lasting value. It is a satisfaction to add that its merit has been widely appreciated, as has recently been evidenced by the award of the Draper and Rumford medals. Keeler was president of the Astronomical Society of the Pacific and a councilor of the Astronomical and Astrophysical Society of America. He was elected an Associate of the Royal Astronomical Society in 1898 and a member of the National Academy of Sciences at its last meeting. His kindly and genial manner, combined with unusual tact and rare judgment, drew to him many friends, who will long mourn his loss.

GEORGE E. HALE.

*ADDRESS OF THE PRESIDENT BEFORE THE BRITISH ASSOCIATION FOR THE AD-VANCEMENT OF SCIENCE.**

I.

TWENTY-SEVEN years ago the British Association met in Bradford, not at that time raised to the dignity of a city. The meeting was very successful, and was attended by about 2000 persons—a forecast, let us hope, of what we may expect at the present assembly. A distinguished chemist, Professor A. W. Williamson, presided. On this occasion the Association has selected for the presidential chair one whose attention has been given to the study of an important department of biological science. His claim to occupy, however unworthily, the distinguished position in which he has been placed, rests, doubtless, on the fact that, in the midst of the engrossing duties devolving on a teacher in a great university and school of medicine, he has endeavored to contribute to the sum of knowledge of the science which he professes. It is a matter of satisfaction to feel that the success of a meeting of this kind does not rest upon the shoulders of the occupant of the presidential chair, but is due to the eminence and active co-operation of the men of

* Given at Bradford on September 5, 1900.

science who either preside over or engage in the work of the nine or ten sections into which the Association is divided, and to the energy and ability for organization displayed by the local secretaries and committees. The program prepared by the general and local officers of the Association shows that no efforts have been spared to provide an ample bill of fare, both in its scientific and social aspects. Members and Associates will, I feel sure, take away from the Bradford meeting as pleasant memories as did our colleagues of the corresponding Association Française, when, in friendly collaboration at Dover last year, they testified to the common citizenship of the Universal Republic of Science. As befits a leading center of industry in the great county of York, the applications of science to the industrial arts and to agriculture will form subjects of discussion in the papers to be read at the meeting.

Since the Association was at Dover a year ago, two of its former presidents have joined the majority. The Duke of Argyll presided at the meeting in Glasgow so far back as 1855. Throughout his long and energetic life he proved himself to be an eloquent and earnest speaker, one who gave to the consideration of public affairs a mind of singular independence, and a thinker and writer in a wide range of human knowledge. Sir J. William Dawson was president at the meeting in Birmingham in 1886. Born in Nova Scotia in 1820, he devoted himself to the study of the geology of Canada, and became the leading authority on the subject. He took also an active and influential part in promoting the spread of scientific education in the Dominion, and for a number of years he was principal and vice-chancellor of the McGill University, Montreal.

SCIENTIFIC METHOD.

Edward Gibbon has told us that diligence and accuracy are the only merits

which an historical writer can ascribe to himself. Without doubt they are funda- mental qualities necessary for historical re- search, but in order to bear fruit they re- quire to be exercised by one whose mental qualities are such as to enable him to ana- lyze the data brought together by his dili- gence, to discriminate between the false and the true, to possess an insight into the com- plex motives that determine human action, to be able to recognize those facts and inci- dents which had exercised either a primary or only a secondary influence on the affairs of nations, or on the thoughts and doings of the person whose character he is de- picting.

In scientific research, also, diligence and accuracy are fundamental qualities. By their application new facts are discovered and tabulated, their order of succession is ascertained, and a wider and more inti- mate knowledge of the processes of nature is acquired. But to decide on their true sig- nificance a well-balanced mind and the ex- ercise of prolonged thought and reflection are needed. William Harvey, the father of exact research in physiology, in his mem- orable work ' De Motu Cordis et Sanguinis,' published more than two centuries ago, tell us of the great and daily diligence which he exercised in the course of his investiga- tions, and the numerous observations and experiments which he collated. At the same time he refers repeatedly to his cogitations and reflections on the meaning of what he had observed, without which the compli- cated movements of the heart could not have been analyzed, their significance deter- mined, and the circulation of the blood in a continuous stream definitely established. Early in the present century, Carl Ernst von Baer, the father of embryological re- search, showed the importance which he attached to the combination of observation with meditation by placing side by side on the title page of his famous treatise ' Ueber

Entwickelungsgeschichte der Thiere' (1828) the words *Beobachtung und Reflexion*.

