Immunity,' by B. T. Terry, p. 310 of 'Sleeping Sickness Bulletin,' No. 29, which gives a most interesting account of a long series of experiments with different trypanosome infections, with special reference to the immunity following cure. Some of these experiments gave most encouraging results. A paper by Paul Behn in 'Sleeping Sickness Bulletin,' No. 35, p. 111, on the same subject, and Bulletin No. 25, p. 127, should also be consulted.

It is interesting but not very profitable to speculate upon the past history of immunity in nature. Such parasitical forms of life as trypanosomes and piroplasms may have evolved, zoologically, comparatively recently or may have been recently promoted to a life cycle in the blood-stream of vertebrates. There are many blood parasites known, such as halteridia and certain leucocytozoons, and also certain trypanosomes, which produce no disease in the animals in which they are found at the present day, but they may have caused great mortality among these animals in the past, before their hosts developed an immunity and became tolerant of them. In 'Sleeping Sickness Bulletin,' No. 36, p. 142, some interesting information is given on 'The Life-History of Trypanosomes in Vertebrate Blood,' by C. Franca.

The question of immunity therefore appears to be one of great importance. If wild animals can acquire an immunity in nature and domestic native cattle can also acquire immunity, is it not possible that the greatest success may eventually result from an artificially produced immunity ?

THE ORGANIC CELL

Part II.—Its Methods of Division and Status in the Process of Heredity

By E. Wynstone-Waters, F.R.S.Edin., &c., *Late Senior Demonstrator of Anatomy at the Royal College of Surgeons Edinburgh.*

As we saw in the last article the term ' cell ' is badly selected, and was used by the seventeenth-century botanists to describe the cells of certain plants, which on section do give the appearance of a honeycombed structure. These cells being separated by distinct solid walls, Schwann (the father of the cell-theory) mistook these solid walls for their essential physiological part. The living portion filling up the spaces was at first probably mistaken for a waste product. H. von Mohl, in 1846, named this living substance protoplasm. Later researches demonstrated the fact that most cells are solid bodies, and in many cases—e.g. lymph-corpuscles—are naked portions of protoplasm not possessing any distinct wall or peripheral membrane. It was thus clearly shown that the hollow vesicular condition and the presence of a cell-wall were not necessary to the cell, but that the protoplasmic content must be the basis of life.

Somewhere within the protoplasm of the cell there is situated a definite, somewhat rounded body called the *nucleus*, and this nucleus may contain one or more smaller bodies called *nucleoli*. The earlier observers attached only a secondary importance to the nucleus, but the latest researches go to prove beyond a doubt that the nuclear material, whether collected into a single mass or scattered about as small particles, is always present, and that it is probably the most important part of the cell. Leydig and Max Schultze, thirty years ago, defined the cell as 'a mass of protoplasm containing a nucleus, that both nucleus and protoplasm arise through the division of the corresponding elements of a pre-existing cell,' and it may be stated that this definition still holds good.

I will devote a short space to the general morphology of the cell. An isolated cell is, roughly speaking, spherical, e.g. in unicellular plants and animals. In the great majority of cells the spherical form is altered by various conditions, such as movements of the cell-substance, the effects of mechanical pressure, &c.

Protoplasm, which forms the basis of the cell, is a translucent viscid substance, at times appearing homogeneous, in other cases finely granular, giving as a rule the appearance of a network or 'reticulum.' In addition to this living active protoplasm the cell almost universally contains certain lifeless bodies, which are found in the meshes of the network. Among such lifeless substances may be mentioned pigment bodies, drops of oil, food particles, and excretory products. These passive elements may be termed metaplasm in order to differentiate them from the active protoplasm.

The cell-wall must also be looked upon as a lifeless product of the protoplasm.

Unfortunately there has been introduced a somewhat exuberant nomenclature regarding the cell. For the sake of clearness the term protoplasm will apply to the whole active cell-substance, including the nuclear material; this latter may be termed the karyoplasm, while the substance of the cell-body will be termed cytoplasm.

This is the nomenclature introduced by Strasburger and Flemming, and it will probably be found more useful than any of the others. It must be strongly impressed on the memory that neither term expresses a single homogeneous substance; for, as will be seen later, the cytoplasm and karyoplasm consist of several distinct elements.

During the process of cell-division the membrane which usually surrounds the nucleus disappears, and the cytoplasm and karyoplasm become continuous. It should also be remembered that when the cell is in the so-called resting stage the intra- and extra-nuclear material may be continuous with the nuclear membrane.

