Mexico and Siberia. *Biblarium emarginatum* is now known as *Tetracyclus emarginatus* (Ehrenb.) W. Smith and it is possible that the Mexican and Siberian specimens are from different species (Williams, 1997 and In Prep.; and discussed in Williams, *et al.*, This Volume). In which case, this would place them on either side of the Pacific (Williams, 1994, 1996).

In this regard, Ehrenberg's words are significant: "... the Rocky Mountains are a more powerful barrier between the two sides of America, than the Pacific Ocean between America and China; the infusorial forms of Oregon and California being wholly different from those of the east side of the mountains, while they are partly identical with Siberian species" (Ehrenberg, 1850: 140, paraphrased by the translator of Ehrenberg, 1849: 76-77).

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1 The identity of *Biblarium chilense* is unknown as Ehrenberg's specimens have not been examined and he did not provide any illustrations. According to Ehrenberg "B[iblarium] chilense ist eine dem B.compressum vermandte neue Art ... 649 Erde von Zellebaue einer Megachile der Cordilleren VII" (Ehrenberg, 1854: 301). His comparison with *B. compressum* implies synonymy with *Tetracyclus ellipticus* (Williams, 1996). A further possibility exists in that *B. chilense* is a synonym of *Tetracyclus ellipticus* var. *lancea* f. *chilensis* Krasske (1939: 357, pl. 10, figs 14-19; Lange-Bertalot *et al.* 1997: 185, 204, Tafel 1, figs 1-8). It seems that this taxon should perhaps be elevated to species level and thus another endemic *Tetracyclus* identified by Ehrenberg relevant to the Pacific divide (pers. obs.; see Lange-Bertalot *et al.*, 1997: Tafel 1, figs 1-8)

Without specimens or relevant literature such distributional patterns go unnoticed, as they have for at least 100 years with respect to *Tetracyclus*. It is also important to note that although in the case of *Tetracyclus* the relevant Ehrenberg specimens are types, for biogeographical endeavours access to all kinds of material, whether types or not, is required.

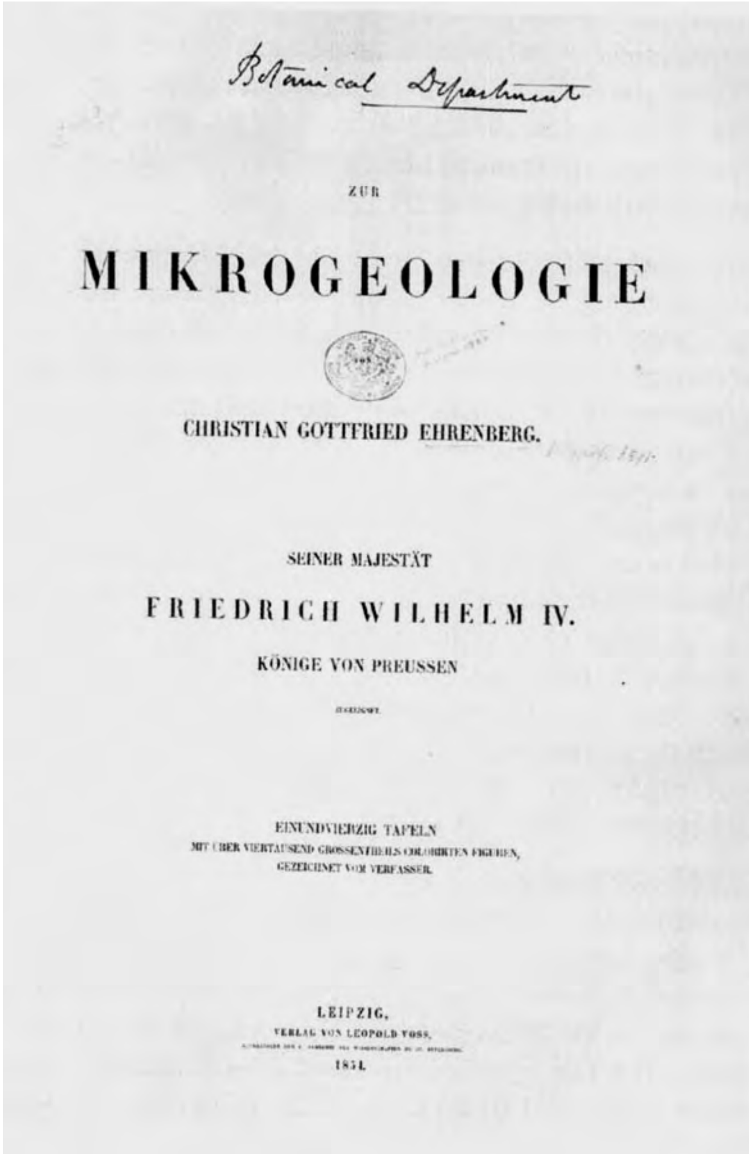
Ehrenberg's scientific respect declined largely due to his mistaken conclusions concerning the 'animal' nature of the infusoria encapsulated in his 'Polygastria' theory (Churchill, 1989). His theory allowed the possibility of refuting the transmutation theories of the *Naturphilosophen* (as well as the later Darwinian theories): if all 'animals' were essentially the same then there is no gradation from simple to complex[2]. Maybe, like Huxley, Ehrenberg's motivations were not solely based on scientific issues. Whatever complexities lie behind understanding scientists' motivations in general, the point of these examples is not to cast retrospective judgement on either Ehrenberg or Huxley[3] but to suggest that both seemed more comfortable with what was observable, recognising the value of examining specimens over 'idle' speculation. In Huxley's words, "I think there is no greater mistake than to suppose that distribution ... can be studied to good purpose by those who lack either the opportunity or the inclination to go through what they are pleased to term the drudgery of exhaustive anatomical, embryological, and physiological preparation" (Huxley, 1888: 116).

The Darwin correspondence clearly records Ehrenberg badgering Darwin for further specimens as well as Darwin's eagerness to get them identified. Ehrenberg wanted material from any and every locality "–and, indeed, material from any person who would send it. His researches culminated in a second massive compilation, the *Mikrogeologie* (Ehrenberg, 1854: Figure 3), following some 16 years after *Die Infusionsthierchen als vollkommene Organismen* in which Ehrenberg described all the known bacteria, protozoa, diatoms, desmids and rotifers (Ehrenberg, 1838).

As well as his two major monographs, Ehrenberg published an enormous amount of primary literature, the bulk of which was published in the *Abhandlungen*, *Berichte* and *Monatsberichte* of the Royal Prussian Academy of Science and either re-published as translations and summaries in various other natural history publications or as separate 'pre-prints'. These reports are

2 For an interesting example of what perhaps Ehrenberg was opposing, see Barry (1836; 1837).

3 ... many years ago I thought that it was a pity that he [Huxley] attacked so many scientific men, although I believe that he was right in each particular case, and I said so to him. He denied the charge indignantly, and I answered that I was very glad to hear that I was mistaken. We had been talking about his well-deserved attacks on Owen, so I said after a time, 'How well you exposed Ehrenberg's blunders;' he agreed and added that it was necessary for science that such mistakes should be exposed" (Darwin in Barlow, 1958: 106-7).


Botanical Department

ZUR

MIKROGEOLOGIE

CHRISTIAN GOTTFRIED EHRENBERG.

SEINER MAJESTÄT

FRIEDRICH WILHELM IV.

KÖNIGE VON PREUSSEN

EINUNDVIERZIG TAFELN
MIT ÜBER VIERTAUSEND GROSSENTHEILS COLORIRTEN FIGUREN,
GEZEICHNET VOM VERFASSER.

LEIPZIG,
VERLAG VON LEOPOLD VOSS.
1854.

Figure 3. Reproduction of title page from Ehrenberg's *Mikrogeologie. Das Erden und felsen schaffende Wirken des unsichtbarkleinen selbständigen lebens auf der Erde* (1854).

not now widely available and their dating for nomenclatural purposes somewhat problematic. This issue is further discussed by Williams *et al.* (This Volume).

The legacy of written descriptive work is probably of limited use without specimens available for further study by future generations of scientists, so that those who do have "the inclination to go through what they are pleased to term the drudgery of exhaustive anatomical, embryological, and physiological preparation" also have the opportunity. Most of Ehrenberg's material is held in one place at the Institut für Paläontologie, Museum für Naturkunde, in Berlin. The collection now has a curator and plans can be made to make the collections and accompanying manuscript material more easily accessible (Lazarus, This Volume; Jahn, 1995b gives a description of the task with reference to one study).

To get some idea of the scope of Ehrenberg's endeavours, the recently published *Names in Current Use* (Greuter *et al.*, 1993) contains 46 of Ehrenberg's diatom genera (Jahn, 1995a). This figure, while accounting for 11% of all described diatom genera, was obtained from a draft listing which included at least *c.* 100 names, this figure probably being a conservative estimate. Clearly, any detailed study on Ehrenberg's generic names is likely to have a profound effect on diatom nomenclature; one may only speculate at the impact of species level studies (Reichardt, 1995)[4].

In general, there is, quite rightly, growing concern over the instability caused by the changing of taxonomic names, especially when the changes are effected solely for reasons of publication priority. The expenditure of time and effort on the quest for establishing priority of publication has recently been questioned, as perhaps exemplified by some of the papers in Hawksworth (1991). It is worth noting that scientific names, when applied to a species or other higher taxa, may change for one of four reasons: "homonymy, synonymy, mis-identification, or because a taxon is false and has been divided or re-organised" (Humphries, 1991: 320; Ackery & Vane-Wright, 1984). The first three are failures of nomenclature, while the last can be understood as the result of progress in systematics. Nevertheless, to effect the change properly one must examine specimens and come to some conclusions. This is not the place to discuss how one achieves progress in systematics but whatever one's persuasions the key to advance is having specimens available for study. To push perhaps a somewhat contrived analogy, a collection of specimens is similar to a library. Common understanding, at least with reference to scientific literature, is that the 'shelf-life' of most contributions is extremely short. But which contributions have 'real' lasting value? And which contributions are neglected first time around, as of no significance?[5] Suppose it was suggested that scientific literature was destroyed after 10 years (after all it only takes up space) – what would be the general reaction of the scientific community? We suspect no such thing could or would ever be seriously considered! Some publications gain new life once viewed in a different context (e.g. Lauterborn's 1896 publication; see Pickett-Heaps, *et al.*, 1984); much the same could be

4 As phycologists our comments are limited to Ehrenberg's diatom studies. We suspect the situation is similar with respect to other groups Ehrenberg studied (e.g. Lazarus, This Volume).

5 The case of Gregor Mendel's studies and publications spring to mind (e.g. Gasking, 1959).

said of 'old' specimens that gain new significance after fresh study (e.g. Sims, 1994). These and related issues deserve further discussion, especially with respect to micro-organisms, which comprise the bulk of the species names proposed by Ehrenberg (Mann, This Volume). In a further contribution, Hawksworth wrote that "[p]rotection from uncatalogued and unknown names is the main object of the current approach" (Hawksworth, 1992: 559). There appears no conflict with this aim, as a good many of Ehrenberg's names are known and used, if not yet fully understood. In addition, Hawksworth (1992: 553) encouraged "... students to delve into *relevant* material, directing them to promising sources of pertinent biological and systematic data". Given the wide geographic range that Ehrenberg's specimens came from, this also seems not to conflict with modern aims, if indeed biogeography and systematics are seen as useful modern areas of investigation (Humphries & Parenti, 1998).

With renewed emphasis being made on the value of biological collections to modern research, especially those housed in various museums (Wheeler, 1995; Blackmore and Cutler, 1996; Mehrhoff, 1997), it comes as no surprise that those scientists who preceded us perceived a similar need for the preservation of biological material. Rather than finish this introduction with yet another 20th century jargon-filled plea, we consider of significance the words of Alfred Russel Wallace, written on this subject some 130 years ago while Ehrenberg was still working: "... It is, therefore, an important object, which governments and scientific institutions should immediately take steps to secure, that in all countries the most perfect collections possible in every branch of natural history should be made and deposited in national museums, where they may be available for study and interpretation. If this is not done, future ages will certainly look back upon us, as a people so immersed in the pursuit of wealth as to be blind to higher considerations. They will charge us with having culpably allowed the destruction of those records which we had within our power to preserve; of having allowed many to perish irrecoverably from the face of the earth, uncared for and unknown" (Nelson, 1995: 31, modified from Wallace, 1863)[6].

6 The full quotation from Wallace (1863: 234) is as follows: "...It is, therefore, an important object, which governments and scientific institutions should immediately take steps to secure, that in all tropical countries colonised by Europeans the most perfect collections possible in every branch of natural history should be made and deposited in national museums, where they may be available for study and interpretation. If this is not done, future ages will certainly look back upon us, as a people so immersed in the pursuit of wealth as to be blind to higher considerations. They will charge us with having culpably allowed the destruction of some of those records of Creation which we had it within our power to preserve; and while professing to regard every living thing as the direct handiwork and best evidence of a Creator, yet, with a strange inconsistency, seeing many of them perish irrecoverably from the face of the earth, uncared for and unknown".

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C.G. Ehrenberg: the man and his contribution to botanical science

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Abstract

When D. Christianus Gothofredus Ehrenberg became a Foreign Member of the Linnean Society in 1833, he was chiefly known to the scientific community for his exploration and collection of the natural history of North Africa and the Near East. With field observations of living organisms and meticulous drawings of unknown species, he investigated many aspects of the flora and fauna, from monkeys and birds to corals and infusorians. His belief in the separate, independent identity of lower organisms had already resulted in the description of many new species of fungi in his dissertation (1818). From 1830 onwards he concentrated his research on the infusorians, compiling all available information and extending the knowledge of microscopical organisms which resulted in many publications and his two important books: *Die Infusionsthierchen* (1838) and *Mikrogeologie* (1854). Intensive use of the microscope, great detail in drawing and repeated observation were traits of his research. His description of hundreds of new taxa, interpretation of morphological observations, thoughts on ecology, geography and geology, as well as his belief in perfect microscopical organisms, have left a deep mark on microbiology, micropalaeontology, protozoology and above all on phycology.

INTRODUCTION

C. G. Ehrenberg's scientific work spans six decades, almost 400 publications and much of the field of natural history. A number of papers have been written about his work, covering many aspects of natural science, e.g. protozoology (Corliss, 1989, 1996; Hausmann, 1996), micropalaeontology (Siesser, 1981) and microscopy (Wetzel, 1966), and on his life (Laue, 1895; Hanstein, 1877; Bolling, 1976). This paper will focus on his studies of botany, i.e. fungi, higher plants and algae. Since the different facets of his science are inextricably linked to specific events, his life will also be dealt with briefly.

SCHOOLING AND FUNGI (1795–1820)

Christian Gottfried Ehrenberg was born on Easter Sunday, 19 April 1795, in Delitzsch near Leipzig. It is said that even as a boy he was interested in living things. From 1809 to 1814 in the respected boarding school Schulpforte, he not only learnt Greek and Latin, but was very much interested in biology, which was not a school subject at that time. His interest in Linnaeus' nomenclatural system, prompted by his discovery of an orchid close by, the dissecting of animals and his meticulous drawings encouraged his teachers to allow him to take care of the school garden and to search the school grounds (Koehler, 1943).

After passing his Abitur (final school examination) his father made him study theology, to which he consented, in the hope that this would allow him to explore foreign countries as a missionary. He enrolled at the University of Leipzig but, when his father heard him preach one Sunday, he acknowledged that theology might not be his true vocation and allowed him to study medicine. The war with Napoleon and the subsequent Vienna Congress changed the map of Central Europe considerably, and with it the regional affiliation of Delitzsch to Prussia. That meant that, in 1817, Ehrenberg moved to Berlin, the capital of Prussia in order to combine study and possible military duty (Laue, 1895).

At Berlin University he studied medicine and simultaneously undertook research on fungi with Heinrich Link (1767–1851), who was Professor of Botany and Director of the Berlin Botanic Garden from 1815 to 1851 (Zepernick & Timler, 1979). By1818, he had handed in his dissertation entitled *Sylvae mycologicae Berolinensis*, a study of fungi collected in the nearby royal hunting grounds called the Tiergarten, now a district in the centre of Berlin (Ehrenberg, 1818). Through keen microscopical observation, he saw hyphae developing from spores, and recorded 248 species, 62 of which he described as new. He proved that fungi have an identity of their own and do not rise from dirt or mud, which was the common belief for lower animals and plants at that time (Hanstein, 1877).

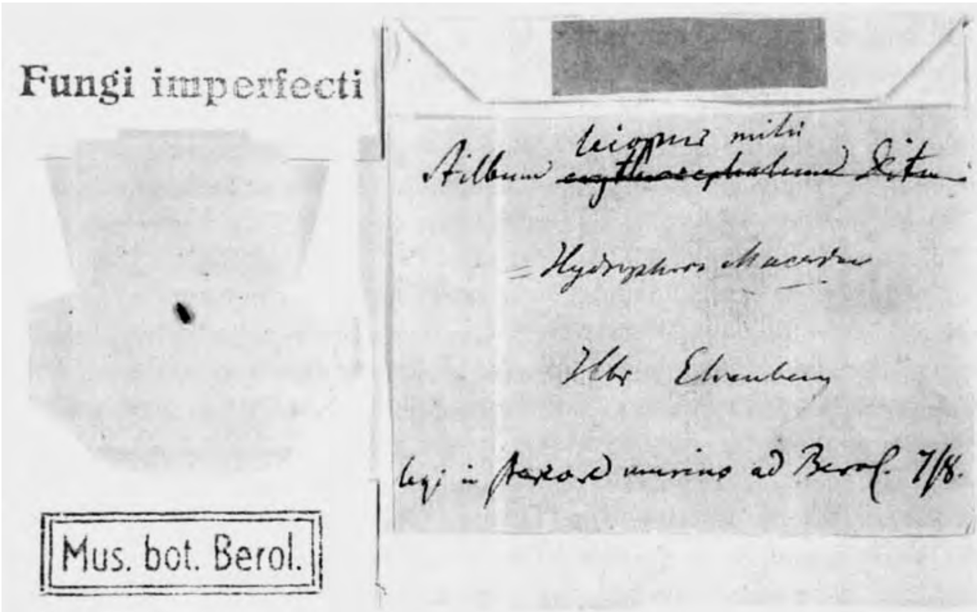

Figure 1. Herbarium sheet of a fungal type, named and collected by Christian Gottfried Ehrenberg in Berlin in July 1818.

Ehrenberg also became friends with the German poet Adalbert von Chamisso (1781–1838), who served as assistant and curator at the Berlin Botanic Garden from 1819 to 1838 (Zepernick & Timler, 1979). Ehrenberg undertook research into the fungi collected during Chamisso's circumnavigation of the world on the *Rurik*, from 1815 to 1818 (see bibliography in Laue, 1895: 264). As a result of his eight early publications on lichens and fungi, in which he also described conjugation (Geus, 1987). Names in Current Use, (Greuter *et al.*, 1993) lists nine fungal genera established by Ehrenberg between 1818 and 1821 (see Appendix). His fungal herbarium, comprising 40 fascicles including types, was donated to the Berlin Botanical Museum (B) by his family after his death in 1876 (Urban, 1916). One of his herbarium sheets is illustrated in Figure 1. The Fungi imperfecti collections are extant in Berlin (B).

EXPLORATIONS AND HIGHER PLANTS (1820–1830)

His scientific approach caused Alexander von Humboldt (1826) to recommend him to the Prussian Academy of Sciences for a scientific expedition. From 1820 to 1825, he and his friend Wilhelm Hemprich travelled along the Nile and collected in the Libyan Desert, Mount Sinai, the cedar woods of Lebanon, and the Red Sea up to Abyssinia. They sent home 114 boxes filled with 46,000 plant and 34,000 animal specimens, plus seeds, rocks, fossils and mummies (Stresemann, 1954). Once more, Ehrenberg was dissecting, drawing and undertaking microscopical research, mostly on plants, invertebrates and infusorians. For example, in the Red Sea he observed and described the morphology of corals; at Mount Sinai he proposed an explanation of biblical mannah as a product of the insect *Coccus maniparus* sucking *Tamarix mannifera* (Hanstein, 1877; Baker, 1997). In the Libyan Desert he examined 300 drops of dew and found no spontaneous infusorian life (Ehrenberg, 1838).

This expedition was undertaken at an extremely difficult political time in the region, and the explorers often found themselves caught between warring tribes (Hanstein, 1930). In addition, the health situation was disastrous. By the time it ended three-quarters of the expedition members had died, including Hemprich. When he returned after six years, the Prussian State was so pleased with Ehrenberg's enormous collections and drawings that he was made professor at Berlin University and given an institute to assist him in completing 800 copperplates for his *Symbolae Physicae*. However, because of his extremely exact textual research, he was only able to finish 80, which included animals and some infusorians. In all his works he tried to include as wide a range of source material as possible, starting with Aristotle. He even included Arabic sources, which language and script he had learnt during the expedition. Clearly, he also missed the scientific companionship of Hemprich with whom he had shared the collecting, and whose name and studies appear first in the *Symbolae Physicae*. In addition, Ehrenberg was upset that the director of the Zoological Museum, Lichtenstein, had sold duplicates from his collection, even before he had returned to Berlin, in order to finance the expedition. For Ehrenberg these had not been duplicates but ecological modifications and morphological series which he had wanted to investigate (Laue, 1895).