Though I have drawn from biological sci- ence my illustrations of the need of this com- bination, it must not be inferred that it applies exclusively to one branch of scien- tific inquiry ; the conjunction influences and determines progress in all the sciences, and when associated with a sufficient touch of imagination, when the power of seeing is conjoined with the faculty of foreseeing, of projecting the mind into the future, we may expect something more than the discovery of isolated facts ; their co-ordination and the enunciation of new principles and laws will necessarily follow.

Scientific method consists, therefore, in close observation, frequently repeated so as to eliminate the possibility of erroneous seeing ; in experiments checked and con- trolled in every direction in which fallacies might arise ; in continuous reflection on the appearances and phenomena observed, and in logically reasoning out their meaning and the conclusions to be drawn from them. Were the method followed out in its in- tegrity by all who are engaged in scientific investigations, the time and labor expended in correcting errors committed by ourselves or by other observers and experimentalists would be saved, and the volumes devoted annually to scientific literature would be materially diminished in size. Were it ap- plied, as far as the conditions of life admit, to the conduct and management of human affairs, we should not require to be told, when critical periods in our welfare as a nation arise, that we shall muddle through somehow. Recent experience has taught us that wise discretion and careful prevision are as necessary in the direction of public affairs as in the pursuit of science, and in both instances, when properly exercised, they enable us to reach with comparative certainty the goal which we strive to at- tain.

IMPROVEMENTS IN MEANS OF OBSERVATION.

Whilst certain principles of research are common to all the sciences, each great division requires for its investigation specialized arrangements to insure its progress. Nothing contributes so much to the advancement of knowledge as improvements in the means of observation, either by the discovery of new adjuncts to research, or by a fresh adaptation of old methods. In the industrial arts, the introduction of a new kind of raw material, the recognition that a mixture or blending is often more serviceable than when the substances employed are uncombined, the discovery of new processes of treating the articles used in manufactures, the invention of improved machinery, all lead to the expansion of trade, to the occupation of the people, and to the development of great industrial centers. In science, also, the invention and employment of new and more precise instruments and appliances enable us to appreciate more clearly the signification of facts and phenomena which were previously obscure, and to penetrate more deeply into the mysteries of nature. They mark fresh departures in the history of science, and provide a firm base of support from which a continuous advance may be made and fresh conceptions of nature can be evolved.

It is not my intention, even had I possessed the requisite knowledge, to undertake so arduous a task as to review the progress which has recently been made in the great body of sciences which lie within the domain of the British Association. As my occupation in life has required me to give attention to the science which deals with the structure and organization of the bodies of man and animals—a science which either includes within its scope or has intimate and widespread relations to comparative anatomy, embryology, morphology, zoology, physiology, and anthropology—I shall limit myself to the attempt to bring before you some of the more important observations and conclusions which have a bearing on the present position of the subject. As this is the closing year of the century it will not, I think, be out of place to refer to the changes which a hundred years have brought about in our fundamental conceptions of the structure of animals. In science, as in business, it is well from time to time to take stock of what we have been doing, so that we may realize where we stand and ascertain the balance to our credit in the scientific ledger.