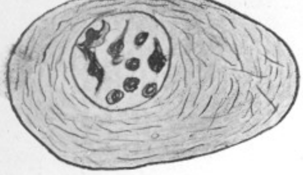
The fact still remains that the cytoplasm and karyoplasm have a different chemical composition, the latter containing a substance called nuclein, which is rich in phosphorus, whilst the cytoplasm contains no nuclein, but possesses an abundance of albuminous substances, such as albumins, globulins, &c.

Speaking broadly, the cell-substance must be differentiated into a nucleus and cell-body, because of the universal presence of the nucleus, and also as representing the two forms of metabolism, destructive and constructive, which are essential characters of cell-life.

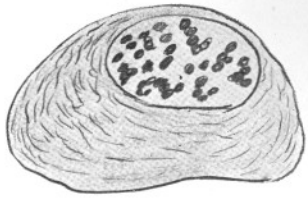
Protoplasm

Under low powers protoplasm shows no definite structure, but has a somewhat granular appearance. Using high powers and staining re-agents it is possible to show that both nucleus and cell-body have a very complex structure. Observers

A

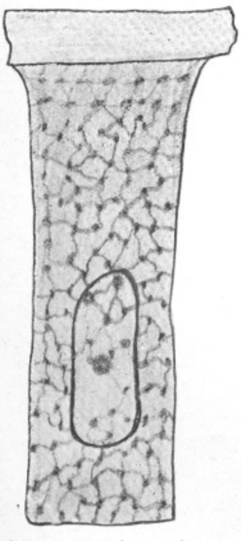


B



A and B.—CARTILAGE-CELLS SHOWING FIBRILLAR STRUCTURE OF THE PROTOPLASM.
[*Flemming.*]

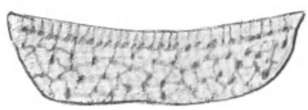
A



Alveolar structure of protoplasm, according to Bütschli.

A.—EPIDERMAL CELL OF EARTHWORM.

E



E.—ARTIFICIAL EMULSION OF OLIVE OIL, COMMON SALT AND WATER, have sought to show that all protoplasm, from whatever source obtained, possessed a common form of structure. No definite result has followed. In many forms of protoplasm, both in life and death, the basis of the structure is seen to be a meshwork consisting of two substances. One of these is the meshwork itself, the other a ground substance filling the spaces between. In addition to these, there are minute, deeply-staining granules situated along the branches of the meshwork, often quite irregularly, at other times forming regular chains, as if the meshwork were entirely composed of them. The above three elements may be regarded as constituting the active substance of the protoplasm. Besides these, as mentioned before, the protoplasm contains certain passive substances, e.g. crystalline bodies, drops of oil, &c. These passive bodies lie in the spaces of the meshwork.

Most of the earlier observers regarded the network as a fibrillar substance, forming either a continuous network, or consisting of threads simple or branching, and this view is sustained by many at the present day. According to this view the granules are regarded as nodes in the network seen at the points of crossing, or else as actual granules situated in the meshwork.

The more recent observations of Bütschli are strongly opposed to the above theory. He looks upon protoplasm in the light of an emulsion having an alveolar structure. Experimenting in support of this theory he has produced artificial emulsions bearing a remarkably close resemblance to living protoplasm, and has even gone so far as to demonstrate that drops of oil emulsion placed in water may show amœboid physical changes. Bütschli's position is the following: He maintains that protoplasm consists of drops of a liquid alveolar substance, situated in an interalveolar substance of a different physical consistency. This interalveolar substance forms the walls of the spaces or alveoli in which are situated the minute drops of alveolar substance. The so-called network according to this theory is due to optical section of the interalveolar walls. These walls produce the appearance of a network, while the spaces of the network are merely optical sections of the alveoli. These two theories are called respectively the fibrillar and alveolar. The most recent work tends to show that neither of these theories has succeeded in giving a universal type for the structure of protoplasm, and probably Kölliker's early opinion is correct: viz. that the different appearances described in each theory are connected by intermediate stages and may be transformed one into another during cell activity. According to Flemming, no single type can be characterised as diagnostic of the living substance. It is probable that the protoplasm of the same cell may at one time be homogeneous, at another fibrillar, and at another alveolar, according to its period of growth, &c. The source of physiological activity in living protoplasm must probably be sought for in its ultra-microscopical organisation.