So, rather than reaping the fruits of his exploration himself, by describing and publishing about 500 new plant taxa, he became known as a great collector of North African flora, e.g. by Schweinfurth (1867) and by Lorentz (1869). Some of his original botanical copperplates were published decades later by Schumann (1900) and many of the plants he collected were named in honour of him. The *Index Kewensis* (Hooker & Jackson, 1895–1991) lists about 250 taxa in honour of Ehrenberg, with 350 taxa having Ehrenberg as author although only 125 were published by Ehrenberg himself. Of these 125 taxa, 73 were from the New World and belong to the Cactaceae, including the genus *Pelecyphora* (NCU 3, Greuter *et al.*, 1993). However, these were described by his younger brother Carl August, who worked in Mexico for a British company for some years. As a hobby, Carl August collected plants and seeds and sent them to his brother, Christian Gottfried and the Botanical Garden Berlin (see Figure 3) (Urban, 1897; Hunt, 1985). The NCU and *Index Kewensis* do not always differentiate between Ehrenb. (Christian Gottfried) and C. Ehrenb. (Carl

August). Nevertheless, the NCU (Greuter *et al.*, 1993) lists three genera of higher plants described by Christian Gottfried, published between 1827 and 1832 (see Appendix). Stafleu & Cowan (1976) cite *Ehrenbergia* by C.F.P. Martius (1827) and *Ehrenbergia* by K.P.J. Sprengel (1820 under eponymy), which have been synonymized. His six publications on higher plants resulted from this expedition; including detailed drawings of pollen tubes (Ehrenberg, 1831) which are noteworthy for the period.

In 1829 Ehrenberg went on another excursion for 9 months, this time as a guest of the Russian Czar. He travelled to Siberia with Alexander von Humboldt, again drawing and collecting plants and infusorians. Mosses collected on this expedition also survive at B (Schultze-Motel, 1963, see Figure 2).

Although Ehrenberg stopped publishing on botany, he retained a close interest in the subject, teaching his five children how to press plants and to prepare a herbarium, raising cacti in his garden from seeds that his brother Carl August sent from Mexico (Clara Ehrenberg, 1905). One of his four daughters married Johann Hanstein, who was curator at the Berlin Botanic Garden (1861–1865), and Professor of Botany at the University of Bonn from 1865 (Zepernick & Timler, 1979). In contrast to his zoological collections, Ehrenberg did not hand over his plants to the Royal Herbarium in Berlin (B) until late in his life, apparently in order to do research later on (Hanstein, 1877; Urban, 1916). Unfortunately, most of his herbarium was destroyed during World War II,

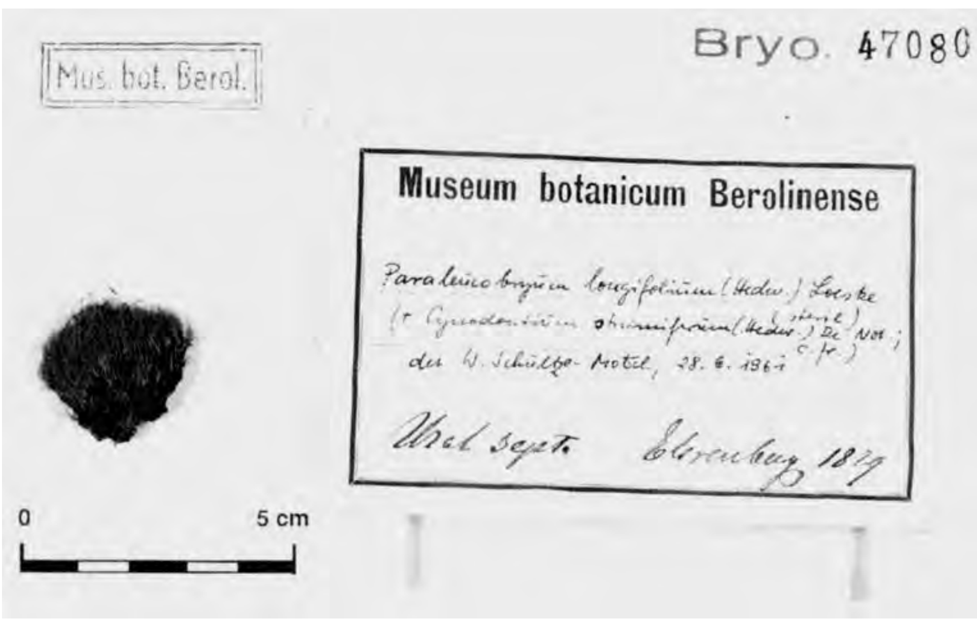

Figure 2. Herbarium sheet of a bryophyte collected by Christian Gottfried Ehrenberg on his expedition to Siberia in 1829.

except for the pteridophytes, the Fungi imperfecti and the bryophytes of the Siberia expedition, which were rediscovered in the 1960s.

INFUSIONSTHIERCHEN AND ALGAE (1830–1838)

Abandoning the *Symbolae Physiceae* from 1830, the emphasis of Ehrenberg's research shifted to microscopical work on the infusorians. He had already demonstrated that fungi (lower plants) should be considered as proper organisms, and now wanted to investigate the origins of lower animals. By repeated observations of dew drops he had proven that they did not appear spontaneously and concluded that all organisms, even the smallest, not necessarily the simplest, originated from an egg (Ehrenberg, 1838). He stood against the idea of *generatio aequivoca,* i.e. of ambiguous origin, a popular idea of Schelling's and Oken's Naturphilosophie in Germany at that time, in which the smallest unit of life was called infusoria, and growth meant the addition of further infusoria (Jahn, 1990).

In his book *Infusionsthierchen als vollkommene Organismen (as perfect organisms)* (Ehrenberg, 1838) Ehrenberg contradicted the contemporary theory of step-wise simplification of organisms towards the smallest space, known today as the Stufenleiter System or Scalae Naturae (Jahn, 1990; Mayr, 1982). He split off the Infusoria from Linnaeus' 6th class, the *Vermes,* and showed on 64 plates that there are many recognizable, consistent organisms behind Linnaeus' term *Chaos infusorium*. Ehrenberg divided the infusoria into 2 classes, *Rotatoria* and *Polygastrica* (animals with stomachs). The *Polygastrica* comprise the 10 families of the *Enterodela* (with intestine), most of which are now grouped with the protozoans, and the 12 families of the *Anentera* (no intestine), which include the unicellular and/or motile algae plus bacteria (for more details see R. Jahn, 1995).

The folio-book, with its 64 coloured plates, was enthusiastically received by the entire scientific community. Both to us today as well as to his colleagues at that time his beautiful and detailed drawings were awesome, although his interpretation was considered rather strange. He was utterly convinced that with better microscopes the completeness of the smallest infusorians would be seen. The variable colouring of his species did not bother him since he considered that the chloroplasts were ovaries, and the organisms animals. He was so eager to prove that even small organisms are complete that he endowed them with the organs found in complex animals, such as nervous, digestive and sexual systems. Ehrenberg was the first to recognize the community-structure of *Volvox*, even though at that time he either did not see the flagella, or called them 'Rüsselchen' (little trunk). His book provoked much research into microscopic organisms and, over the next forty years, many opposing and

Figure 3. Herbarium sheet of *Cyperus ehrenbergii* collected by Carl August Ehrenberg (C. Ehrenb.) in St. Thomas.

different concepts (Kristiansen, 1995) were put forth until Bütschli established the cellular nature of these organisms (Churchill, 1989), termed infusorians, protozoans, protoctista or protists (for definitions and meanings of these terms, see Rothschild, 1989).

Nevertheless, two-thirds of Ehrenberg's 553 polygastrica species (Ehrenberg, 1838) are photosynthetic organisms and therefore now considered as algae. Seventy-one algal genera described by Ehrenberg are listed in the NCU (Greuter *et al.*, 1993), among them some of the earliest names and therefore the most common species (see Appendix). By 1838, 28 genera had been described: 22 are motile algae but only six are diatoms. In this book Ehrenberg summarized his earlier findings, in addition to citing his and other researchers' previous literature; he included the habitat and collection locality of each organism. Ehrenberg was a model nomenclaturalist, since he wrote his diagnosis in Latin and presented illustrations, two regulations which have been obligatory for the description of new algal taxa only since 1 January 1958 (ICBN § 39, § 36.2.; Greuter *et al.*, 1994). However, the sheer volume of his reports, papers and descriptions of new taxa often make it difficult to date the names of types, even though Ehrenberg's daughter Clara had prepared a taxonomic reference book (see Lazarus, This Volume).

From an early date Ehrenberg preserved his infusorians to prove to anyone that what he had seen and drawn was correct. These early preparations of infusorians (see drawing in Ehrenberg, 1838:XVIII) were recently rediscovered (cases 52 and 53). The other 51 cases relate to the *Mikrogeologie* (see Lazarus, This Volume). Since Ehrenberg did not distribute exsiccatae like his contemporary phycologist Friedrich Kützing, the Ehrenberg Collection at the Museum für Naturkunde in Berlin is the only place where the types for his names can be consulted. Unfortunately, very few scientists have checked this original material, and many contemporary or later colleagues re-interpreted or misinterpreted Ehrenberg's taxa (for examples, see Jahn & Lange-Bertalot, 1995; McLachlan *et al.*, 1997). Many genera have not been typified (Greuter *et al.*, 1993), and even more names of taxa are uncertain (Jahn & Geissler, 1993). In addition to his mounted material, Ehrenberg's unpublished drawing sheets (see Figure 4) are immensely valuable. Because they were drawn from original material, they can be considered holotypes if the organism itself is not extant (ICBN § 9.7, §8.3. footnote, Greuter *et al.*, 1994). They are of higher rank than the published illustrations.

Even though Ehrenberg played such an important role in the discovery of motile algae only one algal genus has been named after him, *Ehrenbergiella*, by Skvortsov and Noda. This belongs to the Euglenophyceae (Greuter *et al.*, 1993).

MIKROGEOLOGIE AND DIATOMS (1839–1854)

Ehrenberg continued to travel, although he no longer took part in major expeditions (see Laue, 1895). At the time of publication of *Infusionsthierchen* in 1838, he went via Paris to a meeting in Newcastle, received the Wollaston Medal of the Geological Society and gave an improvised lecture in French. He also travelled to Edinburgh, Glasgow, Dublin, Liverpool, and London, where he took samples, visited the museums of natural history and was invited for dinner, including the typical microscopical demonstration afterwards. In 1847, he went to Oxford to meet Charles Darwin with whom he had corresponded (see Lazarus, This Volume) and from whom he had received many samples, and to Cambridge where he received an honorary Master's degree from Prince Albert (Laue, 1895).

Not only Darwin but many colleagues sent him soil, dust, volcanic ash, marine and freshwater samples from all over the world. He investigated virtually every possible habitat in air, water and soil, and showed in how many places the small but prolific infusorians can grow, and how many deposits they formed (Ehrenberg, 1838). He was eager to demonstrate the constancy of species, not only in every area but also across the ages. He began to concentrate on the practical part of the infusorians, as he called it, namely the soil and rock forming groups, which study culminated in his folio-book *Mikrogeologie* (Ehrenberg, 1854), which was extended later on. Diatoms, which Ehrenberg at first found

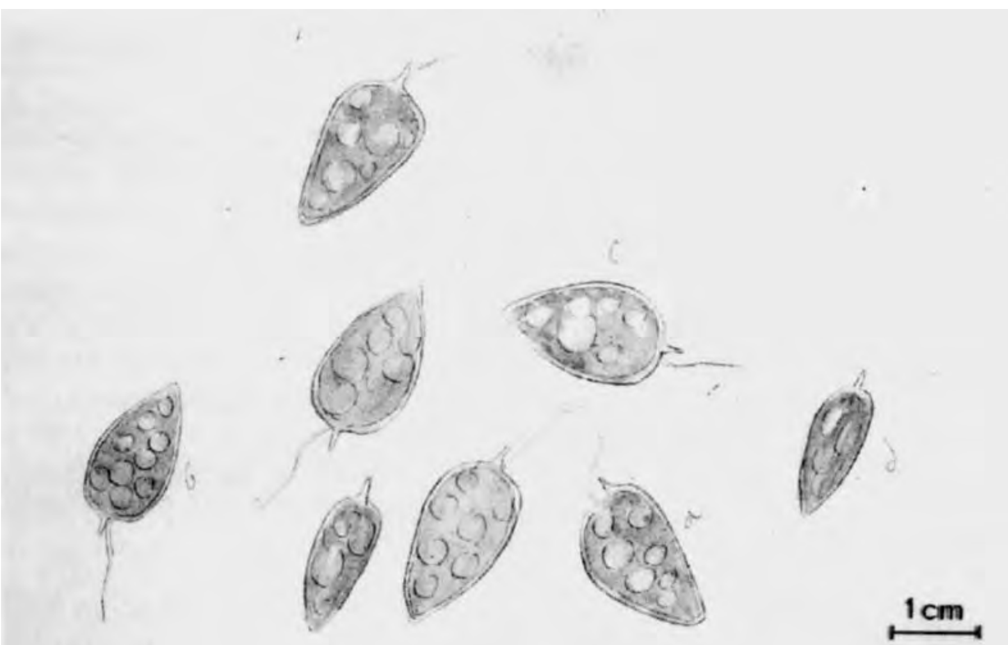

Figure 4. Ehrenberg's drawing sheet Nr. 1026. Holotype of *Prorocentrum micans* Ehrenb.

difficult to classify had, by the end of his life, become the most important group (R. Jahn, 1995; for Ehrenberg's radiolarians see Lazarus, This Volume). This can be seen again by consulting the NCU (Greuter *et al.*, 1993). Between 1838 and 1854 Ehrenberg named 36 diatom and four unicellular algal genera (see Appendix).

Nevertheless, his focus on micropalaeontology (= Mikrogeologie) at this time did not restrict him and he described many non-fossil, freshwater diatoms, as can be seen from approximately 450 taxa in the recent Central European freshwater diatom flora by Krammer & Lange-Bertalot (1986–1991). In addition, work on living organisms remained a hallmark of his research all his life (Hanstein, 1877). He continued to take samples in and around Berlin, and inoculated the contents of the fire buckets in front of his house so that he would have live material available at any time (Clara Ehrenberg, 1905). On his many excursions to the Baltic to visit his first wife's family in Wismar, or his trip to Italy in 1855 when he collected specimens from the Mediterranean, he always took his microscope and drawing sheets, collecting in the daytime and writing up his researches at night (Ehrenberg, 1860).

"RETIREMENT" (1855–1876)

After 1854 Ehrenberg named only one more diatom genus and two other algal genera (see Appendix). Nevertheless, he continued to work on infusoria, and by the end of his life, over 60% of his publications were on infusoria, 1% on fungi, 1% on higher plants and 1% on medical issues (for detailed information on medical issues see Kirsche, 1977).

Ehrenberg's work had opened up the microscopical realm. He became very popular among the general public because he could explain mysterious phenomena such as bloody bread, red snow and marine phosphorescence, all of which could be explained by the presence of micro-organisms. He was even better known among the scientific community, receiving many medals, including the first Leeuwenhoek medal in 1875. By the end of his life he had accumulated honorary membership of seventy scientific academies. He was also well respected in Berlin society. From 1842 to 1867 he was secretary of the Mathematical Class of the Prussian Academy of Science and in 1855/56 he became Rector of the University. He was a member of the Naturforschende Freunde Berlin for many years, and lived there from 1856 until the end of his life (Clara Ehrenberg, 1905).

His microscopical collection was very important to him. As early as 1835 he had started preserving samples and slides in order to be able to demonstrate, decades later, what he had seen. He also welcomed the development of photography as a more objective method than drawing (Ehrenberg, 1862). This is revolutionary considering that, almost 100 years later, the famous diatomist Friedrich Hustedt did not believe in photography, but in drawings. When in 1864 Ehrenberg's eyesight was deteriorating badly, he began to organize his immense microscopical collection with the help of his youngest daughter Clara, who never married but was his assistant for 12 years. Her handwriting, fortunately predominantly Latin script and not old German, is much more legible than Ehrenberg's, and can be found throughout the collection. Six weeks before his death on 26 June 1876, Ehrenberg handed over his collection to Berlin University where it survived two world wars, the division of Berlin and its subsequent unification (see Lazarus, This Volume).

CONCLUSION

Ehrenberg was an all-round natural scientist, who in the course of his long life established the nomenclatural and taxonomical basis for many microscopic organisms within the two traditional kingdoms of plants and animals. He started his academic life as a botanist working on fungi and higher plants. He then switched to microscopic organisms, his term 'Infusionsthierchen' including not only protozoa, but also bacteria and motile and/or unicelled algae. As a result of his botanical taxonomic work the NCU (Greuter *et al,.* 1993) lists 83 plant-genera as described by C.G. Ehrenberg. Nine of these are classified as Fungi, three as Higher Plants, and 71 as Algae. Thus the bulk of his botany is phycology, the types for which are found, not in the Botanical Museum Berlin, but in the Museum für Naturkunde Berlin. His name appears as author of hundreds of taxa, particularly of diatoms, a term he never used because he considered them animals and preferred the name Bacillaria. Although he is considered to be a great protozoan researcher (Corliss, 1994), he did not like Goldfuss's term, Protozoa, because he opposed its implication of degradation from perfect higher organisms (Ehrenberg, 1838). Ehrenberg wanted to prove (1838): "1. their completeness in all main systems and 2. the great direct influence of the microscopical organisms on inorganic nature". Today's research has provided deeper insight into Ehrenberg's perfect/complete organisms, but the debate over the names and numbers of Kingdoms for organisms other than traditional animals and plants continues (Corliss, 1989, 1994; Margulis *et al.,* 1989; Christensen, 1990). Although, during his long life, Ehrenberg was involved in many of the discussions raised by this issue (Churchill, 1989), he made clear (1854) that: "all names and drawings are not my private ideas but scientifically proven and evidenced facts of nature which can be ordered differently but not doubted".

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APPENDIX

Plant-Genera by C.G. Ehrenberg and their dates of publication*

ALGAE

BACILLARIOPHYCEAE
Actinocyclus (1837)
Actinoptychus (1843)
Amphitetras (1840)
Anaulus (1844)
Asterolampra (1844)
Asteromphalus (1844)
Aulacodiscus (1844)
Auliscus (1843)
Cerataulus (1843)
Ceratoneis (1839)
Chaetoceros (1844)
Climacosphenia (1841)
Cocconeis (1837)
Coscinodiscus (1838)
Craspedodiscus (1844)
Desmogonium (1849)
Dictyolampra (1847)
Endictya (1845)
Entomoneis (1845)
Entopyla (1848)
Eucampia (1839)
Eunotia (1837)
Gomphonema (1831)
Grammatophora (1840)
Hyalodiscus (1845)
Lithodesmium (1839)
Mastogonia (1844)
Pinnularia (1843)
Podosira (1840)
Rhabdosira (1869)
Rhaphoneis (1844)
Rhizonotia (1843)
Sceptroneis (1844)
Sphenosira (1841)
Stauroneis (1843)
Staurosira (1843)
Stephanodiscus (1845)
Stephanogonia (1844)
Stephanopyxis (1845)
Synedra (1830)
Terpsinoe (1843)
Triceratium (1839)
Xanthiopyxis (1844)

BODONOPHYCEAE
Bodo (1831)

CHLOROPHYCEAE
Arthrorhabdium (1869)
Chlamydomonas (1834)
Chlorogonium (1837)
Eudorina (1832)
Polytoma (1831)
Spondylomorum (1844)

CHRYSOPHYCEAE
Dinobryon (1834)
Epipyxis (1838)
Syncrypta (1834)
Synura (1834)
Uroglena (1834)

CRYPTOPHYCEAE
Chilomonas (1831)
Cryptomonas (1831)

DICTYOCHOPHYCEAE
Mesocena (1843)

DINOPHYCEAE
Blepharocysta (1873)
Dinophysis (1839)
Glenodinium (1836)
Peridinium (1830)
Prorocentrum (1834)

EUGLENOPHYCEAE
Chaetoglena (1835)
Chaetotyphla (1834)
Colacium (1834)
Cryptoglena (1832)
Distigma (1831)
Euglena (1830)
Trachelomonas (1835)

PRASINOPHYCEAE
Chloraster (1848)

FUNGI

ASCOMYCETES:
GYALECTACEAE
Coenogonium (1820)

ASCOMYCETES:
RHYTISMATACEAE
Placuntium (1818)

ASCOMYCETES:
XYLARIACEAE
Thamnomyces (1820)

COELOMYCETES
Cytospora (1818)

HYPHOMYCETES
Actinocladium (1819)
Sarcopodium (1818)

MYXOMYCETES:
ENTERIDIACEAE
Enteridium (1819)

ZYGOMYCETES:
MUCORACEAE
Rhizopus (1821)
Syzygitis (1818)

SPERMATOPHYTA

DICOTYLEDONES:
ASCLEPIADACEAE
Desmidorchis (1832)

DICOTYLEDONES:
UMBELLIFERAE
Actinanthus (1829)

DICOTYLEDONES:
TAMARICACEAE
Hololachna (1827)

*Data taken from Greuter *et al.* (1993)

The Ehrenberg Collection and its curation

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Keywords: type material – diatoms – radiolaria – microfossils – Berlin Museum

Abstract

C.G. Ehrenberg's extensive collections from his pioneering studies of microscopic organisms, both living and fossil, are stored at the Institut für Paläontologie, Museum für Naturkunde, Berlin. The Ehrenberg Collection consists of some 40,000 microscope preparations, several thousand raw samples, thousands of illustrations, and several hundred letters. It is believed to hold several thousand type specimens, including the types for more than 10% of the described genera of diatoms and radiolaria. Ehrenberg's documentation of his numerous named taxa is often insufficient for modern taxonomic research, and the collection itself (the Museum being located in the former East German side of the city) was until recently not widely available for scientific study. With the new resources available since the re-unification of Germany, and the appointment of a new curator in 1996, plans are being made to re-catalogue the collection, improve access to materials, and to identify and re-illustrate the type material.

INTRODUCTION

Christian Gottfried Ehrenberg (1795–1876) was one of the founding fathers of the discipline known today as micropalaeontology, as well as being an active member of the scientific establishment in 19th century Germany, holding a professorship for many years at the University in Berlin. Ehrenberg, born in the small town of Delitzsch near Leipzig, studied first for the ministry before switching to his preferred field of natural sciences. Soon after completing his doctoral work on the fungal biotas in and around Berlin, he was invited by Alexander von Humboldt to go on two major expeditions – the first, under the command of the Prussian General von Minutoli to the Middle East (1820–1825), the second, with Humboldt, to Russia and Siberia (1827). Ehrenberg, with the help of his colleagues, collected thousands of specimens of plant and animals on these expeditions, which were sent back to the University Museum in Berlin.