The Nucleus

A portion of a cell from which the nucleus has been removed will live for a considerable period of time and will show response to stimuli. This enucleated mass of protoplasm, however, cannot repair its lost portions, neither can it grow, and more important than all, it is unable to assimilate to itself those substances by which a prolonged existence can be maintained, and by which energy can be stored up. After a somewhat brief existence its fate is but to die. To state the case in another way, it may be said that the enucleated mass of protoplasm possesses the functions which require destructive metabolism, and the functions persist probably until the reserve of potential energy has been resolved into kinetic energy.

From many experiments it has been clearly shown that the nucleus is the chief factor in the constructive or synthetic metabolism of the cell.

That the nucleus possesses this most important function of synthetic metabolism is demonstrated by the fact that digestion of food and growth cease with its removal. It is also indicated 'by the position and movements of the nucleus in relation to the food-supply and to the formation of specific cytoplasmic products.' It also agrees with what is now universally admitted, that exchanges of material occur between nucleus and cytoplasm. The varying changes of staining capacity exhibited by the chromatin of the nucleus during the life of the cell, as well as the work of physiological chemists on the staining reactions of the nuclein series, show clearly that the substance known as nucleinic acid (which is very rich in phosphorus) plays the most important part in the constructive process.

It is extremely interesting to note that during the vegetative state of the cell the nucleinic acid is combined with a large amount of the albumin radicles to form nuclein. During the reproductive or mitotic stages of cell activity the combination breaks down, to a large extent leaving the chromosomes with a very high percentage of nucleinic acid, as shown by analysis of the head of a spermatozoon. It is strongly probable that this is the most important element passed on from cell to cell, and is very possibly the essential factor in the synthetic process of the nucleus, and indirectly with those of the cytoplasm.

It must be remembered that the constructive metabolism exhibited by the nucleus is closely related to its function of morphological synthesis, and thus with inheritance. As a proof of this we have experiments on unicellular plants and animals, which go to show that the power of redeveloping lost parts is lost when the nucleus is removed, though the portion from which the nucleus has been removed may still show vital phenomena for a limited period, due to its inherent faculty of destructive metabolism. There is little doubt that the chromatin factor of the nucleus is the most important substance in the process of inheritance. This is shown very clearly by the fact that the germ and sperm nuclei are, by an exceedingly complicated and elaborate process, involving the evolution of a large amount of energy, prepared for their subsequent union, by which equal numbers of chromosomes are brought together from either sex. During fertilization these elements come together, and by a process of indirect division are exactly distributed to the resulting cells. That the nucleus is the essential factor in inheritance is further shown by the fact that the spermatozoon (which is practically all head, i.e. nucleus) supplies an amount of cytoplasm which is so small as to be almost negligible. From a broad analysis of the subject it seems evident that the nucleus is the great determining factor in the life and organisation of the cell; and that it contains the substance by which the various hereditary factors are passed on from generation to generation.

With regard to the structure of the nucleus it must be noted that the nucleus itself passes through two different states, each of which presents a very different appearance.

In the first or vegetative phase, falsely known as the 'resting state,' the following elements may be made out :—

1. The *nuclear membrane*—well defined and clearly differentiating the nucleus from the surrounding cytoplasm.

2. The *nuclear reticulum*—an irregular branching network which is made up of two essentially different substances: (*a*) The protoplasmic basis of the nucleus called *linin* visible after staining, and closely allied to the cytoplasm of the cell-body ; (*b*) The deeply staining substance called *chromatin*, the most important factor in the cell, which is often the only substance of the nucleus that is passed on during the process of division from cell to cell, and which is capable of producing all the other elements. The chromatin may be present in the form of granules of different sizes, these granules being embedded in the linin. The chromatin often appears as a network closely intermingled with the linin network. As we have seen before, it consists largely of nuclein, which in its turn is a compound of nucleinic acid with albumins. It shows a great affinity for the basic-tar colours, and the depth of the staining capacity at any given period is an index of the proportion of nucleinic acid present.

3. The *nucleoli*, one or more bodies found in the nuclear network, which however may be absent. The nucleoli are of two different kinds—the *plasmosomes*, which are different in composition from chromatin, as shown by the action of stains ; and the net-knots or *karyosomes*, which are closely allied to chromatin, if not identical in composition. These latter nucleoli are doubtless condensed portions of the regular chromatin network.

4. The ground-substance, or *karyolymph*, fills the spaces of the network, and is very negative in its staining activities.

It is interesting to note that the chromatin network shows a great degree of variation in its arrangements, and may exhibit the extremes, either of a loose reticulum as in the various epithelia, or of a solid mass as in the head of the spermatozoon, and between these two every possible variation exists.