Ehrenberg's research interests after his return from the Middle East however turned ever more strongly towards microscopic organisms. Publishing extensively in the two journals of the *Akademie des Wissenschaften,* Berlin – the *Monatsberichte* and the *Abhandlung* – Ehrenberg described a vast number of new forms of organisms, both living and fossil. He became internationally known for his research on microorganisms, and received a substantial amount of additional material in the mail from foreign colleagues and collectors. Much of this work was summarised in two major monographic publications – the *Infusionsthierchen* in 1838, and the *Mikrogeologie* of 1854. In later years Ehrenberg's eyesight began to weaken, and he was helped in the enormous work of cataloguing and cross-indexing his collections by his youngest daughter Clara. Ehrenberg's collections were donated to the University of Berlin upon his death in 1876, and are now stored at the Museum für Naturkunde (MfN) in Berlin.

DESCRIPTION AND PREVIOUS HISTORY

Of Ehrenberg's extensive collections of larger organisms, most still remain at the MfN. These are distributed among the Museum's taxonomically organised major collections in the Institut für Systematische Zoologie. Researchers interested in these materials should contact the taxonomically relevant MfN curator for more details. Because the collections are normally only catalogued on paper by taxonomic category or locality, one should be prepared to give precise taxonomic and/or locality names for any material desired.

The bulk of the Ehrenberg Collection at the MfN however refers to the microscopic part of Ehrenberg's legacy – the collections used in his *Mikrogeologie* and *Infusionsthierchen* publications. These materials, together with supporting documents, are stored together in the Institut für Paläontologie as the 'Ehrenberg Collection', and are the subject of the remainder of this paper. Ehrenberg examined a wide taxonomic range of material, including coccolithophores, silicoflagellates and other algal groups, foraminifera, sponge spicules and other microscopic parts of multicellular organisms – indeed almost whatever he found in the samples. The bulk of the collection however is concerned with the siliceous shells of fossil and recent diatoms, and, to a somewhat lesser degree, of radiolaria. As explained above, Ehrenberg collected extensively on his own, and received many samples in addition from correspondents world-wide. There is a correspondingly broad range of material in the collection. Material comes from Europe, North, Central and South America, Africa, the Near East, the North Atlantic, North Pacific, Australia – indeed, almost every major geographic region on Earth; and includes samples of living material, sediment, soils, and indurated rock.

Because Ehrenberg included many rock samples in his studies, there is a substantial geological range as well to the collection. The samples, having been collected more than a century ago, are not well dated (at least by modern standards), but at least some samples appear to be of Cretaceous age, and there is a great deal of Palaeogene material as well. Thus, although most of the material is geologically quite young – soils, Holocene sediment etc., there is a substantial interest in the collection from palaeontologists as well as biologists.

Size, type specimens, type species

The Ehrenberg Collection contains nearly 5,000 raw samples, more than 40,000 microscope preparations, approximately 3,000 drawings, 800 letters and various other documents. It is a remarkable legacy, even in terms of simple size.

The Ehrenberg collection's great importance, however, lies in the large number of type specimens contained within it. There are no definitive figures for this, as Ehrenberg's own lists are not complete, but the following estimates can be made, based on numbers given by Locker (1980): 4,500 type specimens for species or other species-level taxa, and nearly 200 type species of genera, distributed among protistan groups, as shown in Figure 1. These are probably, however, minimum values. Recent work by diatom specialists indicates, for example, that although there are 46 Ehrenberg diatom genera in the botanical list of Names in Current Use (Jahn, This Volume), a detailed compilation from Ehrenberg's own publications gives 99 genera (Jahn & Geissler, 1993). Although no complete list exists yet for the radiolarians, Dr. Jean Pierre Caulet in Paris has been compiling a radiolarian generic list for some years. In Dr. Caulet's list (*pers. comm.*, 1994), there are 15 genera with Ehrenberg type species within the letter 'A' alone. Assuming that this ratio holds for the entire list, and given that the 'A's make up about 10% of it, a rough estimate of about

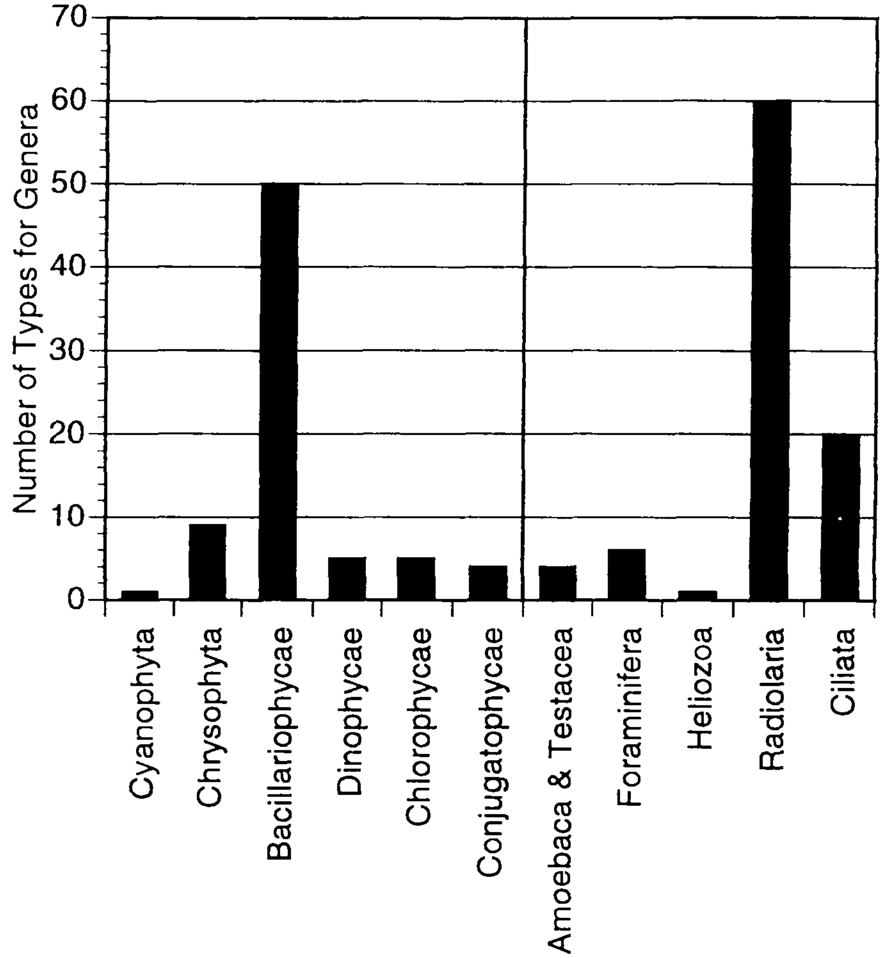


Figure 1. Approximate composition of type genera in the Ehrenberg Collection, after Locker (1980). Groups on the left are handled under the botanical code, those on the right under the zoological. Only relative numbers are reasonably reliable, as absolute numbers (see text) may well be double those shown.

150 generic type species is obtained. These numbers – thousands of type specimens, of which some hundreds are the types of genera – give the Ehrenberg Collection enormous taxonomic importance.

Importance to radiolarian and diatom workers today

Given that the Ehrenberg Collection is dominated by diatom and radiolarian taxa, it is worthwhile to briefly summarise the development of these fields, and comment more specifically on the significance of the Ehrenberg Collection to the taxonomy of these groups.

Diatoms (Figure 2) are one of the most diverse and abundant groups of photosynthetic protists, with tens of thousands (the precise number is not

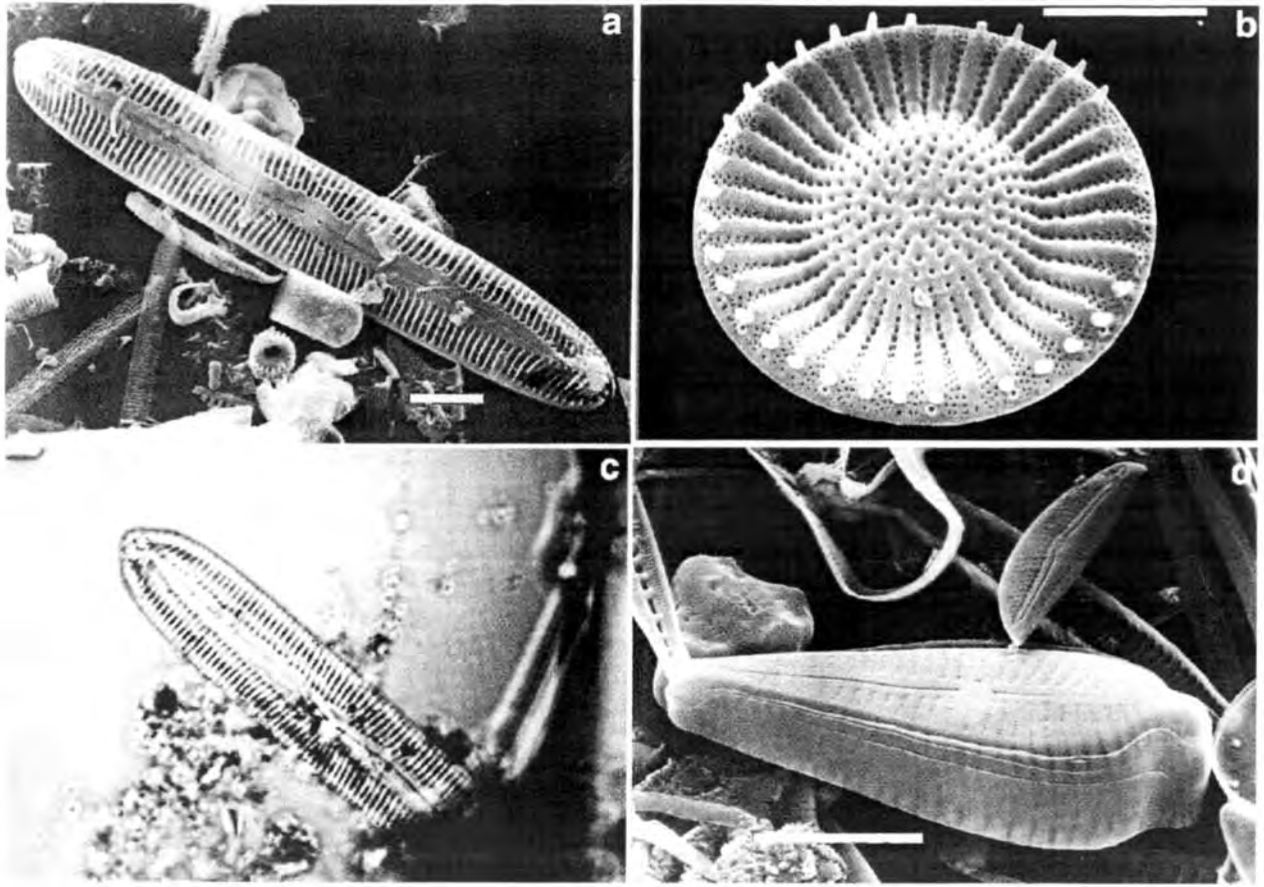


Figure 2. Diatom shells. a - West Point New York, diatomite, Ehrenberg-Sample Nr. 1756, SEM, *Pinnularia* species and centric species. b - *Cyclostephanos malawiensis* Casper and Klee. Lake Malawi/Nyassa, Plankton, September 1899, collected by F. Fülleborn (material at Berlin Botanical Museum - see Jahn ,1996) c - *Pinnularia* species, Cayenne, Guyana gallica, soil, Ehrenberg-Sample Nr. 1108, Photograph from an Ehrenberg mica (see Reichardt, 1995). d - *Gomphonema augur* Ehrenberg, Epiphyte-Sample from River Spree. West Berlin, January 1983. All photographs courtesy R. Jahn.

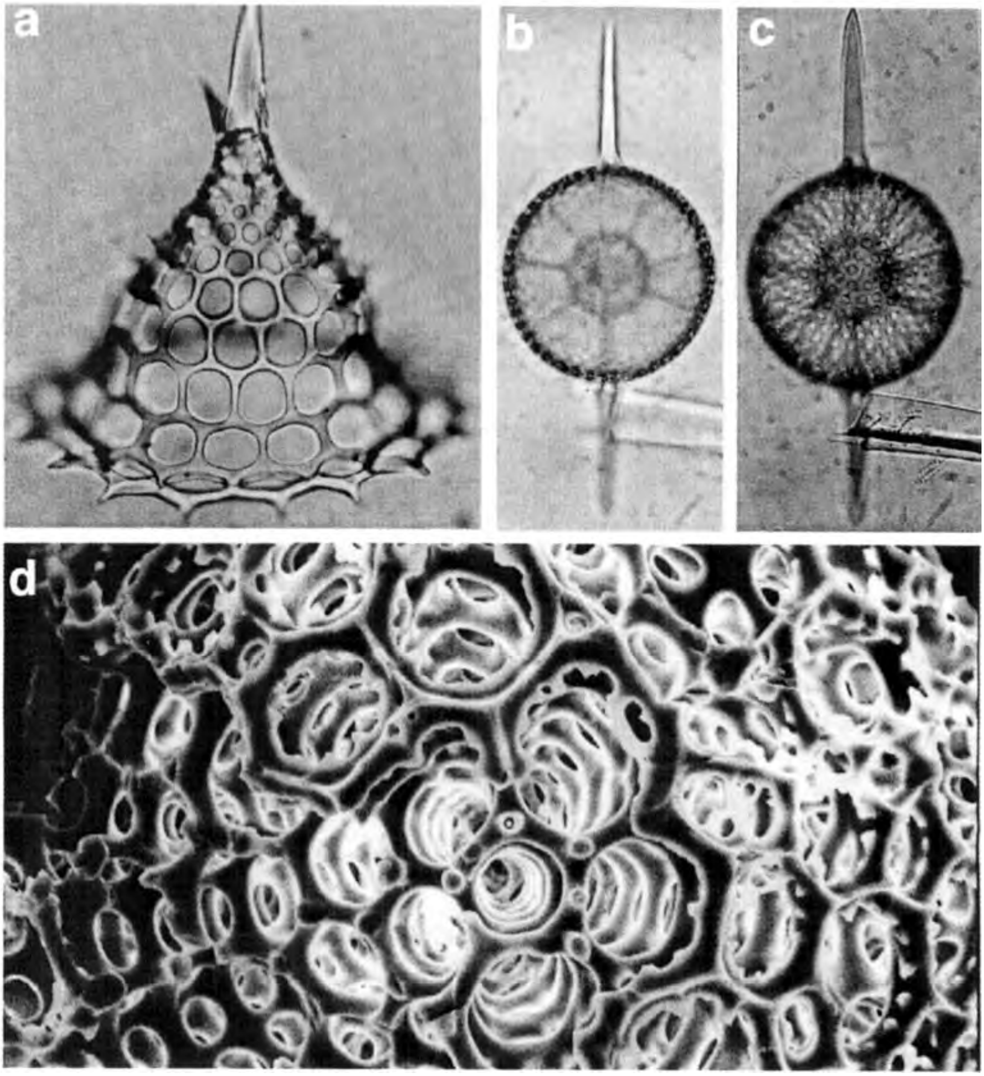


Figure 3. Radiolarian shells. a - *Cycladophora cabrilloensis*, a simple nassellarian from the North Pacific Miocene (DSDP Site 173, California borderland). b and c - stylatractid (gen. et. sp. indet.), a fairly simple spumellarian form from Antarctic deep sea sediments. Two different focal depths to illustrate internal (b) and external (c) morphology. d - SEM micrograph of *Ommatodiscus* sp., an involutely spiralled spumellarian, to illustrate complex morphology of some radiolarian groups. Antarctic Miocene deep sea sediments. Specimens in a-c are approx. 100 μm in longest dimension, d is approx. 300 μm across field of view. d imaged by Dr. I. Popova.

known) of living species, distributed over an enormous range of biological habitats, both freshwater and marine. Diatom research has developed steadily for more than a hundred years, with application to marine and freshwater biology, environmental research, and, to a lesser extent, palaeoceanography – the study of ancient oceans from deep sea sediment samples. There are hundreds of diatom workers active today (mostly studying living or Holocene material), and there are several other large diatom collections (and curators) in the world's museums. The Ehrenberg Collection is however, with something like 10–20% of the described diatom type species, of special importance for diatom nomenclature, and now needs to be re-integrated into the world's diatom taxonomy research community.

Radiolarians have a substantially different biology and geological history from diatoms, and radiolarian research has developed along different lines. Radiolarians (Figure 3) are exclusively holoplanktonic marine organisms, have a modern diversity of only a few hundred species, and are not particularly significant components of modern marine plankton. However, in contrast to the diatoms, where perhaps 90% of the described species are living, approximately 90% of the several thousand described radiolarian taxa are fossil forms. Indeed, radiolarian research is essentially palaeontologic, and radiolarians are widely used in stratigraphy throughout the Phanerozoic, in palaeoceanography, and in palaeobiological studies. Radiolarian research has developed episodically, with an initial phase of interest in the preceding century, a quiet interval between about 1910 and 1950, and a second, mostly geological phase of development since then, in conjunction with renewed interest in subjects such as plate tectonics and paleoceanography after WWII. As this newer phase of research has been more problem-oriented than systematic, radiolarian taxonomy is still dominated by the massive monograph of Ernst Haeckel (Haeckel, 1887), who integrated Ehrenberg's earlier work with his own observations of the then newly obtained Challenger materials. Unfortunately, the current whereabouts of the Haeckel collection is unknown. Radiolarian taxonomic research has thus for many years been hindered by the lack of new systematic syntheses, and the unavailability of most described type material for examination. The Ehrenberg collection is in fact, at present, the only large collection of radiolarian type material known to be deposited in a museum, and the only one as well with a dedicated curatorial position attached to it. It is of unusual potential importance therefore to the future development of radiolarian taxonomy, even beyond the significance that the Ehrenberg Collection itself holds, with its type material for about 10–15% of currently described radiolarian taxa.

History of curation and current condition of the collection

The Ehrenberg Collection was donated to the Berlin University upon Ehrenberg's death in 1876, and was transferred in 1907 to the MfN, which had been established not that many years earlier (the building was opened in 1889). The Collection was only occasionally used from the time of donation until WWII, possibly partly as Ehrenberg had provided excellent illustrations of his material. After WWII the Collection was largely not available, due to political and financial problems. Indeed, after the war it was at first thought by some in the international community to be lost, although it was later realised that it had survived. Some individual visits were made during the DDR (East German) years, and some materials were exchanged by mail, but the collection was comparatively little used.

In the late 1960s Sigurd Locker of the MfN began to restore the Collection, collecting scattered materials, sorting and labelling, and publishing short papers summarising its extent (Locker, 1970, 1980). However, there were not sufficient resources available to undertake many of the fundamental restoration efforts needed. On February 3rd, 1982, a fire broke out on the roof of the MfN. Most of the Collection was at that time stored near the roof, and it was only rescued from destruction by the prompt action of MfN curators. Parts of the Collection did get rather wet from the fire-fighter's hoses, but were carefully dried out again before the collection could suffer any more than very minor water damage (internal report, Locker, 1982).

From the early 1980s until his retirement in the early 1990s Dr. W. Krutzsch assumed responsibility for the Collection, after which it was looked after by Dr. E. Pietrzenuik. In this time interval the Museum built special new cabinets and hundreds of glass-covered trays to safely hold the mica preparation folders. However, due to continued lack of resources, little additional restoration work was possible; it was only in the 1990s that the last cases of micas – containing much of the prepared living material – were finally found and returned to the Collection. In mid 1996 the Collection curatorship was assumed by the author.

Physical organisation of the collection

The Ehrenberg Collection is divided, as described above, into several different subcollections – the microscope preparations, the samples, the drawings, letters, and the index books. All are stored together in a single room in the Institut für Paläontologie at the MfN.

The microscope preparations (Figures 4–5) – which contain all of the type specimens – were, for the most part, made by Ehrenberg on small round (~ 1 cm diameter) sheets of mica. Ehrenberg did so for reasons of practicality and economy – glass slides and cover slips were in his day rather expensive and hard to obtain. The specimens are embedded on one side of the mica under a relatively thick layer of Canada balsam, usually without a cover-slip. Specimens of particular interest, such as types, are marked on the surface of the balsam by small coloured glued-on paper rings. These micas themselves are not secured to glass slides, but instead are fixed with small drops of additional Canada

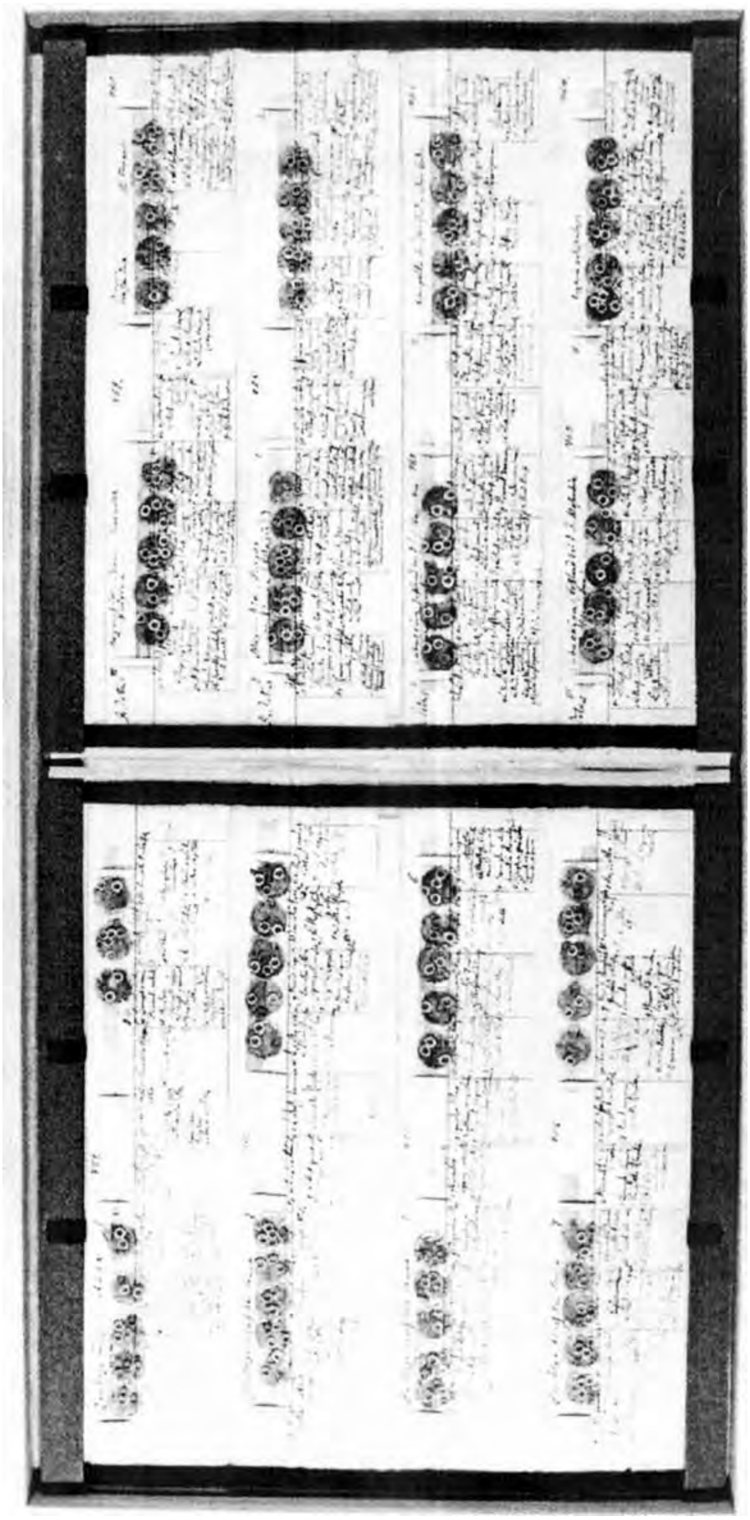


Figure 4. Folder with mica preparations. Up to 80 micas can be held in each folder. The mica collection is geographically arranged, with the micas on one strip frequently coming from one or more samples from one location.

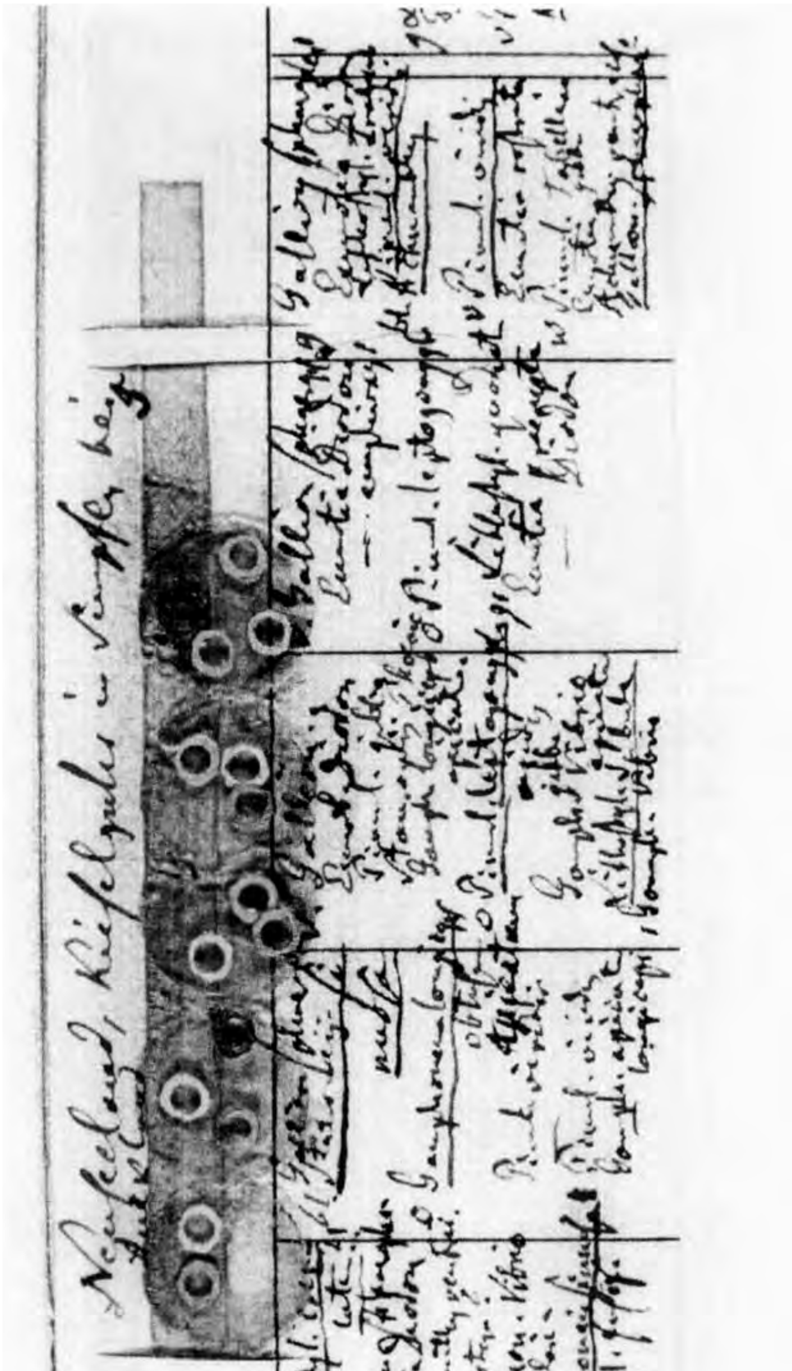


Figure 5. Close up of mica strip. The mica discs are glued to mica strips, and held in place by inserting the strip ends into slits in the folder's paper backing. The labels under each strip (not directly attached to the micas) give the observations made by Ehrenberg for each mica, mostly taxonomic names. Letters (R, o, v, etc.) indicate which coloured paper ring marks the taxon. The rings on many micas are however now so discoloured with age that identification is difficult.

balsam in groups of five to strips of mica. The strips are laid out in rows in roughly page-sized cardboard folders (a 'Buch'), and are held in place by inserting the strip ends into slits in the paper backing. Groups of folders are filed together in cardboard cases ('Kasten'). Each case holds approx. 800 preparations, and there are 51 such cases. In addition, there are two cases holding preparations similar to these, but where the micas have been mounted in microslide-like holders (several micas per holder), and two last cases containing glass slide-mounted material, including thin rock sections.

Ehrenberg provided a standard set of paper labels for each mica in the collection, on which he wrote (in a very hard to read, fine hand!) the important taxa he had marked with coloured paper rings. Unfortunately, the ring colours have faded and altered over time, so that it is difficult to identify which of the often many rings correspond to the label text. Ehrenberg also occasionally used the sheet of paper inserted into each folder to protect the micas as an additional notepad, particularly for making more lengthy lists of taxa. Such annotations (on the mica folders, drawings, etc.) are of unusual importance, as Ehrenberg did not keep – or at least did not include in his legacy to the Museum – any sort of daily diary or lab book documenting his work. Nor, it should be noted, did Ehrenberg mark, or specifically indicate in any other location other than

Figure 6. Sample drawer. A wide variety of sample containers is visible, including boxes, trays, bottles, and envelopes. Note the presence of some lithified rock samples (right hand side) as well.

his index volumes (see below), which specimen should be considered the type for a taxon.

The sample collection (~5,000 samples) has been extensively reorganised by Dr. Locker, and is stored in two specially constructed cabinets. Dr. Krutzsch has estimated that there are raw samples available for about 50% of the preparations (Krutzsch, unpubl. MfN document). Samples bear the numbers given to them by Ehrenberg, and are for the most part still in their original containers, complete with the hand-written notes of the collector (Figure 6).

The drawing collection is of particular importance. Some 3,000 approx. US 'Letter' (i.e. 8.5 x 11 inches) sized sheets, bearing the numbers assigned by Ehrenberg, are in this collection. The drawings (Figure 7) are pencil sketches by Ehrenberg, partly coloured, of his microscope observations, and may illustrate several different taxa on a single page. Only a fraction of the illustrations were published, and in at least some instances they portray taxa formally named but never illustrated by Ehrenberg in a publication. The drawings are stored in bundles in cardboard boxes. Numbers on each sheet can be cross-referenced with the help of Ehrenberg's index volumes to the actual mica preparations used to create each drawing.

Lastly, there is the Letter collection, containing several hundred letters of correspondence with various prominent researchers and explorers of Ehrenberg's day, including Alexander von Humboldt, J.D. Hooker, Samuel Morse, and Charles Darwin (Figure 8). This collection is of value to historians of science. Furthermore, as many of the letters accompanied samples sent to Ehrenberg for examination, they are also an important part of the scientific documentation of the specimen collection, containing essential information on localities, collection conditions and the like.

All of the above items – the mica preparations, the drawings, samples, letters – would be of little use unless there was some way to link the various individual items together, and to the many publications of Ehrenberg wherein the taxa are described. Ehrenberg himself typically did not refer to any single system of index numbers in his publications, but instead usually gave a number that was specific to the current publication, or only a locality name, or a citation of one of his earlier publications. Fortunately, Ehrenberg left behind two master index books, in part compiled by his daughter Clara (Figure 9). One book – the Geographic Index – gives a cross index between these numbers and those of his major publication, the *Mikrogeologie*. The Geographic Index also cross references each sample to the micas, to a publication and/or to a letter in the Letter collection. The Taxonomic Index by contrast gives an entry for each identified species to the case and folder where the prepared micas are to be found, to the publication(s) where first used, described, and illustrated; plus

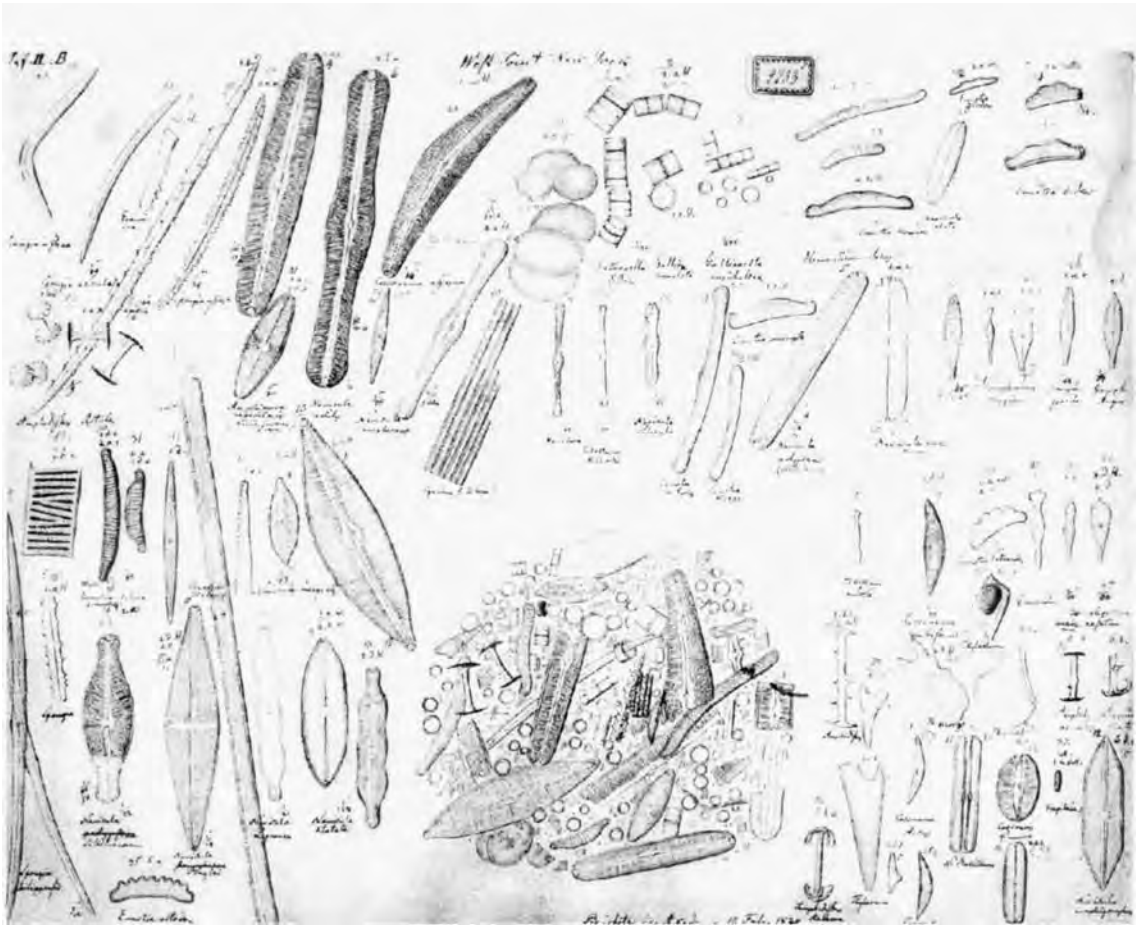
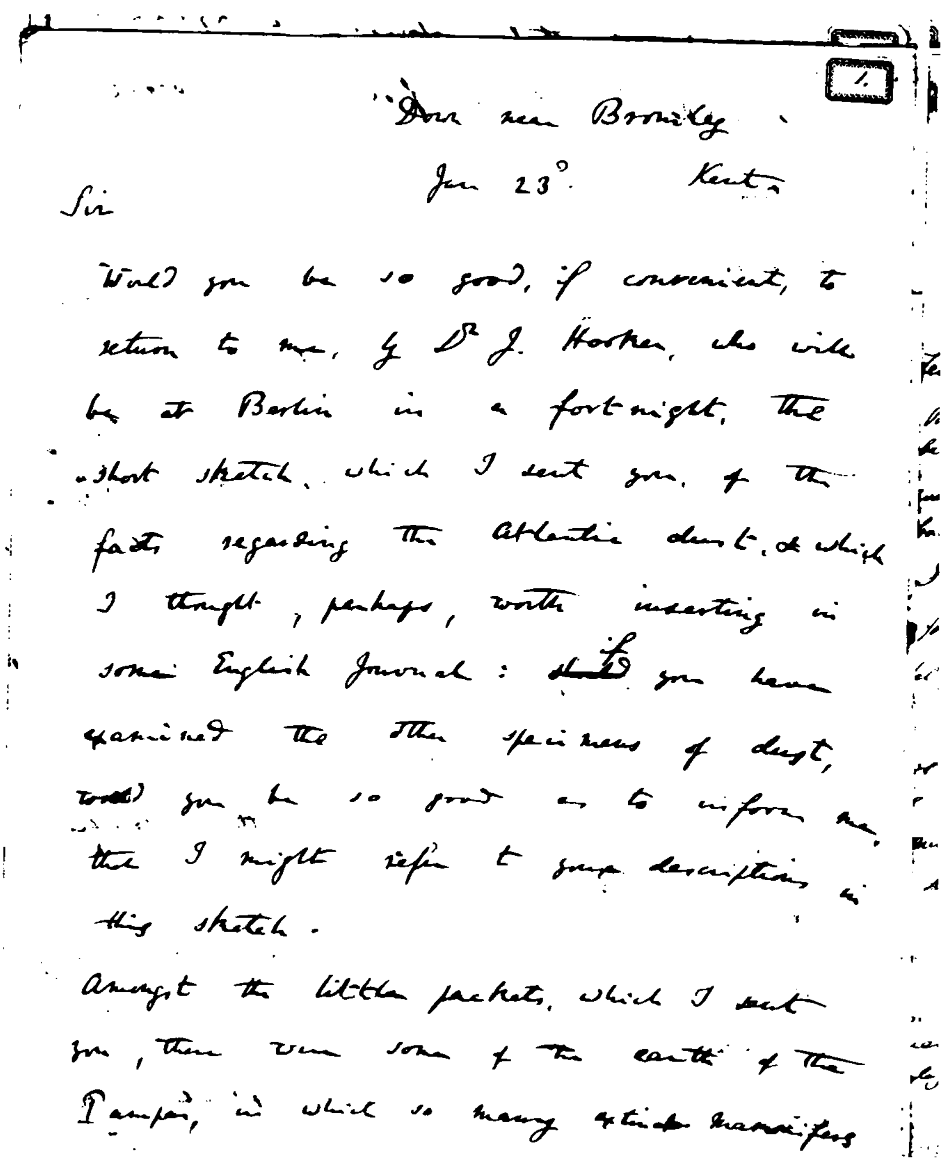


Figure 7. One of Ehrenberg's drawings, this one mostly of diatoms, but with some sponge spicules and pollen grains as well. The drawing is labelled on the back 'West Point New York. Kieselguhr. Abhandl. 1841 p. 294, Microg. Taf. II, Präparat Kast. 26 B3, Probe N. 1756'. Kieselguhr is diatomite. *Abhandl.* refers to the original publication, Microg. to Plate 2 in the *Mikrogeologie* of 1854, Präparat to mica preparations Case 26 folder 3, and Probe to sample number 1756 - Which is still in the collection at the Museum. There are minor differences between Ehrenberg's original pencil drawings and the copper plate illustrations used in the *Mikrogeologie* due to the difference between continuous tone pencil shading and the dot or half tone technique used by the engraver, but they do not appear to be taxonomically significant, at least in this instance.



Down near Bromley
Jan 23rd Kent

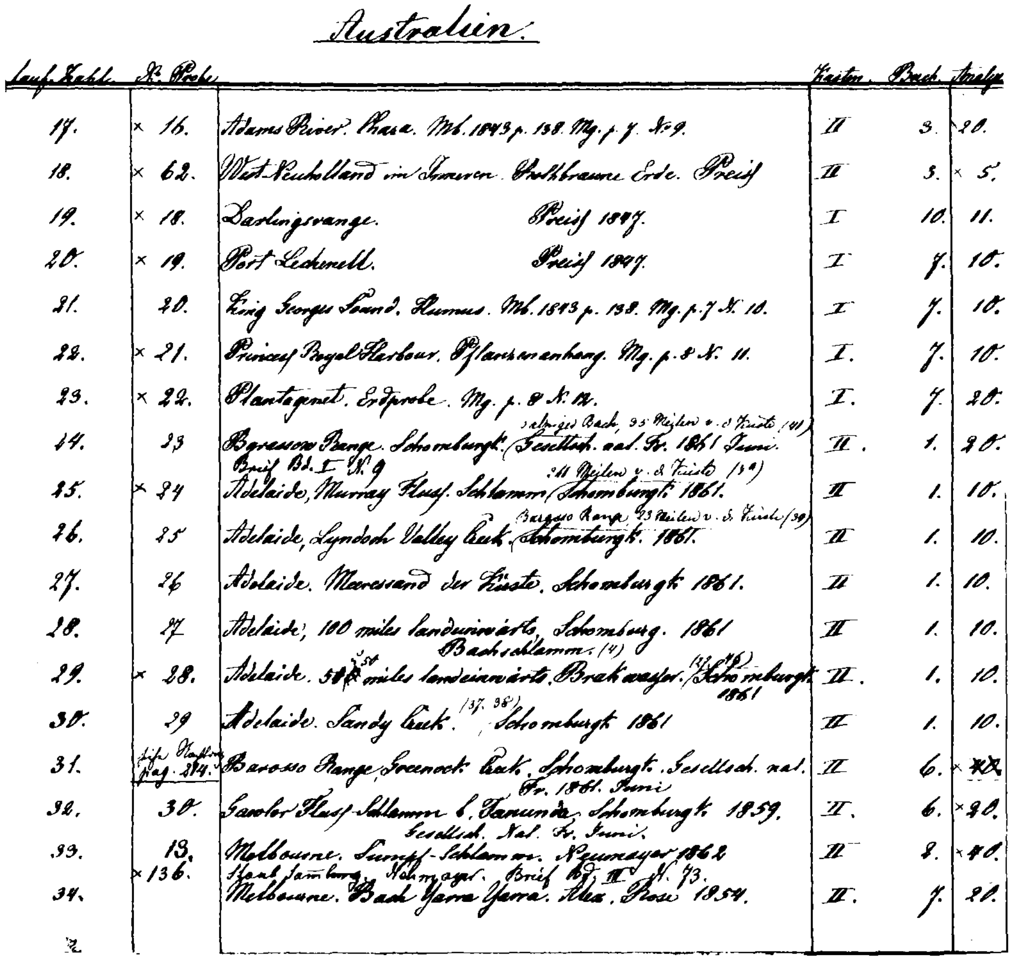
Sir

Would you be so good, if convenient, to return to me, by Dr J. Hooker, who will be at Berlin in a fortnight, the short sketch, which I sent you, of the facts regarding the Atlantic dust, & which I thought, perhaps, worth inserting in some English Journal: should you have examined the other specimens of dust, would you be so good as to inform me that I might refer to your descriptions in this sketch.

Amongst the little packets, which I sent you, there were some of the earth of the Pampas, in which so many extinct mammifers

Figure 8. First page of a letter to Ehrenberg from Darwin. This particular letter is mostly concerned with ensuring the return (by Ehrenberg, and also one of Ehrenberg's German colleagues) of previously loaned information, samples and a manuscript (Burkhardt & Smith., 1987: 130).

a reference to the Illustration collection. It is organised by major group (Ehrenberg's own categories, which correspond roughly to diatoms, radiolarians, etc.), and then alphabetically by genus and species. The Taxonomic Index, compiled late in Ehrenberg's career, at least in some instances used the taxonomy that was current at that time, not the nomenclature used in the original publication. For example, *Navicula splendida* (Ehrenberg, 1838), transferred to *Surirella* by Kützing in 1844, is found in the Taxonomic Index under



Australien.