In the stages before cell-division the chromatin network breaks up into a definite number of rod-like bodies called chromosomes, and these split longitudinally into exact halves as the cell divides. The chromosomes originate as collections of rounded bodies called *chromomeres*, which are identical with Weismann's *ids*.

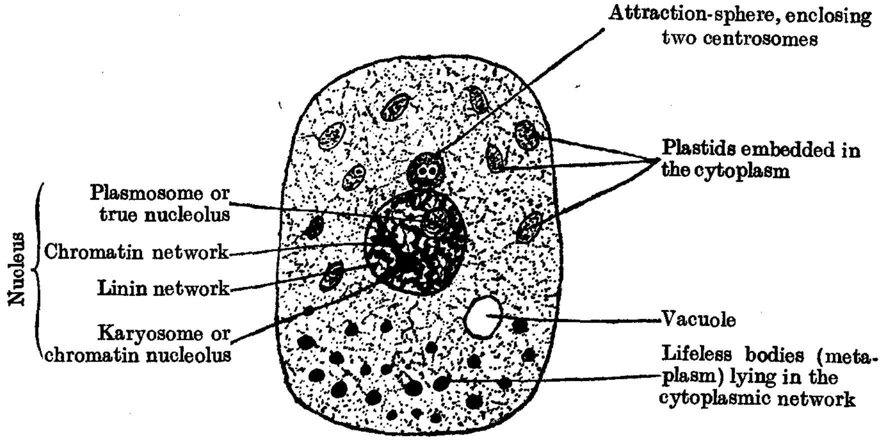


Diagram of a cell. The basis consists of a network containing minute granules (microsomes) and traversing a transparent ground-substance.

THE CENTROSOME

A very minute single body or pair of bodies, surrounded by a rounded mass called the attraction-sphere, is usually situated near the nucleus ; it may, however, lie inside the nucleus.

Two great authorities, Van Beneden and Th. Boveri, regard the centrosome as a persistent cell-organ, which is handed on from one generation to another by division. It has been looked upon as the active organ of cell-division; in fact, as the 'dynamic centre' of the cell. Boveri looked upon the centrosome as the active fertilizing element in the spermatozoon, which gave to the egg its power of division. This fascinating hypothesis of Van Beneden and Boveri doubtless has some truth in it, though doubts have been cast on it by the recent researches on some of the higher plants, in which the presence of a centrosome has so far defied demonstration. If the latter be true, the centrosome loses much of its former importance, and must be looked upon as playing only a subordinate part in the mechanism of mitosis.

The Cell-membrane

The envelope of the cell belongs to one of the passive or metaplastic products of protoplasm.

As a rule, in animal-cells the walls are only very slightly developed ; among plants the peripheral envelope of the cell is of great importance, often attaining a great thickness.

A notable exception to the extreme thinness of cellular envelopes in animal-cells may be mentioned : the intercellular matrix in cartilage.

There is a great probability that all cells have to a certain extent a specially differentiated envelope. Even among leucocytes there is a differentiation of the peripheral protoplasm into a firmer layer, forming a kind of skin or pellicle. Recent research tends to show that cell-walls are generally produced by secretion, though there are cases in which the protoplasm of the cell itself is so altered at its surface as to form an envelope.

Cell Polarity

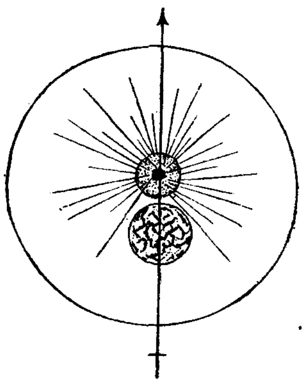
In a great number of cells there is a symmetrical arrangement of the parts in relation to an axis passing from pole to pole. The idea of polarity has been worked out along two different lines, one a morphological conception, the other a purely physiological one.

Van Beneden working along the line of morphology conceived the organic axis as passing through the nucleus and centrosome. Heidenhain has elaborated this theory, teaching that all the structures of a cell have a fixed relation to the axis, going so far as to state that this relation is brought about by tension in the astral rays, the fixed point being at the centrosome.

On the other hand, according to Rabl and Hatschek, cell-polarity ‘ is a polar differentiation of the cell-substance arising secondarily through adaptation of the cell to its environment in the tissues.' This can be shown clearly in epithelium, which is the most primitive of all tissues. 'The free and basal ends of the cells here differ widely in relation to the food-supply, and show a corresponding structural differentiation. In such cells the nucleus usually lies nearer the basal end, toward the source of food, while the differentiated products of cell-activity are formed either at the free end or at the basal end.'