Lauf. Zahl	N. Probe		Kasten	Bach.	Analyse
17.	× 16.	Adams River? Haa. Mb. 1843 p. 138. Mg. p. 7. N. 9.	II	3.	20.
18.	× 62.	West-Neuholland im Innern. Rothbraune Erde. Preiss	II	3.	× 5.
19.	× 18.	Darlingsrange. Preiss 1847.	I	10.	11.
20.	× 19.	Port Lechenelt. Preiss 1847.	I	7.	10.
21.	20.	King Georges Sound. Humus. Mb. 1843 p. 138. Mg. p. 7 N. 10.	I	7.	10.
22.	× 21.	Princess Royal Harbour. Pflanzenanhang. Mg. p. 8 N. 11.	I.	7.	10.
23.	× 22.	Plantagenet. Erdprobe. Mg. p. 8 N. 12.	I.	7.	20.
24.	23	Barossa Range. Schomburgk. Gesellsch. nat. Fr. 1861 Juni. Brief Bd. I N. 9	II.	1.	20.
25.	× 24	Adelaide, Murray Fluss. Schlamm (Schomburgk) 1861.	II	1.	10.
26.	25	Adelaide, Lyndoch Valley Bach (Schomburgk). 1861.	II	1.	10.
27.	26	Adelaide. Meeressand der Küste. Schomburgk 1861.	II	1.	10.
28.	27	Adelaide; 100 miles landeinwärts, Schomburg. 1861 Bachschlamm (4)	II	1.	10.
29.	× 28.	Adelaide. 50 miles landeinwärts. Brakwasser. (Schomburgk) 1861	II.	1.	10.
30.	29	Adelaide. Sandy Creek. (37. 38) Schomburgk 1861	II	1.	10.
31.	Lit. Kasten Pag. 214.	Barossa Range, Greenock Creek. Schomburgk. Gesellsch. nat. Fr. 1861. Juni	II	6.	× 20.
32.	30.	Gawler Fluss Schlamm (Tanunda) Schomburgk 1859. Gesellsch. Nat. Fr. Juni.	II.	6.	× 20.
33.	13.	Melbourne. Sumpf-Schlamm. Neumayer 1862	II	8.	× 40.
	× 136.	Hamburg. Neumayer. Brief Bd. II N. 73.			
34.		Melbourne. Bach Yarra Yarra. Alex. Rose 1854.	II.	7.	20.

Figure 9. A page from Ehrenberg's Geographic Index book, listing samples from Australia. The majority of the samples listed are still in the collection. The right hand columns (Kasten etc.) give cross-references to the mica collection of preparations.

Surirella, not the original genus *Navicula*. In addition to these two major indices, Ehrenberg included several other volumes of documentation. There is a separate, small index volume, organised by sample number, which gives the taxonomic names for each preparation in the dried, mounted biological material cases. There are also several books in which Ehrenberg attempted to track synonymies. These are organised alphabetically by genus and species. It is not clear to what extent the information in these volumes has been incorporated into the other index volumes, or into his published works. A last, more recent addition are the documents regarding the curation of the collection by the DDR era curators, particularly Drs Locker and Krutzsch.

CURATING AND USING THE EHRENBERG COLLECTION

As anyone wishing to work with the Ehrenberg Collection needs to be aware of the specific challenges it presents, a brief outline of some of these is given below.

Which is the holotype?

Ehrenberg frequently described taxa as new more than once, introduced new names without identifying them as such, and sometimes described taxa without clearly indicating that they had been previously described by others. If this were not problematic enough, the mica and marked specimen corresponding to a type is not directly given anywhere in the collection, but must be inferred by cross comparison of indices, and gives a correct result only when the index itself correctly gives the earliest publication of a new taxonomic name. Unfortunately, there are enough errors in the index volumes that they cannot be considered authoritative sources for determining which specimen is indeed the type for a species. A complete recompilation of Ehrenberg's publications is needed to determine the first usage dates, such as that being undertaken for the algal taxa by Dr. Silva of Berkeley University Herbarium, University of California (Jahn *pers. comm.*, 1995).

Limitations on the quality of the holotype

One major problem with the 'folder and case' storage system for micas used by Ehrenberg is that, with the passage of time, some of the micas have come loose from their paper strip mounting, and have slipped down into the fold of the folder. These micas are hard to identify, and extremely vulnerable to breakage. To solve this problem, the curators at the MfN have prepared new trays to hold the folders in a flat, opened position, thus eliminating the slippage and breakage problems due to storing the folders in cases. All folders in the collection are now being transferred to such trays.

The micas, however, are so small and fragile, and the Canada balsam has become so brittle, that it is difficult to safely handle them or to mount them for examination on a modern research microscope. Also, the irregular, often somewhat mattered surface to the layer of balsam, together with numerous cracks developed during the ageing process, combine to create so many optical problems that it is difficult to image the specimens properly. To deal with this will require some sort of 'remounting' of the micas identified as being in need of re-examination. Even so, SEM imaging, particularly important for the diatoms, can only be done for specimens prepared from the sample material, as attempting to extract type material from the Canada balsam mounts would not be possible without great risk of damage to or loss of the specimen.

Which type of type?

This leads to an important consideration for the taxonomic researcher using the Ehrenberg Collection. Because the preparations may not show all the details one would wish for, one might be tempted to (in essence) ignore the type specimen's existence, and declare a new isotype from the sample material, should a sample be available. The use of isotypes, or for that matter multiple type specimens (allowed under the Botanical Code), may be reasonable for living material where one knows that the sample was drawn from a single living population. It is not as appropriate for the fossil or even subfossil material that comprises most of the Ehrenberg Collection. Microfossil specimens in the same sample can easily be up to several thousand years different in actual age, and belong not only to different populations, but even to different species. Although the age differentials are not so extreme in subfossil material (e.g. soil samples), the same problem of mixed populations is still present. One could never stabilise the name this way, as one could never be sure that one had correctly matched specimens found in newly prepared samples to the type specimen from the same sample.

It is therefore recommended that, for non living original material, the sample material be used only for the erection of epitypes – a 'supporting' type for the holotype – and then only when the holotype is 'ambiguous', e.g. key characters are not preserved, or not visible in the mica preparation. This will be particularly important for diatoms where characters need to be examined under the SEM, although, given the mixed population problem above, an epitype of non-living sample material cannot definitively stabilise the taxon name. As radiolarians are generally much larger than diatoms, most taxonomically significant characters in radiolarians will probably be visible in the relatively low magnification transmitted light images Ehrenberg's preparations allow, and the use of secondary types will hopefully not be often needed. In general, determining the 'best' material to use for types will be an important task for those using the Ehrenberg Collection – see also Jahn (1995).

Basic restoration work

All of the above comments on using the Ehrenberg Collection assume that the collection is easily accessible. In fact, there are many major curation tasks that must be first completed before the collection is properly available for renewed research. These include: creating a custom collections database to provide a full inventory and index for rapidly accessing the materials;

remounting the type-containing preparations (assuming that they have been identified) so that modern microscope images can be safely obtained; and securing additional supplemental resources needed to effectively use the collection, including literature and collections of modern reference material. Restoration of microscope equipment and lab facilities is also needed. Preserving the unique and irreplaceable paper documents and indices is an urgent problem, as with increasing age they are becoming more fragile, and should not be handled on a daily basis. Scanning and the creation of working copies from the scanned document images is a possible solution. Work on these problems has begun, but will take many years to complete. Researchers wishing to use the collection are advised to first contact the curator to ensure that their use of the Ehrenberg Collection can be made as easy as possible.

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Unravelling Ehrenberg's names: applying the past to the present

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Abstract

Christian Gottfried Ehrenberg discovered and described many new organisms, from birds, mammals and insects to diatoms, radiolarians and foraminiferans. In our paper we examine three different aspects of Ehrenberg's work and how they relate to the naming and recognition of specimens. Firstly, Ehrenberg considered all the organisms he studied as 'Infusoria' animals. Does this have any adverse affects on nomenclature now and in the future? Secondly, we review Ehrenberg's publication record, the sources, dates and availability. Thirdly, we present one example of the relevance of the Ehrenberg Collection to a contemporary problem in systematics. To close, we make a few suggestions that might indicate and assist possible ways forward in the resurrection of Ehrenberg's collections.

INTRODUCTION

Christian Gottfried Ehrenberg's contribution to our knowledge of biology was wide-ranging – he discovered and described many new organisms, from birds, mammals and insects to diatoms, radiolarians and foraminiferans (Jahn, 1995 and This Volume; Schlegel & Hausmann, 1996). Our own experience, as phycologists, is somewhat more limited than Ehrenberg's, hence we restrict our commentary to diatoms alone. Nevertheless, we imagine that the principles we discuss are general enough that they apply elsewhere in the living world – and perhaps extend to scientists other than Ehrenberg.

In this paper, we briefly examine three different aspects of Ehrenberg's work and how they relate to the naming and recognition of specimens. Firstly, we consider the effects, if any, of Ehrenberg's view that all organisms understood as 'Infusoria' are really animals. Secondly, we briefly review Ehrenberg's publication record, with regard to their sources, dates and availability. Finally, we present one example of the relevance of the Ehrenberg collections to a contemporary biological problem in diatom systematics and biogeography. To close, we offer a few preliminary suggestions that might indicate and assist possible ways forward.

WHEN IS A PLANT AN ANIMAL?

Ehrenberg held the notion that all the micro-organisms referred to as Infusoria were really 'true' animals complete with muscles, digestive and sexual organs, as well as nervous tissue and vascular systems. While this belief lead him to separate several hundred species into a new class, the Polygastern (Churchill, 1989), his classification of the Infusoria was seen as progressive. Indeed, it was put in a particularly clear way by Nordenskiöld (1929: 428) in his history of biology: "The whole of this careful and praiseworthy work, however, Ehrenberg used in support of an utterly unprofitable theory"[1]. His views on the 'animal' properties of the Infusoria did not go unchallenged and were soon called into question by Dujardin (1841) and Siebold (1845) among others. Nevertheless, it seems that Ehrenberg clung to his beliefs, claiming that his opponents' views were based on unreliable observations. Whatever the merits of this claim Ehrenberg was acknowledged then, as he is now, as a keen observer (Corliss, 1996; Williams & Huxley, This Volume).

Ironically, Ehrenberg might now be considered partly 'right' but for entirely the wrong reasons. For instance, it seems reasonable, at least with respect to diatoms, that they are not, strictly speaking, plants but members of the kingdom 'Protista', which in itself now contains a variety of different organisms neither

1 This passage is taken from a translation of the earlier Swedish text (Nordenskiöld, 1924: 185).

plant nor animal (e.g. Patterson 1994; indeed, it is clear that even the 'Protista', as currently understood, should not be considered a monophyletic group and that diatoms are better understood as members of the 'Stramenopiles' (Saunders *et al.*, 1997); yet the notion that there are more than the standard three Kingdoms has also had a long history (Ragan, 1997). As far as it goes then, Ehrenberg was correct in his recognition of diatoms not being plants. Nevertheless, he treated them as animals and today, for nomenclatural purposes, they are treated as plants. It is quite possible that in the near future there may be a unified Code of Nomenclature for all living organisms (Greuter *et al.*, 1996[2]) and any potential problems will evaporate. Nevertheless, as the current Code of Botanical Nomenclature (Greuter *et al.*, 1994) deals with predominantly photosynthetic organisms, diatoms are treated accordingly. This may necessitate some attention to detail. Nevertheless, it is worth pondering McNeil's (1996) recent perceptive comment: "Biological nomenclature is not an end in itself. It is not even a part of scientific endeavour; it is a regulatory system that seeks to serve the needs of science" (see also Williams, 1993: 23).

EHRENBERG'S PUBLICATIONS

According to the Royal Society Catalogue (Royal Society of London, 1868), Ehrenberg must have published well over 300 scientific contributions. Keen to disseminate his work, he frequently distributed pre-printed separates to his colleagues which ended up in many major biological institutions in Europe, such as the Académie des Sciences in Paris and the Royal Society in London. In addition, Ehrenberg's papers were frequently translated and summarised in many natural history journals. It is important, from the perspective of nomenclature at least, to be aware of these multiple publications for the possibility of any variation among them. Although titles sometimes vary, as well as perhaps the content, if the article in question includes descriptions of new taxa, the date of each publication is significant. For instance, most of Ehrenberg's published reports on the North African fossil Infusoria, collected during his expedition with Hemprich in the 1820s (Stresemann, 1954), appeared in the *Abhandlungen* of the Royal Prussian Academy of Sciences. One paper related to the material from this expedition dealt with the microscopical organisms in chalk and marl from Europe, Lybia and Arabia. It appeared in the 1838 edition of *Physikalische-Mathematische Abhandlungen der Königlichen Akademie der Wissenschaften*[3]. *This particular volume of reports was*

2 A proposal that has not been greeted with uniform enthusiasm. See, for instance, the contributions in Reveal, 1996 and Mann, This Volume.

3 This particular publication started in 1737 with the title Miscellanea Berolinensia ad Incrementum Scientarum ex Scriptis Societati Regiae Scientarum. From 1745 to 1769 it was Histoire de l'Académie Royale des Sciences et des Belles-Lettres; from 1770 to 1786 it was Nouveaux Mémoires de l'Académie

published in 1840 not 1838, the date recorded on the title page (Ehrenberg, 1838 [1840]). In addition, Ehrenberg had already sent out an identical pre-printed separate a year before (Ehrenberg, 1839). Thus, the 'official' 1838 report was actually published in 1840 and the separate a year earlier in 1839. From the point of view of nomenclature, the preprint is the valid place of publication even though it appears to be published after the 'official' publication[4]. In this particular case there is no difference in content between the two versions apart from the publication date.

A further, perhaps more interesting, example concerns the diatom *Asteromphalus darwinii* Ehrenb., first described in 1844 (Ehrenberg, 1844a; for a modern account of this diatom see Hernández-Becerril, 1991: 28). *A. darwinii* was described by Ehrenberg in an article which included descriptions of material from Captain Ross' South Polar expedition as well as the voyages of Darwin and Schayer. In all, Ehrenberg described 71 new species. Among the new species of diatoms, Ehrenberg described, for the first time, the genus *Asteromphalus* in which he included seven new species, one of which was *A. darwinii*. Ehrenberg did not select a species for the type of the genus, hence *A. darwinii* was subsequently designated as type by Boyer (1927: 72).

The description for *A. darwinii* was published in the May issue of the Prussian Academy's *Monatsberichten* (Ehrenberg, 1844a). A little later, the article appeared in translation in the September issue of the *Annals and Magazine of Natural History* (Ehrenberg, 1844b) which itself was reprinted in the *Calcutta Journal of Natural History* (Ehrenberg, 1845a). Neither of these translated accounts included species descriptions or illustrations (all three publications are listed in the Royal Society's catalogue; Royal Society of London, 1868: 458) therefore it is relatively easy to establish accurately the place and date of publication. As it happens, Ehrenberg provided Charles Darwin with a manuscript illustration of *A. darwinii* as well as a reprint: "Yesterday through the good offices of Mr Gibsone of Perth I sent you the printed offprint of my report (in the May issue of the *Monatsberichten* of the Berlin Academy of Science) on a part of my shipment" (translated letter from Ehrenberg to Darwin, dated 11 July 1844 which includes the manuscript illustration, Burkhardt & Smith, 1987: 383; the original German letter is on p. 45). Ehrenberg's letter

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Royale des Sciences et des Belles-Lettres, Berlin; from 1786 to 1804 it was Mémoires de l'Académie Royale des Sciences et des Belles-Lettres, Berlin; from 1804 to 1829 it was *Abhandlungen der Physikalischen Klasse der Königlich-Preussischen Akademie der Wissenschaften*; from 1830 to 1907 it was *Physikalische-Mathematische Abhandlungen der Königlichen Akademie der Wissenschaften*; from 1908 it changed name a further four times. While none of this may be particularly significant, it is worth noting as citations to Ehrenberg's publications span at least two of these name changes.

4 For those who might believe this approach to dating publications is an idiosyncratic foible of our forefathers, see Schmid, 1989.

to Darwin is dated 11th July and although the publication date of the *Monatsberichten* is May, Ehrenberg's words suggest that the 'printed offprint' might possibly have been a printed 'preprint' pre-dating the 1844 *Monatsberichten* publication. VanLandingham, in his Catalogue of Diatoms, lists the publication as "Uber das kleinste Leben im Weltmeer am Sudpol und die Meersestiefen. Mit kupfertafeln, Berlin 1844" (Van Landingham, 1967: 429) and two copies of the 'reprint' are held in the Natural History Museum (BM). In this case it is relatively straightforward to establish that the reprint was just that and has no separate status.

The publication of *A. darwinii* presents all the potential problems of Ehrenberg's bibliography: multiple publication with the possibility of preprints rather than reprints, and a species that became the type of the genus at a later date.

Establishing the first and unambiguous date of any publication is essential to nomenclatural stability and provision of a fool-proof method of resolving this confusing situation would be of immediate benefit. At present it is possible to establish which of Ehrenberg's publications appeared first and roughly when by reference to contemporary records, such as those published in the *Compte Rendu* of the Paris Academy of Science. Each edition of the *Compte Rendu* published a list of papers received by the Academy and thus it is possible to be reasonably precise about actual publication dates by comparison with these receipt dates. While it is possible to establish when a particular publication actually appeared, it would be of enormous benefit to track down, date and record electronically all of Ehrenberg's publications. This need not be a particularly time consuming exercise, given access to appropriate libraries (such as the BM which has the benefit of previous taxonomists' annotations on some of Ehrenberg's publications) and would only need be done once. The effort would ensure that subsequent workers are made aware of Ehrenberg's publication record and provide confirmed dates of publication. Such a task is being undertaken by Dr. P. Silva (see Lazarus, This Volume).

While such an effort is largely non-scientific, it should not be regarded as a wholly historical or 'pseudolegalistic', as Hawksworth (1992) succinctly and correctly characterises many such endeavours, but would serve to provide information to remove ambiguity from the use of Ehrenberg's names, allowing application of accurate species descriptions (based on modern techniques of light and electron microscopy) that are relevant to contemporary systematics, taxonomy and biogeography.

BIOGEOGRAPHY, FOSSILS AND EHRENBERG

Ehrenberg's ideas on the origin of species were somewhat idiosyncratic, even by the standards of his own contemporaries. His Polygastrea theory

——— *emarginatum:* B. corpusculorum valvis lateralibus quadrangulis, ad Crucis formam subaequaliter profunde angulosis, radiis obtusis duobus oppositis (ventralibus) emarginatis, striis transversis validis laxis in $\frac{1}{96}'''$7, in $\frac{1}{72}'''$8. Sutura nulla. Longit. $-\frac{1}{72}'''$. Sibiria. Mexico. Fossile. Valvas s. foliola 19 in singulo libello observavi, duos libellos semel concatenatos vidi.

Figure 1. Reproduction of Ehrenberg's (1845) description of *Biblarium* (=*Tetracyclus*) *emarginatus.*

allowed him a refutation of the transmutation theories of the *Naturphilosophen*. He did not accept the notions behind idealism, that all forms shared a single archetype, or the ideas of spontaneous generation but "saw life as sharing in a unity of organs dictated by the universality of basic functions" (Churchill, 1989: 191). Ehrenberg also rejected Darwinism (and materialism), suggesting that Darwin's evolutionary theory was "eine sympathische Krankheit" and that the *Origin of Species* was "einen Unterhaltung schaffenden Roman" (quotations from Zölffel & Hausmann, 1990: 293). Regardless of these opinions, we have noted above (Williams & Huxley, This Volume) that Ehrenberg was an acute observer and his opinion's on biogeography, for instance, were somewhat more interesting. In the following example we demonstrate the relevance and necessity of the interplay between data acquired from specimens and publications and its application to a contemporary scientific problem.

The diatom species currently known as *Tetracyclus emarginatus* (Ehrenb.) W. Smith was originally described by Ehrenberg (1845b) and placed in his new genus *Biblarium* Ehrenb. (Williams, 1987: Figure 1). While Smith (1856) appears to have been just in his assessment of the synonym between his own new genus *Tetracyclus* and Ehrenberg's *Biblarium*, he also suggested that there were no appreciable differences between the fossil species of Ehrenberg's *Biblarium* and his own extant material. Smith retained only two species in the genus *Tetracyclus*:[5] *T. lacustris* (=*T. glans* (Ehrenb.) F.W. Mills, see Williams,

5 "The genus *Biblarium*, constituted by Ehrenberg in 1845, appears to differ from the present merely

1987) and *T. emarginatus*. Smith's judgements were most probably made on the basis of only Ehrenberg's illustrations as no relevant fossil material is in Smith's collections at BM. In the 1845 protologue, Ehrenberg described *T. emarginatus* in material from 'Sibiria' and Mexico[6] (Ehrenberg, 1845b). When he compiled the massive *Mikrogeologie* (Ehrenberg, 1854), he included five different illustrations for *T. emarginatus* from three localities: Siberia and Mexico (Figures 2 & 3) were included along with Loka, Sweden from additional material (Figure 4)[7]. However, without access to Ehrenberg's specimens, it still remains difficult to positively identify any of the specimens depicted in his five illustrations. Interestingly, examination of specimens of non-type material from Mexico in the BM collections reveals only species of *T. lacustris* var. parvula Forti (1932)[8]. Remarkably, one of the distinguishing features of *T. lacustris* var. *parvula* is that the girdle bands are closed (complete hoops), rather than the usual open kind (for further details see Williams, in prep. & Figure 5). Thus it seems quite possible that the specimens Ehrenberg illustrated from the Mexican locality may be *T. lacustris* var. *parvula.* Again, it is possible that even the Siberian specimens may belong to *T. lacustris* var. *parvula*, a viewpoint supported perhaps by some illustrations in Li (1984) who studied a fossil deposit from Shandung in China (the same material has been studied by Williams, in prep.; see footnote 5). The traditional view of *T. emarginatus*

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in the solitary character of its frustules, and this character arises from the fossil nature of the gatherings from which Ehrenberg derived his specimens. I feel assured that all the speeies of *Biblarium* are filamentous in a living state and that a greater number of them are casual varieties of *Tetracyclus lacustris.*" Smith (1856: 38). "It [T. emarginatus] is possibly only a variety of the latter [T. lacustris] ..." Smith 1856: 37. This viewpoint still appears in the more modern literature, for instance Round *et al.* (1990: 400).

6 "B. corpusculum valvis laterabilis quadrangulis, ad Crucis forman subaequaliter profunde angulosis, radiis obtusis duobus oppositis (ventralibus) emarginatis, striis transveersis validis laxis in 1/96'''7, in 1/72'''8. Sutura nulla. Longit. -1/72'''. Sibiria. Mexico. Fossile. Valvas s. foliola 19 in singulo libello observavi, duos libellos semel concatenatos vidi" (Ehrenberg, 1845b: 74).

7 See Williams, 1987: fig. 35 for a reproduction from Ehrenberg 1854: pl. 33/2, fig. 6. This specimen came from "Barulina, Sibirien" and was erroneously labelled as *Biblarium strumosum* in Williams, 1987, legend to figures 33-44; Williams 1987: figs 37-40 for reproductions of Ehrenberg 1854: pl. 33/7, figs 3-5*. These specimens came from "Tisar, Mexico". The figure numbers corresponding to Ehrenberg's plate were incorrectly recorded in Williams 1987. Williams, 1987, fig. 37 corresponds to Ehrenberg's 1854 pl. 33/7, fig. 3; Williams, 1987, fig. 38 corresponds to Ehrenberg's 1854 pl. 33/7, fig. 4; and Williams' figs 39 and 40 correspond to Ehrenberg's 1854 pl. 33/7, figs 5 and 5*.

8 This taxon should probably be recognised at the species level (Williams, in prep.). Material for a light microscope study came from two sources: China and Mexico. The Chinese specimens comprise three complete valves from the Miocene fossil deposit at Den Hua Jiling Province and Shangdu County of Inner Mongolia (BM 81618), five specimens of complete valves from the fossil deposit at Fusong Basin of Jiling Province and Weixi of Yuana Province (BM 81619) and two specimens of complete valves from the fossil deposit at Shan-wang, Lin-chu district of Shantung deposit (BM s.n. Voigt; from material first described in Voigt, 1937). The Mexican material is from Vallée de Toluca (BM 14801, Tempére and Peragallo, Diat. monde entier, 1st edn. no. 547), Istlahuaca, (BM s.n., Müller) and a slide labelled simply "Mexico" (BM 71507, Wm. Gattrell Barnes). Ehrenberg's Mexican material was from "Tisar".

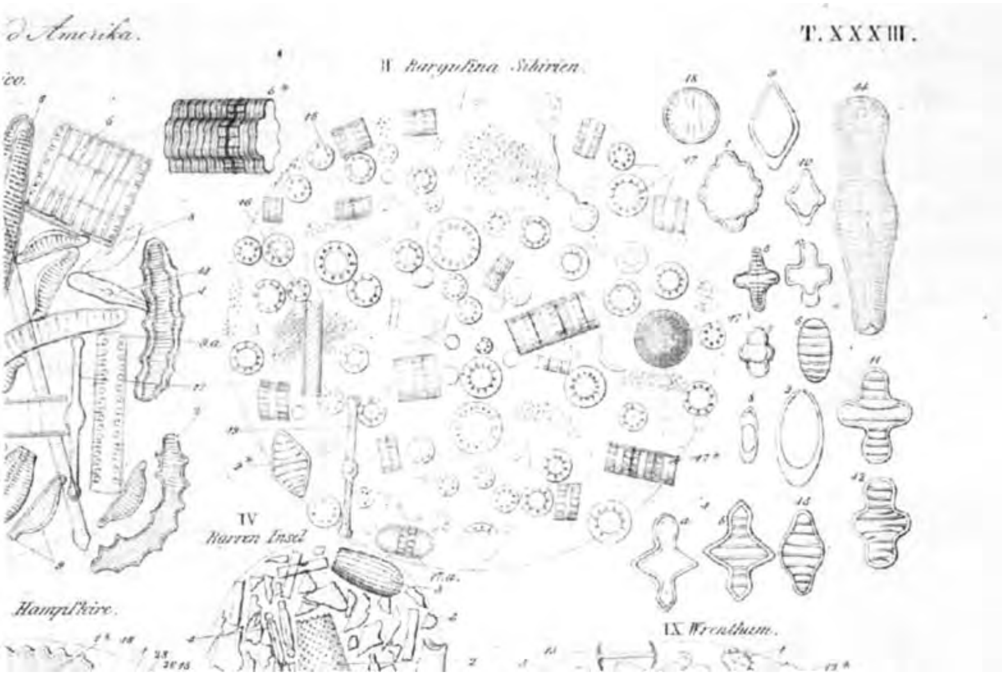

Figure 2. Reproduction of Figure II, Taf. XXXIII from Ehrenberg's *Mikrogeologie* (1854), illustrating specimens from Siberia.

(with open bands) is neatly captured by the specimen from Ehrenberg's Swedish locality ("Loka", from Ehrenberg, 1854: pl. 16/3, fig. 5a, b)[9].

T. lacustris var. *parvula* occurs only as a fossil and along the Pacific rim areas of western USA, Mexico and possibly Chile, and along eastern Japan, Siberia, and China. Its distribution is more or less circum-Pacific, a pattern mirrored by many plants and animals inviting various explanations relating to the history of the earth (for more general details of current understanding see Humphries & Parenti, 1998). *T. emarginatus sensu stricto* is, however, a distinctly boreal species, still living, reasonably common and possibly not even closely related to *T. lacustris* var. *parvula* (Williams, 1996).

Without appropriate specimens or accompanying literature, establishing the patterns of distribution among these species might not have been possible – and no definitive decision can be made until Ehrenberg's specimens have been studied. To illuminate the present situation with respect to the identity and distribution of *T. emarginatus*, examination of Ehrenberg's material will allow

9 While Ehrenberg's illustration of the 'Loka' seemingly has a closed band, examination of preserved material shows this not to be the case (BM 31746). The ambiguity in these and other illustrations can only be resolved by examination of material.

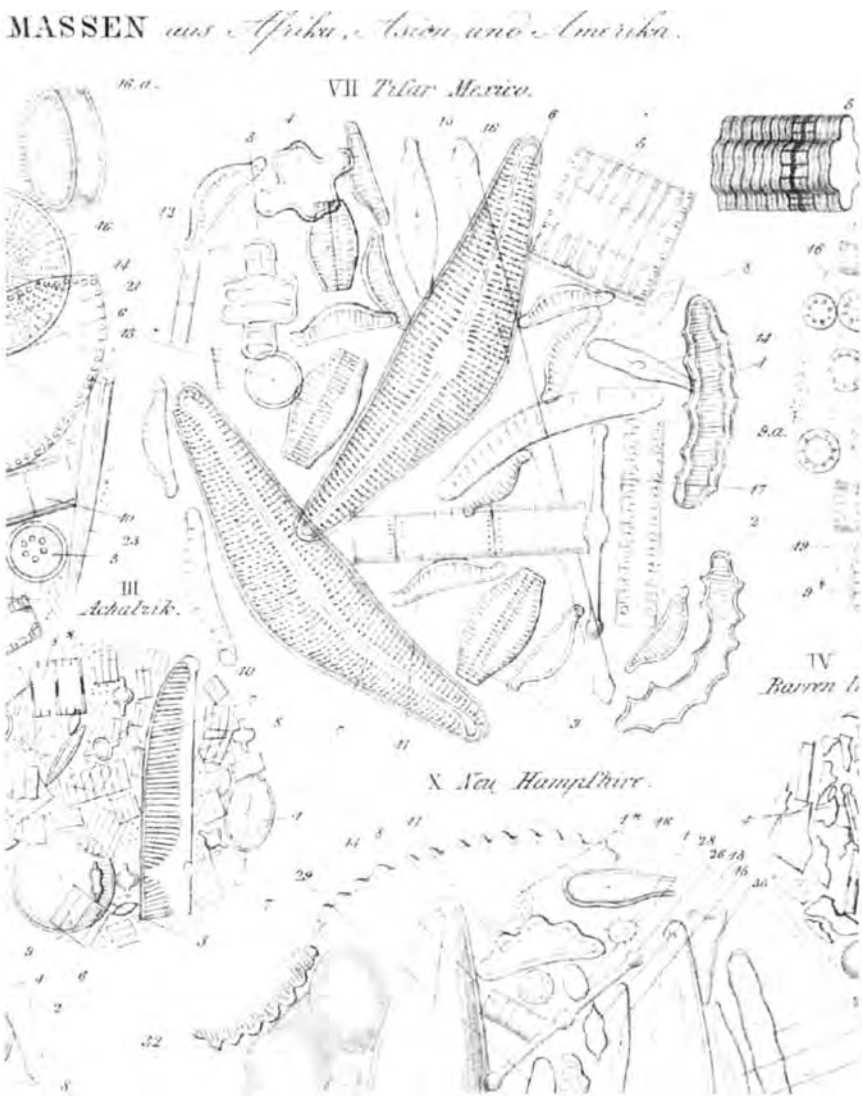

Figure 3. Reproduction of Figure VII, Taf. XXXIII from Ehrenberg's *Mikrogeologie* (1854), illustrating specimens from Mexico.

refutation or confirmation of the thesis presented above. To extrapolate further, without extensive collections not only would such distributional patterns go unnoticed, as they have for at least 100 years with respect to this particular taxon, but the entire enterprise of biogeography would be rendered almost impossible. Ehrenberg was working and writing over 100 years ago. With respect to diatoms alone, a considerable amount of work has contributed to the wealth of information superbly captured, for instance, in *The Diatoms of the USSR, Fossil and Recent* (Gleser *et al.*, 1974, 1988, 1992). Ehrenberg felt it was possible to make generalisations concerning Pacific biotic distribution as

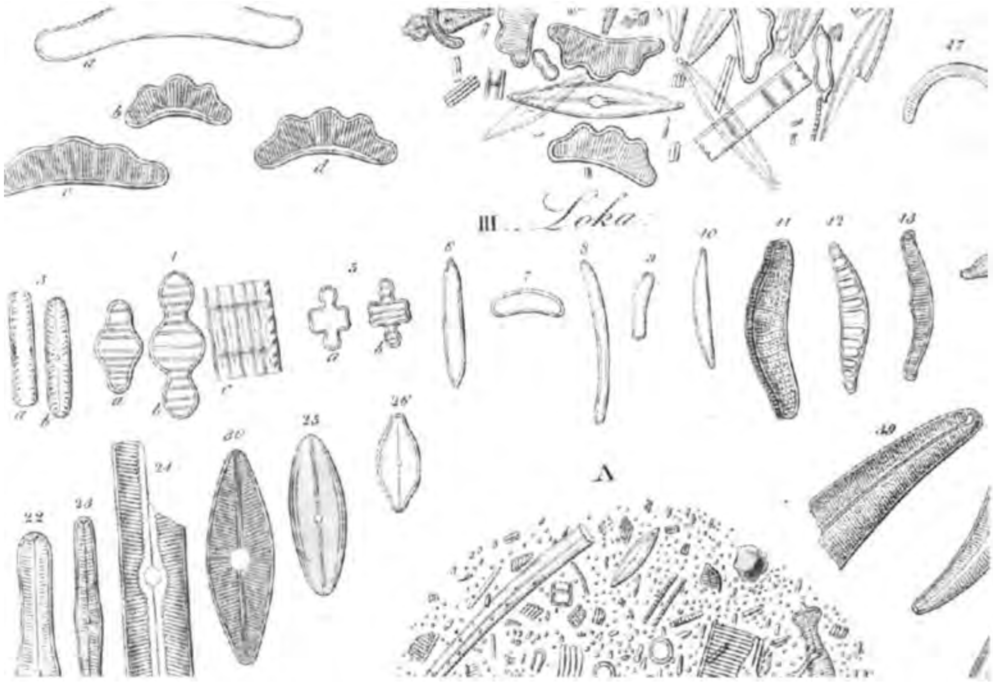

Figure 4. Reproduction of Figure III, Taf. XVI from Ehrenberg's *Mikrogeologie* (1854), illustrating specimens from Loka.

evidenced by his comments in Ehrenberg (1849, 1850, cited above in Williams and Huxley, This Volume). As such, we may regard Ehrenberg's proposals as worthy and potentially testable hypotheses concerning the relationship between the Pacific continental margin and diatom distributions relative to other organisms (see also Kociolek *et al.*, 1997).

THE WAY FORWARD

Any major initiative for improving access to Ehrenberg's collections will come from those most closely associated with the material (Lazarus, This Volume) as well as those whose studies can be directly enhanced by their examination (we humbly submit as an example the biogeographic studies relating to *Tetracyclus*; Williams, 1996). It hardly need be said, but a co-operative spirit from the taxonomic community is an absolute necessity: many biologists stand to gain from collective effort. From our perspective, as working curators and researchers at one of the world's largest and most significant diatom collections, we propose a few preliminary suggestions (some of which need not necessarily be undertaken in Berlin) that may allow Ehrenberg's work and collections to be part of the 'modern' enterprise of systematics.

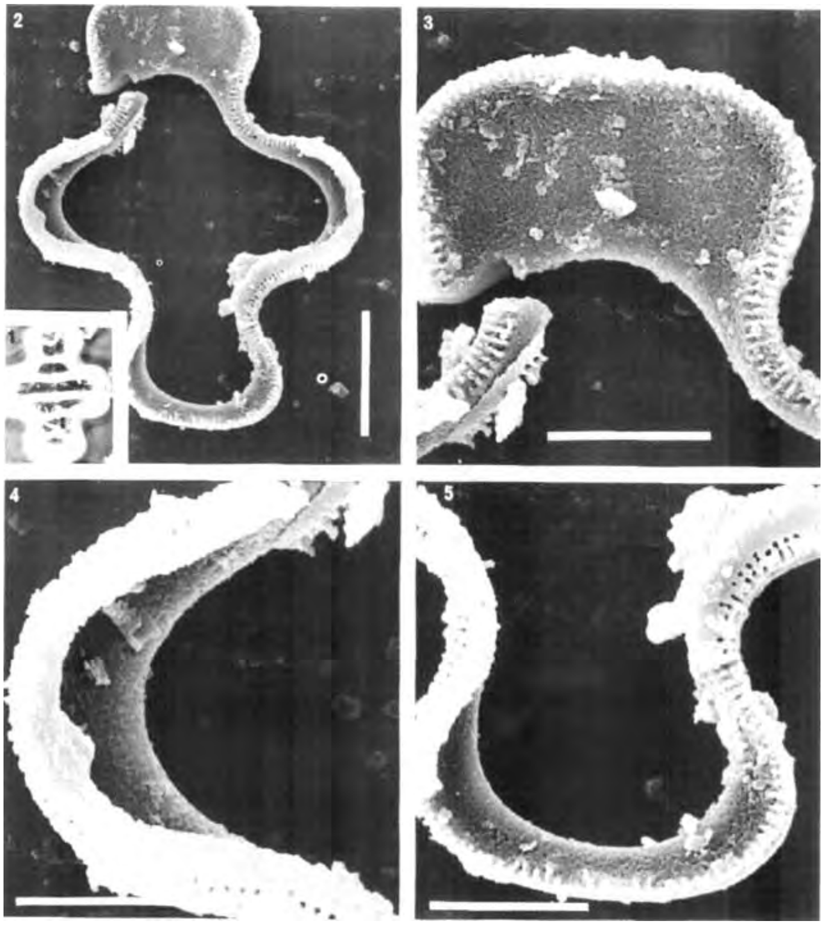

Figure 5. *Tetracyclus emarginatus* var. cf. *parvula.* (1) Light micrograph from Mexico, BM 711507; (2-5) Detail of girdle band from a specimen of *Tetracyclus emarginatus* var. cf. *parvula.* Material from Shan-wang, China, ex Voigt, housed in BM. (2) Scale bar=9.0µ (3) Scale bar=4.0µ (4) Scale bar=3.0µ (5) Scale bar=4.0µ.

Locating publications and establishing dates of publication

The problems of both multiple publications and codes are soluble given a relatively small amount of time and effort. Various catalogues exist that list most of Ehrenberg's output and the major libraries of Europe are easily accessible. For instance, our own experience with the excellent libraries at BM testifies to the amount of time required to trace the various journals, monographs and preprints.

A catalogue of Ehrenberg's taxonomic names

Many of Ehrenberg's publications contain descriptions of new species. These names should be catalogued with a reference to the appropriate literature. It would seem sensible to document the names prior to validating them. The primary reason is that the task would appear monumental. Just a glance at Van Landingham's diatom catalogue gives some idea of the nature of the task. We suggest that a more useful approach, after the names have been collated, would be to focus around particular problems seen as relevant.

Creation of a link between names and publications

To enhance the usefulness of Ehrenberg's material, the protologue requires linking to the specimens. In terms of what is now possible electronically, there is a real possibility that Ehrenberg's taxonomic names could be directly linked to the literature and would provide a valuable source when eventual typification is made by the relevant person.

Geographical data

Any database can be organised geographically and would provide valuable biogeographic data, at the very least guiding researchers to relevant parts of Ehrenberg's collection. This allows the opportunity to frame studies on Ehrenberg's collections around distributional as well as taxonomic questions and emphasize the importance of conserving and making available data.

CONCLUSIONS

It is necessary for systematists to continue collecting specimens. It is necessary to preserve this material in such a way that future generations will benefit. It is necessary that all observations made today are verifiable (and enhanced) by those that come after us. It is our view that, just as in the case of such great taxonomists as Linnaeus (Jarvis *et al.,* 1994), we bear the responsibility of acknowledging and preserving what Ehrenberg achieved, just as we expect those that come after us to treat our own endeavours with appropriate respect.

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Ehrenbergiana: problems of elusive types and old collections, with especial reference to diatoms

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Abstract

Contrary to popular opinion and the recent appetite among some nomen- claturists for a unified BioCode, the main impediments to systematics research are not inconsistencies between the five current codes of nomenclature. Instead, one of the principal difficulties is the inordinate time spent searching for holotypes or lectotypes of taxa published before 1958, and the apparent pointlessness of this search, especially given the recent trend for 'current usage' to be preferred over authors' original intentions. Measures to increase the efficiency of the type method in practice could include the registration of types of new taxa and their deposition in designated repositories, and a time limit for registration of the types of older names, after which existing typifications would be non-mandatory. If 'current usage' can be defined satisfactorily and is to be preferred in the interests of stability, it seems logical to alter the laws of nomenclature to remove the automatic priority given to holotypes or lectotypes. To lessen the chance that current usage will drift away from correct usage in future, information about types must be made more readily available to users of taxonomy, e.g. as images disseminated via hard-copy and the Internet. Diatom types should only ever be single specimens.

INTRODUCTION

This volume celebrates the work of C.G. Ehrenberg and the welcome prospect that his remarkable collections, unique not only for their scientific value but also in the manner of their preparation and storage, may soon be restored to a state where they can be studied by taxonomists and also, perhaps, where they can be used for other kinds of research. I have little to add to the evaluations of Ehrenberg's work made here by others, since most of my essay is not directly about Ehrenberg, but about the problems old collections (including Ehrenberg's) pose for taxonomists, particularly those who study diatoms. However, first I should like to make some observations about Ehrenberg in relation to the study of diatom protoplasts, following an interesting recent paper by Jahn (1995).

Jahn describes how Ehrenberg came to the conclusion that diatoms are animals, with complex internal organs, and she documents the obstinacy with which he held to this view as scientific advances (from around 1840 onwards) showed, ever more clearly, the similarities between diatoms and other algae (e.g. Kützing, 1844; Smith, 1853–6; Pritchard, 1861) and began to reveal the true nature of the eukaryote cell. Ehrenberg seems to have been unable to adjust to new ideas and, even during his life, his interpretations of diatom cells must have come to appear not merely wrong but foolish, though he was not alone in his views (e.g. Meneghini, 1853, a translation of a paper published in 1845). But in one way diatom research took a step backwards when Ehrenberg's views were discredited and the diatoms (and many other microscopic algae included by Ehrenberg in the 'Polygastrica') were established to be autotrophic organisms, since there was then far less reason to study the organisms themselves, rather than their shells.

For as long as diatoms were thought to be animals, and while their chloroplasts, nuclei, vacuoles and storage products were still interpreted as digestive and reproductive organs, the structure of the diatom protoplast *had* to be studied, since only then could diatoms be compared with all the other organisms that Ehrenberg and his contemporaries included within the Infusoria – rotifers, ciliates, flagellates, amoebae, desmids, etc. Once diatoms were accepted to be algae, however, and shown to have the same basic cell structure as any other plant (save the blue-green algae), the main problem of classification appeared to have been solved. The main tasks for taxonomists seemed now to be to catalogue diatom diversity and to provide means of identification. In this, the fascinating complexity of the frustule and the convenience of using preserved, mounted material quickly led most people to use cleaned valves and frustules as almost the sole basis for taxonomy, and to ignore the cell itself. Thus, between 1850 and 1950, students of the protoplast were relatively few, notable exceptions being Pfitzer (1871), Lauterborn (1896), Karsten (e.g. 1899), Mereschkowsky (1901, 1902–3, 1903, 1904a, b, 1906) and Geitler (e.g. 1937a, b) (see also Mann, 1996). Unfortunately, by ignoring the plastids, nucleus and other cytological features, phycologists denied themselves a rich source of systematic data and the opportunity to study many interesting processes, including mitosis and cytokinesis, plastid movements and division, and morphogenesis.