These two theories widely differ, but in some cases lead to the same result. This is the case with the ovum and sper-

A. Morphological polarity of Van Beneden. Axis passing through nucleus and centrosome. Chromatin - threads converging towards the centrosome.



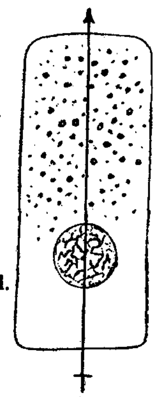
A

VAN BENEDEN.

B. C. Physiological polarity of Rabl and Hatschek.

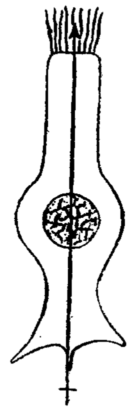
B. In a gland-cell.

C. In a ciliated cell.



B

RABL.



C

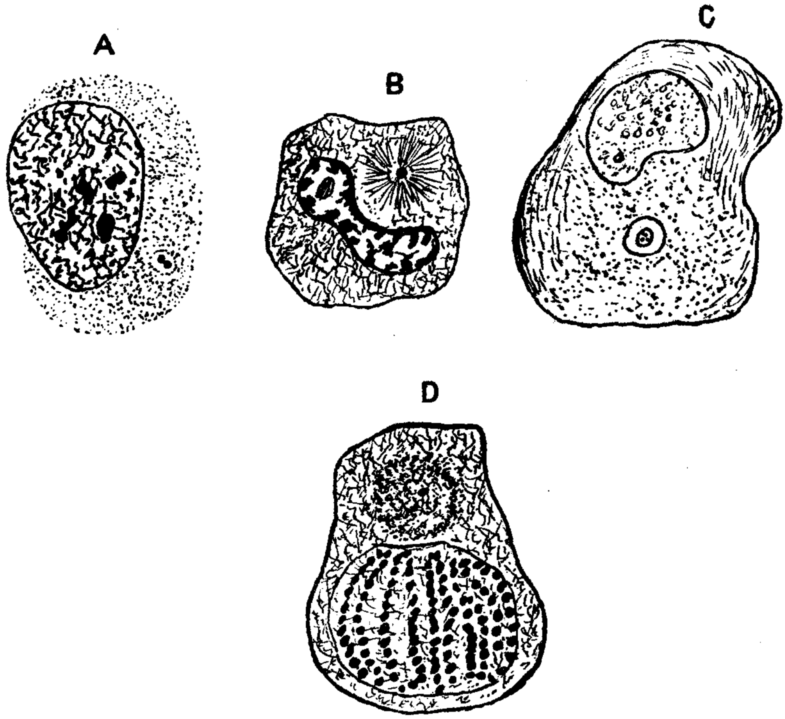
HATSCHEK.

matozoon, for in these cases the morphological and physiological axes are the same. This has also been shown to be the case in certain epithelia, the centrosomes here lying very often near the surface, and there is evidence to show that the basal bodies to which the cilia are attached in ciliated epithelium may be the centrosomes.

THE MULTICELLULAR BODY AND THE CELL-UNIT

Perhaps there is no biological problem of greater importance than the proper understanding of the means by which the individual cell-activities are co-ordinated, and the organic unity of the whole maintained; for upon this very problem depends the question of the transmission of acquired characters, and more important still our very conception of life itself.

When making a study of the single cell, one regards it as an independent organism. It can only be such, however, in



Cells, showing the typical parts.—A. Showing two centrosomes. Nucleus with net-knots (Flemming). B. Aster, containing a single centrosome. Nucleus with single plasmosome (Hermann). C. Special ganglion of a frog. Attraction sphere containing a single centrosome, with several centrides (Lenhossék). D. Nucleus in the spireme stage. Centrosome single; attraction-sphere well seen (Hermann)

unicellular plants and animals, and in the germ cells of multicellular forms. Looked at from one point of view it cannot be denied that the multicellular body is equal to the aggregate of the one-celled forms which make up its constitution. One cannot quarrel with the aphorism that the whole cannot consist of more or less than the sum of its parts. Speaking physiologically, however, the single cell cannot be looked upon as an independent unit, for its very existence depends on the general life of the organism.

Schwann many years ago stated that 'the whole organism subsists only by means of the reciprocal action of the single elementary parts.' Schwann erred to a certain extent in this statement, for he denied the influence of the whole organism upon the functional activities of the individual cell.