The change in approach can be illustrated by comparing Ehrenberg's beautiful plates of living (sometimes recently dead) diatoms in the *Infusionsthierchen* (1838) and Kützing's exact but dull drawings six years later (1844). In Kützing's monograph the cell contents are represented perfunctorily, if at all, in the plates and they are neither described nor labelled; in the text the main focus is on frustule morphology and colony formation. Ehrenberg's illustrations, on the other hand, show the protoplast in considerable detail and its features are described and carefully (though wrongly) interpreted in the lengthy species descriptions and figure captions.

The same trend is documented in Pritchard (1861), which contains plates from different editions of a *History of Infusoria.* The later plates, by Tuffen West, are more useful taxonomically and more accurate than the earlier ones (as they ought to be, with improvements in microscope design), but they lack the biological interest and cytoplasmic detail of the plates produced in 1841 and 1852 by Pritchard himself, who had clearly been inspired by Ehrenberg. In W. Smith's *Synopsis of British Diatomaceae* (1853–6), cellular detail is depicted in seven colour plates and discussed briefly in the Introduction, but it forms no part of the descriptions of species and genera. Curiously, another feature only seen in living material – colony formation – remained important in Smith's classification, as it did in Kützing's.

THE NEED FOR HISTORIC COLLECTIONS

The main purpose of this essay is to consider some general issues surrounding the value, use and curation of historic collections and the typification of diatoms. Most herbaria take especial pride in their older material and type specimens, particularly if these were collected or studied by eminent scientists like Ehrenberg. I suspect I am not the only one, however, who has wished rather more frequently than conscience should allow, that bomb, fire or flood had destroyed more herbaria and museums – or at least the types they contain – providing, of course, that this could have been done without hurting their curators! I admit that I have certainly had such wicked thoughts about the Ehrenberg Collection.

After many years in which the Ehrenberg Collection has been preserved but unused, plans are now in hand to restore it to 'full working order'. There should soon be no need for anyone to be other than profoundly thankful that the Collection did not fall victim to enemy action in the last world war and that it has in fact survived remarkably well since Ehrenberg's death. But let us consider what would have happened if there had been no new plans to make it more accessible: what if there had been no perestroika and the Ehrenberg Collection had remained in East Berlin, effectively hidden from most of those who might have wanted or needed to study it, even within the eastern bloc itself? What if the scientific academies of the German Democratic Republic or their successors in the reunited Germany had made no special provision for this large and historically important collection of material? These are not idle speculations. There are many collections around the world that languish in old buildings, or in cupboards that are never opened. In western Europe, many universities no longer support any research in systematics and have no use for old collections of preserved animals and plants. What should be done with them?

In many cases, it is irresponsible to discard collections, since parts or all of a collection may be irreplaceable and even a modest collection represents a very considerable investment. I have suggested elsewhere (Mann, 1997) that herbarium specimens of angiosperms may cost around £25 on average to acquire and incorporate into a European collection. This is an acquisition cost, not a valuation, but it does give some idea of the investment that has been made in developing collections and the cost of replacing them, if indeed this were to be possible. Slides of diatoms are probably even more expensive, as a result of the work necessary to clean specimens using concentrated acids or other oxidizing agents, and the subsequent washing and mounting in high refractive index media.

Clearly, then, one should think carefully before throwing away a collection that has cost many thousands or millions of pounds to build up and may be even more expensive to replace. But there are many other reasons too why old collections should be kept. They are a resource for new research and they document and validate the work of previous generations of scientists and collectors. Battarbee (1979) was able to check and re-interpret early twentieth century studies of the phytoplankton of Lough Neagh, N. Ireland (Dakin & Latarche, 1913), by studying two of the original samples that had been preserved at the Natural History Museum in London (see also Flower, 1986). Specimens often record the date and place of collection, so that it is possible to work out changes in distribution through time, as a result of pollution, habitat destruction, the spread of alien species and so on. Sometimes, specimens that were collected quite accidentally can be as useful or more useful than specimens collected deliberately. Thus, for instance, Van Dam & Mertens (1993) were able to use diatoms attached to herbarium specimens of aquatic macrophytes to determine the long-term effects of eutrophication in a nature reserve in the Netherlands. Their data gave useful insights on the likely outcome of a management strategy proposed for the reserve, involving reduction in phosphorus loading. The labels on herbarium specimens of angiosperms may record ethnobotanical information (e.g. Chaudhuri, Banerjee & Guha, 1977), which may be useful in the search for new plant products and pharmaceuticals.

Sometimes old collections contain species that are now extinct, such as the angiosperm *Trochetiopsis melanoxylon* (R. Brown ex Aiton f.) W. Marais, formerly endemic to St. Helena but extinct since *ca* 1780 and now represented by just five herbarium sheets (Q.C.B. Cronk, personal communication to Mann, 1997). In this and many less dramatic examples, museum and herbarium specimens are irreplaceable in an obvious and non-trivial sense.

However, for various reasons, parts of a valuable collection may not be actively studied for years or decades. We could suggest that in these circumstances, there may be no need for any curation to be done, beyond a minimum of care and maintenance. The collections may not be being used now, they may not even be usable, but one day they may be. I have heard of a university Head of Department who stopped short of suggesting that the collections in his charge should be thrown away, but did threaten to board them up. By accident or design, many old collections today are, in effect, boarded up, and perhaps we should simply be glad that they survive at all.

But although this laissez-faire attitude may be acceptable for some kinds of collection – specimens formerly used in research or teaching, for example, or the voucher specimens of ecologists and palaeoecologists – it is not satisfactory for collections that contain type specimens, such as the Ehrenberg collection. Type specimens are biological standards, defining how the names of taxa are to be applied, and it must be possible to refer to them when there is any controversy about which name is correct. Laissez-faire, as a policy for dealing with moribund collections containing types, is not merely unsatisfactory, it is intolerable. We must take steps, by whatever means are available, to make sure that information about type specimens is easily available, and that the types themselves are usable for their prime purpose: the standardization of nomenclature.

THE NEED FOR TYPES

The type method is now accepted as a fundamental tenet of botanical nomenclature. The current *International Code of Botanical Nomenclature*

[ICBN] (Greuter *et al.*, 1994) requires that the use of names is to be determined by reference to types, which are usually preserved specimens, unless it is impossible to preserve anything useful. Hawksworth & Kirk (1995) have called types the "keystones of unequivocal communication in biology". It is salutary to remember, however, that typification has been mandatory for only 40 years. Indeed, during the first 150 years after Linnaeus' invention of biological nomenclature, the type method scarcely existed at all. The type method was not part of the first laws of nomenclature (de Candolle, 1868). It was formally introduced in the *American Code of Botanical Nomenclature* (Arthur *et al.*, 1904, 1907) and has gradually won acceptance since (Perry, 1991), becoming fully established only on 1 January 1958 (Greuter *et al.*, 1994: Article 37). The progress of the method can be seen by examining issues of a suitable taxonomic journal, such as the *Notes from the Royal Botanic Garden, Edinburgh.* Between 1910 and 1920, a few authors designated types (e.g. Simpson, 1915) but most did not (e.g. Balfour, 1919). By the 1930s, types were usually specified (e.g. Cowan, 1932), but Tagg (1931) did not indicate types for several new species of *Rhododendron.* It should come as no surprise, therefore, that there are many problems of typification arising from before 1958, and it is no disgrace to taxonomists that a backlog of typification still exists.

However, in the last ten years there has been a change to the ICBN which makes me wonder what role types now play or will play in future. Article 57 of the current ICBN (Greuter *et al.*, 1994) says "a name that has been widely and persistently used for a taxon or taxa not including its type is not to be used in a sense that conflicts with current usage unless and until ... [proposals for conservation or rejection have been] submitted or rejected" – a presumption in favour of re-typification. Article 24.1 of the Draft BioCode (Hawksworth, 1996) also says that when there is a conflict between the current usage of a name and 'correct' usage, as determined by the type, current usage is to be preferred. This surely means that, if the identity of the type is known and the use of the name that it typifies is uncontroversial and correct, the type is unnecessary (since standardization of nomenclature is essentially complete); if the identity of the type is not known, the type is a fiction; and if the identity of the type becomes known and would require a change to current usage, the type is to be ignored and replaced. Perhaps the authors of this change to the Code considered that there would be only a few cases where 'current usage' conflicts with correct usage, but this is not true in diatoms: there are many. For diatoms at least, the type method seems to have been seriously undermined by Article 57 and the type itself no longer seems to have much importance. True, when the type of one taxon is found to belong to another at the same rank with an earlier name, the type method still holds sway, and the later name will have to be replaced or conserved with a new type, but in diatoms this is probably not common, since there are many fewer names available than there are taxa needing names. When taxa are divided, the type is used to determine which of the daughter taxa bears the original name. However, if a taxon is found to be heterogeneous, assigning names to the segregate taxa might as well be arbitrary, since the information gathered about the composite parent taxon cannot usually be apportioned between the taxa segregated from it. Presumably too, if current usage were again to drift after a taxon has been conserved and neotypified to make 'correct usage' conform to 'current usage', Article 57 would require typification to be adjusted yet again. If so, types are a strange kind of standard.

The principle of using types as a basis for nomenclature is excellent, but in practice it has been weakened by changes in the International Code, especially the extension of conservation to the species level. It would be weakened still further by the adoption of lists of names in current use (see Hawksworth, 1996). One wonders why time and money should be spent in searching for holotypes, isotypes or syntypes if, in the end, all that matters is current usage. A great deal of effort could be saved by designating neotypes. Indeed, there seems to be a philosophical inconsistency in the present version of the ICBN. Article 57 and other measures that have been proposed seek to stabilize nomenclature in current use. On the other hand, according to Article 9.13, a holotype or lectotype is always to take precedence over a neotype. Yet, if there is a neotype, it is more likely to correspond to 'current usage' than any holotype or lectotype that may subsequently be discovered. Article 9.13 thus creates the kinds of problem that Article 57 then attempts to circumvent, via the slow procedures of conservation and rejection.

All these difficulties arise because of a fundamental weakness in what we could call the 'type system', i.e. the application and operation of the type method day-to-day. The type system is weak because typification and current usage are almost decoupled. When I use a ruler to estimate length, I am using a near facsimile of a standard rule, itself calibrated directly or indirectly by reference to the definition of a metre as the distance travelled *in vacuo* by light in 1/299 792 458 of a second. We can calibrate our clocks every day by reference to standard time, broadcast via radio or television. But those who use biological units – genera, species, varieties, etc – have little or no opportunity to calibrate their identifications and usage. For ecologists, biochemists and other users of taxonomy, the types are out of sight, masked by layers of interpretation and exposition in monographs, floras and field guides. Their material nature is described but not experienced; in many cases it is not even illustrated. To some extent the standardization of biological nomenclature is inevitably weaker than the standardization of units of time or physical measurement, since each taxon is not a single, unvarying quantity, like a metre or a kilogram, but a group concept. The type offers no help in standardizing the concept of a particular species or other taxon: its only, but vital, function is to standardize nomenclature. However, although names will change their meaning from time to time, as the groups they refer to are made more or less inclusive, there would certainly be less doubt and error, and far less conflict between current and correct usage, if types could be made as easily available as rulers and standard time.

Types have to be specimens unless preservation is impossible and there are good reasons for this. Descriptions are derivative and subjective, and contain only as much information as was present in them at the instant of their creation. Illustrations also allow only limited new interpretation and research. Specimens, on the other hand, usually yield more and more information with further study. Thus, if a new character is found, which helps separate a taxon into two or more daughter taxa, this can often be studied in a type specimen, whereas no information about that character may be evident in the protologue or illustration. The penalty of using specimens as types is that the types themselves cannot be distributed (except in limited numbers, as isotypes). Images and text, on the other hand, can be duplicated indefinitely, either electronically, or as photographs, or in printed material. Ironically, therefore, now that light and electron microscopy can provide a detailed photographic inventory of the morphology of even the smallest cell, the nomenclature of unpreservable, wall-less algae and protists may in future prove more stable than that of vascular plants, bryophytes and macroalgae, preserved in their millions in herbaria.

Thus, one of the most important contributions that could be made to nomenclatural stability, perhaps more important than any other, would be for herbaria and museums to produce illustrated catalogues of their types, as recommended also by Williams (1993). This has been done for some diatom collections, e.g. by Williams (1988) and Simonsen (1987, 1992). In future I hope that such catalogues will be made freely available via the Internet, as well as being produced as hard-copy. In diatoms, a photograph (or a series of photographs, taken in different focal planes) can show virtually all of the features necessary for identification. In this special case, we should ask ourselves which should be considered the real nomenclatural standard: the image and any accompanying textual material in type catalogues (which will probably be the principal influence on future usage), or the specimens from which the images were derived? For diatoms, I would prefer the image. If a type photograph did not show some feature subsequently found to be important for diagnosis, further photographs could be added as epitypes (Greuter *et al.*, 1994: Article 9.7), or other defining data, such as nucleotide sequences (as yet, the ICBN does not allow this).

THE TYPE METHOD IN PRACTICE

Although the type method seems to have been seriously undermined by Article 57 of the current ICBN, let us assume for the remainder of this essay that the type method will continue to play an important part in botanical nomenclature.

I wrote to someone once that Ehrenberg's collections are the greatest single obstacle to progress in diatom taxonomy. This was an exaggeration, but it contained more than a grain of truth. The species and genera that he described have been, and are still, a source of confusion, dispute and nomenclatural instability. Ehrenberg lived for a long time in an age of exploration and discovery, and almost inevitably he described many new species and genera. Unfortunately, in most cases we do not know what his names mean. We use them, sometimes consistently, sometimes inconsistently, but we often have no idea whether our use of his names corresponds to his.

I will take the genus *Diploneis* as an example. Ehrenberg described several species that are now referred to the genus *Diploneis* and the genus itself is also his. Among the species Ehrenberg described are the marine diatoms *D. didyma* (Ehrenb.) Cleve, *D. crabro* (Ehrenb.) Ehrenb. ex Cleve and *D. bombus* (Ehrenb.) Ehrenb. ex Cleve. These names are commonly used today and there has been a fair degree of consensus in the last 60 years about what they refer to. The consensus began to develop from 1875 or so onwards, and hence after Ehrenberg's death; but although these three diatoms, like many *Diploneis* species, are coarsely structured and quite large relative to many other pennate diatoms (so that it is less likely that Ehrenberg and other early authors could misinterpret each other's illustrations and text), today's consensus may bear no relation to Ehrenberg's original intentions. Some other Ehrenberg names, such as *Diploneis entomon* (Ehrenb.) Cleve, which also refer to large, coarsely structured diatoms, can be found only in old Floras, nomenclatural catalogues and indices. For some reason they, unlike *bombus, crabro* and *didyma*, have been neglected and are now uninterpretable, a source of instability for the future. As noted above, it is now possible to conserve a name of a species in such a way as to exclude its original type and thus allow 'current usage' to be protected and continued. Thus, whatever Ehrenberg meant when he used the names *didyma*, *crabro* and *bombus*, could be made irrelevant by conservation. However, it now appears that the species concept in diatoms is generally too broad (Mann, 1989; Droop, 1994; Mann & Droop, 1996), so that the consensus concepts of *didyma*, *bombus* and *crabro* are no longer tenable and therefore must not be protected. These species are heterogeneous and need to be divided into several, more narrowly circumscribed entities, each with its own distinctive morphology, ecology and distribution. Which, if any of them, is Ehrenberg's *crabro*, which is *bombus*, which *didyma*, which *entomon*? Only type material can give the answers.

Another species described by Ehrenberg, *Navicula lyra*, has become the type species of a new genus, *Lyrella*, which was described by Karayeva (1978). *Lyrella* species share a number of characteristics of frustule structure, chloroplast arrangement and chloroplast division patterns, and sexual reproduction that link them together and separate them from *Navicula* Bory species, and also from superficially similar diatoms now classified in *Fallacia* Stickle & D.G. Mann. In all *Lyrella* species the striae are interrupted by a lyre-shaped area and it is the shape and ornamentation of this area, together with valve shape and size and striation density, that form the basis for species differentiation. But in fact, we do not know what Ehrenberg was looking at when he described *Navicula lyra* from material collected in the Falkland Islands in the 1830s: we know only what other people have thought he meant. Type material has not been examined, because it has been inaccessible, as a result of the history of the Ehrenberg collection and the complex politics of twentieth century Europe. We do not even know whether Ehrenberg's species would fit within *Lyrella* as this genus is now circumscribed, though we can be certain it does not belong to *Navicula* (Cox, 1979; Round, *et al.*, 1990).

None of these nomenclatural problems can be solved until Ehrenberg's collections can be consulted. Similar problems exist in relation to many other collections and names. They are the kinds of problems every taxonomist faces and their solution is an essential step that cannot be circumvented. In a taxonomic research programme, we do the 'science' first, examining many specimens and many taxonomic characters. Then a preliminary classification is formed, which if possible is tested against other evidence and further specimens. Once we are satisfied with our classification, we have to find the correct name for each taxon. From available floras, monographs and papers, and any catalogues, indexes and databases that have been made, we try to find all the names that could conceivably be relevant. Then we examine type material to see how these names should be applied. Finally, we use the rules of nomenclature to determine what names are in fact legitimate for the taxa we wish to retain. This last, purely nomenclatural phase is the shortest of all, unless it leads to an application for conservation or rejection, and it could be made even shorter by the development of an interactive computer program that embodies the pseudolegal framework of the relevant code of nomenclature. Even if conservation or rejection procedures are initiated, the nomenclatural phase is slow rather than time-consuming: while a decision is awaited, one can get on with other things. And because it is a short phase, the application of the rules of nomenclature is inexpensive relative to the primary research (studying the variation pattern and producing classifications), and also relative to the middle phase – the search for relevant names and the examination of type material. It is here that the research programme often grinds to a halt. What is the type material? Did anyone ever designate a type? Does it still exist and if so, where is it? Will anyone lend it to you? Will they even reply to your letters and faxes? If they won't lend it, or say that it's up to you to come and find it, because it should be somewhere in the herbarium, can you afford to travel to see it? Can you get a visa? Will there be anyone to show you how to find the types when you arrive and will there be any facilities available to you to examine them?

I can illustrate the difficulties from our experience in Edinburgh. Recently, my colleague Stephen Droop has been trying to revise various groups within the genus *Diploneis*, during the preparation of accounts for a Flora of British Marine Diatoms. New collections of marine diatoms have been made, of which several hundred have been examined so far, using the light microscope, in order to establish the pattern of variation and occurrence of *Diploneis* around British coasts. Many new taxa will undoubtedly have to be described (Droop, 1994, 1995), but before this is done comparisons must be made with existing species and varieties (Droop, 1996). Stephen has therefore needed to study type material of various taxa, including some described by W. Gregory (1856), e.g. *Navicula splendida* Greg. It is well known among diatomists that Gregory's collection is in the Natural History Museum in London, and it is well known too that Gregory's new species were illustrated not by Gregory himself but by R.K. Greville, who received slides from Gregory, illustrated the specimens indicated by him, incorporated the slides into his own collection and, fortunately, labelled them meticulously. The Natural History Museum has indexes to these collections and curators who are willing and able to find slides and lend them. Here the system worked well and we now know what Gregory's name *Navicula splendida* refers to, from studying a slide in Greville's collection (Droop, 1996).

Stephen also wanted to look at type material of *D. bomboides*, described by Adolf Schmidt (1874). This proved more difficult, since we do not know whether Schmidt's collection survives. Stafleu & Cowan (1985) suggest that Schmidt's herbarium is in Halle, but the curator at the herbarium of the Martin-Luther-Universität in Halle told us that the information in Stafleu & Cowan is wrong. Where this information came from is unknown. Schmidt's collection may have been deposited in the Botanical Institute of the Martin-Luther-Universität after Schmidt's death in 1899, but when the collections of the university were rearranged after the 1939–45 war, no trace of Schmidt's material was found. Stafleu & Cowan also say that there is some Schmidt material in Bremerhaven (BRM), one of the best curated diatom collections world-wide. Searches on our behalf among the Schmidt slides at Bremerhaven showed that there are indeed some that come from the right places (Hvidingsoe and Sölsvig) and they have the right taxa in them. The slides came from Dr Gründler, not Adolf Schmidt, but since Schmidt (1874) acknowledges Gründler's help in preparing samples, it looks as though the Bremerhaven slides contain isotype material. But of course, we can't be sure that we have found the right material. There will always be a nagging doubt that an attic somewhere harbours the real Schmidt collection and that any type we designate, using the Bremerhaven slides, may eventually have to be replaced or conserved. Perhaps Schmidt's original collection was removed from Germany as war reparations. In 1995, I was in Sevastopol and was shown the library of Professor Max Hartmann, one-time editor of *Archiv für Protistenkunde* and Director of the Kaiser-Wilhelm Institut für Biologie in Berlin – an eminent biologist and an exponent of theories of sexuality, who played an important role in phycology in central Europe between the two World Wars (e.g. Garbary & Wynne, 1996). The library was with Hartmann in Berlin until the end of the Second World War, when the two must have parted company: Hartmann himself ended up in West Germany, while his library went to the Ukraine. Were Schmidt's collections also taken, as spoils of war?

Stephen Droop also wanted to look at material of *Navicula splendida* var. *heemskerkiana*, described by Brockmann (1928). Initially he tried the Geological Survey of the Netherlands because we knew they had a small collection of Brockmann slides (de Wolf, 1993). They did not have specimens of var. *heemskerkiana* and referred Stephen to the Niedersächsisches Institut für historische Küstenforschung, Wilhelmshaven, which also has slides made by Brockmann. The curators took the trouble to check all their slides but found nothing corresponding to the sample numbers given by Brockmann (1928). They suggested, therefore, that we try another museum holding Brockmann material, the Senckenburg Institut, and that does indeed appear to be where the slides we wanted are usually kept. But they were out on loan.

For yet another species of *Diploneis*, it was clear where the type material ought to be, since the author's collection has survived where it was deposited, together with his notebooks. After some months waiting for a reply to our request for a loan, we sent a reminder; eventually, the curator replied that type material could not be found. We can either accept the information we have been given, that the original material is truly lost, in which case we could designate a neotype, or we must find the money and time to go and check for ourselves.

Such quests for original specimens take a great deal of time and are very expensive. The cost of searching for Schmidt's and Brockmann's collections must be well over £1000. This represents the time Stephen and I spent trying to identify where collections might be, writing to curators, and the time these curators spent examining their collections. It excludes the cost of the research Stephen did on *Diploneis* that led him to need to refer to type material and it excludes the cost of the research and manuscript preparation following those parts of the search that were successful. And this is for half a dozen names. The number of entries in VanLandingham's *Catalogue of the Fossil and Recent Genera and Species of Diatoms and their Synonyms* (1967–79) is well over 40,000, and a significant number of these entries refer to names invented by less well-known and less careful workers than Schmidt and Brockmann!

In a way, of course, it can be great fun to be a taxonomic detective, tracking down old collections and types, but I can't help feeling there must be better ways to organize the 'type system'. Admittedly, the next time we try to find Schmidt and Brockmann material, we will know better where to look, but this kind of benefit is small compensation for the amount of work, money and time spent searching for and through old collections. Furthermore, if a search reveals a type and this supports the current usage of the name, we have merely confirmed the *status quo* and any resulting publication is not going to attract much interest nor result in many citations! On the other hand, if the type does not agree with current usage, in a way our search will often have been in vain, since the likelihood is that the type will have to be changed (unless we ignore Article 57, by interpreting 'widely and persistently' in an extreme way).

Accurate nomenclature is essential and we do not need to be apologetic about spending money to achieve it. The case for taxonomy and systematics has been made frequently and well in the last few years, for example in Systematics Agenda 2000 documents (1994), and the long-term benefits of biodiversity research are certain, although there may be no immediate improvement in wealth creation or in the quality of life. Those, like Ehrenberg, who classified diatoms in the nineteenth century and early twentieth century, provided us with a basis for detecting and monitoring environmental change, including pollution and changes in climate (e.g. Flower & Battarbee, 1983; Fritz, Juggins, Battarbee & Engstrom, 1991; Laird, *et al.*, 1996). They were not far-sighted philanthropists and had little or no idea what use would or could be made of their research. Even the most inspired Technology Foresight (Chancellor of the Duchy of Lancaster, 1993) would have failed to predict and provide for present needs. So there is no need to be defensive about research into plant systematics. And to be able to do any research in systematics – or any other field of biology, pure or applied – we need unambiguous nomenclature, so that we can accurately communicate information about the organisms we study and use.

But as in any activity, we should certainly try to achieve our goals efficiently, since, even within plant systematics, there are many other demands on limited financial and intellectual resources. In the Newly Independent States (NIS) of the former Soviet Union many scientists, some of them very able indeed, now receive reduced salaries or none at all, and there is very little money for equipment and consumables. A major taxonomic work on diatoms in the NIS, meant to help provide a foundation for ecological studies and the monitoring of water quality in the rivers and lakes of a badly polluted country, waits in a box where it has been for months. It is likely to remain there for months or years longer, because there is no money to publish it. In such situations the search for types is an unaffordable luxury. Hence we must always be searching for better ways to organize taxonomy.

I am not the first taxonomist, of course, and certainly not the most prominent, to suggest that we need to put our house in order. In 1990, Clifford, Rogers & Dettmann caused an outcry when they said that many herbarium specimens could and should be pulped, and Max Walters (1993), in a more moderate commentary, has suggested that it would be easy to reduce the content of European herbaria by up to 20% by judicious weeding. But actually, creating extra space in overcrowded herbaria is not a major problem. Storage in itself is fairly cheap and often it would probably be more expensive to do the judicious weeding that Walters suggests than to leave the weeds alone. The best way to improve the quality of collections is to concentrate on improving the quality of the intake. Do the weeding if there is time, by all means, but don't get too worried about the weeds – they're dead and won't proliferate! The point is that we must be careful to ensure that any new measures we take to streamline the 'type system', no matter how attractive they may be in theory, will lead to real improvements in practice, in the economy, efficiency and effectiveness of taxonomy.

MAKING TYPES AVAILABLE

The first problem we must address is how to make types more readily available. Over the last 250 years, taxonomists have carefully developed a system which, potentially, can standardize nomenclature through the use of types. What has not been done so effectively is to ensure that types can be found and used, efficiently and economically. It is as if the proponents of SI Units, having persuaded everyone to adopt the kilogram as the base unit of mass, then made it as difficult as possible for anyone to find out what a kilogram is, by hiding the international prototype of the kilogram. Types are essential to biological nomenclature and yet the international community lays down no rules determining where type specimens can be kept, nor does it demand any minimum standards for their curation, nor any measures to promote their accessibility and use. The International Code does not say what should happen if a collection becomes moribund and is no longer curated. The fate of our supposedly precious biological standards, these 'keystones of unequivocal communication', can apparently be left to chance. All we get from the latest version of the Code (Greuter *et al.*, 1994) is Recommendation 7A:

> "It is strongly recommended that the material on which the name of a taxon is based, especially the holotype, be deposited in a public herbarium or other public collection with a policy of giving *bona fide* botanists open access to deposited material, and that it be scrupulously conserved."

These are worthy thoughts, but they do not really help, since 'public' is not defined and the Recommendation has no legal force. I could start a new diatom herbarium tomorrow to house my new types. I could make the types available to other scientists, even advertise on the Internet, and so satisfy the requirement for open access. And in a few years' time, if cuts in funding for systematics got worse, I might get even more disillusioned than I have been at times in the last 10 years and, in a fit of childish pique, destroy the lot – and not tell anyone. In 20 or 100 years' time, some diatomist might search for the vanished collection, fail to find it, but never know for sure whether it might still exist somewhere and awake to create havoc with his latest revision or flora.

Some people may think that, by and large, the situation is not too bad and that, with modern communications, there will be fewer problems in the future. This may be so. But let us learn from Ehrenberg's posthumous example. His ghost has haunted diatom taxonomists for over 100 years, through no fault of his own. Many diatomists know next to nothing about him, yet Ehrenberg was famous in his own day and his contributions to science were immense, as is clear from this volume. Ehrenberg's papers are now difficult to obtain, but they were published by the Imperial Prussian Academy of Sciences in Berlin, in what was scarcely a low-profile journal. His collections have been essentially inaccessible for many years and now need careful restoration and curation, yet they were left in good order to a highly esteemed university. Time passes and what once seemed impossible comes to be. I think it is very likely that many collections containing types – collections that today are well used and well curated – will sooner or later fall into decay and become as much of a problem as any from the eighteenth or nineteenth century that we now curse. There is, after all, very little sign of an overall improvement internationally in funding for herbarium curation and taxonomic research.

As a first step, certain herbaria could be designated as type repositories. After an agreed date, a type would have to be deposited in at least one of the type repositories in order for the taxon to be validly published, just as names will have to be registered after 1 January 2000 (subject to ratification by the XVIth International Botanical Congress, to be held in 1999: Greuter *et al.*, 1994, Article 32.1). Providing this condition were met, isotype material could also be deposited in any number of other herbaria.

If governments and funding agencies were involved in the choice of repositories, there might be some guarantee that the 'type system' will be financed more securely in the future. The list of repositories need not be short, but it would probably be sensible for the types of some groups of organisms to be concentrated in a few institutes, if special expertise is needed for their curation. The repositories would have to meet certain standards of curation and guarantee access, and they would have the duty of registering and advertising the types they hold. If a repository were unable to meet its responsibilities, there would have to be mechanisms that ensured that the type specimens could be removed and transferred elsewhere.

Tightening up the rules on the deposition of types of new taxa will not improve the efficiency of the 'type system' in relation to names that have already been published. For these, we could perhaps set a time limit for registering, cataloguing and illustrating existing holotypes, lectotypes and isotypes, after which any that remained unregistered would have no status under the Code, opening the way to neotypification.

Alternatively, a new 'appeals system' could be introduced, like the current procedures for rejection and conservation, through which types that are unavailable or inconvenient (because of their nature, condition or accessibility) could be set aside in favour of a neotype, which would then be placed in one of the type repositories. Whole collections could be declared nomenclaturally redundant. This may sound like a 'dictatorship of the proletariat', but the Code already proscribes certain names – some because they are nomenclaturally inconvenient, others because they were published in the wrong place or in the wrong way; Article 32.8 makes some names invalid because they appear in certain proscribed books and articles (Greuter *et al.*, 1994), though currently there are very few of these. So why not have rules restricting the siting and curation of types, if they are really the valuable biological standards we always say they are? The Ehrenberg Collection is now being restored and made available for study. However, I believe we should have been able to remove the nomenclatural status of the collection many years ago, so that use of Ehrenberg's own specimens as types was voluntary, not mandatory under the International Code.

Finally, if the philosophy exemplified in Article 57 of the current ICBN continues to hold sway, we might modify the guidance on neotypification. At present, a holotype or lectotype is always preferred to a neotype. Why? Of course, because the holotype or lectotype is the best guide to the author's original intentions. But, as already discussed, the implication of Article 57, and moves to establish lists of names in current use, is that we should place less emphasis on original intentions than on established practice. If no type has been designated, and often even if one has, our concept of how a name should be used will be derived from interpretations of the protologue and later published accounts. In such cases, what was in the author's mind is almost irrelevant. So one could argue, perhaps, that, rather than searching for original material, one should simply designate a neotype, preferably with many duplicates that can be deposited in several herbaria (including one or more type repositories), and protect it against the holotype or lectotype. The neotype would only be replaced if it could be shown, as in Article 9.13 of the present Code, that the neotype is in serious conflict with the protologue or current usage.

There is little doubt that to relax the rule on neotypification would make it easier to get away with poor scholarship. As soon as neotypes are allowed to take precedence over lectotypes, let alone holotypes, we to some extent sacrifice knowledge and integrity to convenience. There would also, inevitably, be discrimination against systematic research done in smaller or poorer countries and published in non-European languages or in journals with low circulations. The question is whether this is a worse tragedy than to use the time of our few remaining systematists to search for types that may no longer exist, in herbaria and museums that may welcome the prestige of holding types but do not accept the responsibilities that come with it.

THE PROBLEM OF COMPOSITE TYPES

Regardless of what action is taken to improve the availability of types, we should also ensure that any research that is done to typify taxa and standardize nomenclature is effective. Our typifications should be unambiguous and documented in such a way as to minimize the chance that our work will need to be repeated. Here, significant improvements can be made in current practice among diatomists, which will save considerable effort in the long-term.

In diatoms, there is a tradition of designating a whole slide preparation as the type, rather than individual specimens. I have done this myself (Mann 1981, 1990), and other authors doing the same include Foged (e.g. 1984), Håkansson (e.g. Håkansson & Mahood, 1993; Håkansson & Kling, 1994), Hendey (e.g. 1974), Kociolek & Stoermer (e.g. 1993), Lange-Bertalot (e.g. Lange-Bertalot, 1993; Lange-Bertalot & Moser, 1994), Round (e.g. Round & Basson, 1995; Bukhtiyarova & Round, 1996), Williams (e.g. Williams & Round, 1987) and many others.

Other diatomists have been more specific, indicating particular specimens by marking the slide in some way (e.g. the typification of *Thalassiosira simonsenii* by Hasle & Fryxell, 1977), or by giving a finder reference (Sims, 1994). R.K. Greville often identified particular specimens by ringing them, and this makes it easier to select a lectotype (Williams, 1988; Droop, 1996). Simonsen's (1987) catalogue of Hustedt's types gives finder references for each type or authenticated specimen, and each is illustrated photographically; this is a model to follow.

There is no barrier to the designation of a whole slide preparation as the type. Article 8.1 of the ICBN states that "for small herbaceous plants and for most non-vascular plants, the type may consist of more than one individual, which ought to be conserved permanently on one herbarium sheet or in one equivalent preparation (e.g. box, packet, jar, microscope slide)" (Greuter *et al.*, 1994; see also the discussion by Molloy *et al.*, 1992). Thus, as Williams (1993) has pointed out, "an entire population (or more accurately that part of the population or clone that has been collected and preserved) becomes the element [that bears the name]." However, this practice is flawed and should be stopped, since it introduces an unnecessary element of interpretation into typification.

The problem with designating a slide or population as a type is that the concept of a species (variety, form, etc) may change; hence, a type that is unambiguous when designated may become ambiguous later. In the recent work by Lange-Bertalot (1993), there are several cases where an array of photomicrographs is said to show the holotype. In most cases all the valves illustrated are very similar and could even represent a single dispersed clone, at various stages of the size reduction sequence. However, discordant elements seem to be present within the 'holotypus' of *Navicula canariana* (*op. cit.*, pl. 55, figs 2-10, particularly fig. 5). Again, do all the valves illustrated of *Brachysira calligraphica* or *B. hofmanniae* (Lange-Bertalot & Moser, 1994: pl. 37, figs 1-9, pl. 8, figs 1-18) really belong to the same species? If the species is split, which of the segregate species will bear the names *calligraphica* and *hofmanniae*? The typification is legal but 'soft', and some of Lange-Bertalot's types will probably have to be re-examined and re-defined. Even so, the excellent micrographs Lange-Bertalot provides will usually make it clear what choice is available to anyone who seeks to clarify the typification of the species he has described or revised.

A further example may be given. The type of *Sellaphora pupula* (Kütz.) Mereschk., designated by Ross (1963), is a slide containing many taxa, made from material Kützing collected at Nordhausen. This slide (BM 17918) and another slide of material authenticated by Kützing (BM 18725: see Ross, 1963) both bear valves of various shapes and sizes, which were probably all included in *S. pupula* (as *Navicula pupula*) by Kützing (1844). He appears to have studied live cells rather than cleaned frustules and all known *Sellaphora* species have a similar, characteristic type of chloroplast (Mann, 1989), which Kützing did not describe but drew (Kützing, 1844: pl. 30, fig. 40). The concept of *S. pupula* adopted by Ross was broad (Ross, 1963: 88) and, as a result, lecto-typification via BM 17918 as a whole, rather than by a single specimen on BM 17918, was sufficient. Thus, when Schoeman & Archibald (1976–80) reinvestigated BM 17918 and photographed three valves, they labelled all of them as 'Type' (*op. cit.,* figs 5-8). One of the specimens they illustrate (fig. 8) is unlike the other two, but Schoeman & Archibald too had a broad concept of *S. pupula*. However, there is now evidence that the variable morphology of *S. pupula* reflects the presence within it of many subtly different entities, some of which deserve to be recognized as separate species (Mann, 1984, 1989; Mann & Droop, 1996). One of the segregate species will have to be chosen to retain the name '*pupula*' and a type specimen selected accordingly. This cannot be done without re-examination of BM 17918 and other authenticated material, in spite of the fact that Schoeman & Archibald provided excellent micrographs. Ross does in fact give a reference to a particular specimen on the slide label, but this is not mentioned in the 1963 paper, nor is there information on the slide as to how to use the reference to find the specimen (the figures are apparently the stage coordinates for an unspecified microscope). The studies by Ross (1963) and Schoeman & Archibald (1976–80) were very careful – I can vouch for this, since it took us 1.5 working days to find all of the very few specimens of *S. pupula* on BM 17918, including the three illustrated by Schoeman & Archibald – and, by most standards, they are well documented. But they were not definitive because they did not designate a single specimen as the lectotype. In contrast, Ross's (1963) typification of *Capartogramma rhombicum* Ross is beyond reproach, like almost all his nomenclatural work.

We can minimize future problems by deciding now to typify only via single valves or single frustules, whose locations must be specified and published effectively. Diatoms are unicellular organisms and there is no problem in defining individuals for the purpose of typification. Admittedly, to designate single diatom valves or frustules as types can be technically difficult. Engraving a ring on the cover slip, as done by Greville, is one possibility, though few people have the necessary equipment or skill to do it well. Furthermore, if several taxa are to be typified on the same slide, ringing may be impractical.

Identifying a specimen via a finder reference is another possibility, though finders do not work equally well with left-handed and right-handed microscope slide holders (see Droop, 1996). Furthermore, some finders are now obsolete, such as the Maltwood Finder used by Greville, O'Meara and others in the nineteenth century, or the Zeiss finder used by Simonsen (1987), though with care any set of references can be translated into those of another type of finder, or into the coordinates of a microscope stage. If neither engraving nor finder references are possible, one could use a series of context photographs, at progressively lower magnifications, to fix the position of the type. Alternatively, specimens could be selected and mounted individually on slides. This is the most certain method, but also the most difficult and expensive. Furthermore, if single specimens are selected and mounted as types, strewn slides of the populations from which they were derived should also be preserved, since selected slides are virtually useless for any purpose other than to act as nomenclatural standards. Strewn slides, on the other hand, can yield information about population variation and frustule ontogeny, size spectra and ecological communities, etc, which may be useful for many fields of research.

In addition, photographs of holotypes and lectotypes of diatoms should always be made and published, as hard-copy or via the Internet, to minimize future need to refer to type specimens and to help ensure that current usage does not drift. I now regret not doing this for *Amphora arcus* Greg. (Mann, 1995).

FINAL THOUGHTS

Some of my readers may not recognize the taxonomic world I have described; my experience may not be yours, especially, perhaps, if you work with higher plants. Algae, especially microscopic algae, do have their own special problems and some of these have already been dealt with by special provisions in the ICBN – e.g., different starting dates for Latin descriptions. I think we should consider further exceptions and special provisions, which take account of particular difficulties in particular groups. In diatoms huge numbers of varieties and forms have been described (the category of subspecies is very rarely used), but I would guess that less than 10% of them are ever used and far fewer have been typified; to search for all the types, catalogue and photograph them, and publish the results is obviously an enormous task. Meanwhile, of the estimated total of 200,000 species of diatoms world-wide (Mann & Droop, 1996), less than 10% have yet been described. It may well be that some of the new species have already been described as varieties or forms, but our experience suggests that this will account for well under half the total. The enormity of the task facing us as we attempt to document and classify the diversity of diatoms world-wide must be set against the fact that there are less than 50 people world-wide, perhaps less than 20, who spend more than half their working week, on average, on diatom taxonomy. I hope that there will be some improvement in staffing in the future, in view of the ecological and biogeochemical importance of diatoms and their utility as indicator organisms in ecological and palaeoecological monitoring, but I suspect that any improvement will be slow. What is the priority for the few taxonomists that exist: to attempt to produce a complete inventory and classification of diatom species and their distributions, or to clear the backlog of nomenclatural difficulties resulting from 150 years of untypified infraspecific taxa? What about wiping the slate clean for all varieties and forms in diatoms, by establishing a new starting date for these categories?

Curiously, at the very time when it would be easier than ever to allow for exceptions and special rules, as a result of information technology, the efforts of some nomenclaturists are being directed towards uniformity. A new unified *Code of Bionomenclature* has recently been proposed (Hawksworth, 1996) and the Introduction extols the virtues of harmonization between the five existing Codes. I believe these efforts at unification are profoundly misguided. Although the application of the rules of nomenclature is not the longest, nor the most difficult phase of taxonomic research, it seems curious when taxonomic expertise is in short supply, to propose changes to the International Codes of Nomenclature that will decrease the effectiveness of taxonomists for the foreseeable future. Whatever the failings of the existing Codes, at least most taxonomists only have to deal with one of them. Specialists in dinoflagellates and other groups of protists that contain many heterotrophic as well as autotrophic representatives are not well served by the separation of the Zoological and Botanical Codes (Patterson & Larsen, 1991), but they too will be little better off under any new 'BioCode'. For the simple fact is, that everyone will still have to learn the old Codes and old terminology, while also learning the new. Ehrenberg's names are some of the few that diatomists have to consider in relation to the Zoological Code; otherwise, the Botanical Code alone is relevant. If a new BioCode is introduced, the Botanical Code will apply to all plant names published up to a certain date, the new BioCode to all names published afterwards. Diatomists will have two codes instead of one; dinoflagellate and euglenoid systematists will have three instead of two. So, those proposing a unified Code for all life, living and fossil, are not setting us free from the ball and chain of the existing, imperfect codes; they are giving us a new ball and chain to wear alongside those we already wear and to which we have grown accustomed. This alone should be enough to make us reject 'harmonization' and seek other ways to deal with the few serious problems in nomenclature, such as ambi-regnal organisms (where the simplest solution is to assign each disputed group to one or other 'nomenclatural kingdom').

To return to Ehrenberg: I believe it would have been pure vandalism to have destroyed the Ehrenberg Collection and it still would be. It is part of the national heritage of Germany, a milestone in the scientific development of a nation, and a resource for new scientific research. I look forward to using it.

CONCLUSIONS

- Old collections, such as Ehrenberg's, often represent a major capital investment, contain irreplaceable material, and are important resources for future research. They should not be discarded lightly.
- The type method is designed to standardize nomenclature and can do so. In practice it is sometimes inefficient, because types and information about types are unavailable or difficult to find, leading to drift of 'current usage' away from the standard. Typification and current usage are decoupled, leading to 'nomenclatural drift' away from the author's original intentions.
- Nomenclatural stability in diatoms could be greatly improved through wide dissemination of high-quality photographic images of types, via publications and the Internet.
- Type repositories should be designated. After an agreed date, types of all new taxa should be required to be lodged in at least one repository.
- A deadline for finding, registering, cataloguing and illustrating existing types should be set, after which any unregistered types would have no status under the ICBN.
- Alternatively, new mechanisms could be introduced, whereby types and whole collections could be declared nomenclaturally redundant, making neotypification possible.
- Diatom types should only ever be single specimens.
- Establishing the identities of the myriad varieties and forms in diatoms seems a waste of limited taxonomic expertise; there should be a new starting date for these categories in diatoms.
- Proposals for a unified BioCode of nomenclature are ill-judged.

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