The cells must be looked upon as centres of a formative power, affecting and influencing the growing mass as a whole: the idea of a physiological independence of the individual cell must recede into the background. The life of the multicellular organism must be looked upon as a whole, its composite character being the result of a secondary distribution of energy among local centres. Looked at in this light it will be necessary to discover the means by which the single cell comes into relation with the whole organism. Tissue cells often appear isolated from their neighbours on account of the non-living walls separating them; one must not, however, conclude, from this apparent isolation, that an actual solution of organic continuity has been established. For instance, there are many cases in which a nucleus may divide, but the cell-body does not share in the process, so that multinuclear cells come to be formed which consist of a uniform and continuous mass of protoplasm, studded in the substance of which are nuclei, the whole mass forming a colony of cells connected by cell-bridges by which free communication can be maintained. Years ago the contention was maintained by Heitzmann that in nearly all forms of tissue the process of division is incomplete, and that though cell-walls may be formed, these walls do not form barriers to communication between adjacent cells, because these cell-walls are penetrated by strands of protoplasm by which organic continuity is established in the mass.

He therefore looked upon the body as a highly protoplasmatic reticulum, the cells being nodal points in the network, the essential factor of the conception being the protoplasmic continuity of the whole.

It has long been known that cell-bridges exist between the sieve-tubes of plants. A. Meyer has shown that in planttissues the cell-walls are connected by intercellular bridges. Bridges of a similar nature have been demonstrated with certainty in practically all forms of epithelium, also in connective tissue cells and nerve cells. Retzius and others have shown that the cells of the Graafian follicles of the ovary are not only connected with one another by bridges, but are also connected with the ovum.

As a result of this evidence many recent observers have accepted Heitzmann's theory.

It is probably a little premature to accept this hypothesis in full in regard to the adult, though in the embryonic stages there seems to be no doubt as to the general continuity between cells.

Sedgwick has shown that in the vertebrates the embryonic body in its earlier stages is a continuous reticulum, and E. B. Wilson points out ' that in a total cleavage, such as that of *Amphioxus*, the results of experiment on the early stages of cleavage are difficult to explain, save under the assumption that there must be a structural continuity from cell to cell that is broken by mechanical displacement of the blastomeres.'

Mrs. Andrews maintains that during the cleavage of Echinoderm eggs the blastomeres spin protoplasmic threads by which continuity is established between them after each division. (See ' Filose Activities in Metazoan Eggs,' Zool. Bull. II. 1, also ' Activities of Polar Bodies,' Arch. Entom. VI. 2.) Flemming has demonstrated that when white corpuscles move among epithelial cells the bridges become broken, but are re-formed afterwards.

The absolute function of the cell-bridges is at present not definitely known. That they are not merely channels for the passage of nutrition, but form the roads by which physiological impulses are transmitted, is proved by Townsend's experiments on plants. Townsend shows that in root-hairs and pollen tubes, if the protoplasm is broken, a membrane may be formed by both nucleated and non-nucleated fragments—by the latter however ' only when they remain connected with the nucleated masses by protoplasmic strands, however fine.'

Should these connecting threads get broken, the power of forming a membrane is lost. This delicate and beautiful experiment very clearly shows that physiological impulses of the most profound importance pass across these protoplasmic bridges, by which the nucleus of one cell regulates the membrane-forming power of a protoplasmic mass from which the nucleus has been removed.

THE TRIBES OF THE TANA VALLEY

By A. Werner.

The Tana Valley is the meeting-point of several different races, and therefore of peculiar interest from an ethnological point of view. Moreover, it is the dividing-line, for this part of Africa, between Bantu and non-Bantu, and an examination of the racial conditions as we find them to-day suggests a series of fascinating problems for the ethnologist.

The Bantu tribe of the Wapokomo form, as is well known, the main population of the Tana Valley. They have been impinged upon, first from the north-east, afterwards from the south-west, by the Galla; at a later date by the Somali from the north-east and the Masai from the south-west. (These last, whose advance is always checked by any great body of water, were stopped by the Tana in 1887, and seem since then to have fallen back and never recovered the lost ground.) And, scattered among them, in the forest on both banks of the river, are little groups of the hunter tribes—the Wasanye and Waboni.

The Wapokomo are divided into thirteen tribes, each occupying a district named after it—though of late years there is a tendency for them to break up, fractions of some tribes settling within the districts of others: thus, there is a small colony of Buu people at Benderani, in the Ngatana district, and another of Bure (Ngatana) in the Kalindi district.