So far back as the time of the ancient Greeks it was known that the human body and those of the more highly organized animals were not homogeneous, but were built up of parts, the *partes dissimilares* (τὰ ἀνόμοια μέρη) of Aristotle, which differed from each other in form, color, texture, consistency and properties. These parts were familiarly known as the bones, muscles, sinews, blood-vessels, glands, brain, nerves, and so on. As the centuries rolled on, and as observers and observations multiplied, a more and more precise knowledge of these parts throughout the animal kingdom was obtained, and various attempts were made to classify animals in accordance with their forms and structure. During the concluding years of the last century and the earlier part of the present, the Hunters, William and John, in our country, the Meckels in Germany, Cuvier and St. Hilaire in France, gave an enormous impetus to anatomical studies, and contributed largely to our knowledge of the construction of the bodies of animals. But whilst by these and other observers the most salient and, if I may use the expression, the grosser characters of animal organization had been recognized, little was known of the more intimate structure or texture of the parts. So far as could be determined by the unassisted vision, and so much as could be recognized by the use of

a simple lens, had indeed been ascertained, and it was known that muscles, nerves and tendons were composed of threads or fibers, that the blood- and lymph-vessels were tubes, and that the parts which we call fasciæ and aponeuroses were thin membranes, and so on.

Early in the present century Xavier Bichat, one of the most brilliant men of science during the Napoleonic era in France, published his 'Anatomie Générale,' in which he formulated important general principles. Every animal is an assemblage of different organs, each of which discharges a function, and acting together, each in its own way, assists in the preservation of the whole. The organs are, as it were, special machines situated in the general building which constitutes the factory or body of the individual. But, further, each organ or special machine is itself formed of tissues which possess different properties. Some, as the blood-vessels, nerves, fibrous tissues, etc., are generally distributed throughout the animal body, whilst others, as bones, muscles, cartilage, etc., are found only in certain definite localities. Whilst Bichat had acquired a definite philosophical conception of the general principles of construction and of the distribution of the tissues, neither he nor his pupil Béclard was in a position to determine the essential nature of the structural elements. The means and appliances at their disposal and at that of other observers in their generation were not sufficiently potent to complete the analysis.

Attempts were made in the third decennium of this century to improve the methods of examining minute objects by the manufacture of compound lenses, and, by doing away with chromatic and spherical aberration, to obtain, in addition to magnification of the object, a relatively large flat field of vision with clearness and sharpness of definition. When in January, 1830,

Joseph Jackson Lister read to the Royal Society his memoir 'On some properties in achromatic object-glasses applicable to the improvement of microscopes,' he announced the principles on which combinations of lenses could be arranged, which would possess these qualities. By the skill of our opticians, microscopes have now for more than half a century been constructed which, in the hands of competent observers, have influenced and extended biological science with results comparable with those obtained by the astronomer through improvements in the telescope.

In the study of the minute structure of plants and animals the observer has frequently to deal with tissues and organs, most of which possess such softness and delicacy of substance and outline that, even when microscopes of the best construction are employed, the determination of the intimate nature of the tissue, and the precise relation which one element of an organ bears to the other constituent elements, is in many instances a matter of difficulty. Hence additional methods have had to be devised in order to facilitate study and to give precision and accuracy to our observations. It is difficult for one of the younger generation of biologists, with all the appliances of a well-equipped laboratory at his command, with experienced teachers to direct him in his work, and with excellent text-books, in which the modern methods are described, to realize the conditions under which his predecessors worked half a century ago. Laboratories for minute biological research had not been constructed, the practical teaching of histology and embryology had not been organized, experience in methods of work had not accumulated; each man was left to his individual efforts, and had to puzzle his way through the complications of structure to the best of his power. Staining and hardening reagents were unknown. The double-

bladed knife invented by Valentin, held in the hand, was the only improvement on the scapel or razor for cutting thin, more or less translucent slices suitable for microscopic examination; mechanical section cutters and freezing arrangements had not been devised. The tools at the disposal of the microscopist were little more than knife, forceps, scissors, needles; with acetic acid, glycerine and Canada balsam as reagents. But in the employment of the newer methods of research care has to be taken, more especially when hardening and staining reagents are used, to discriminate between appearances which are to be interpreted as indicating natural characters, and those which are only artificial productions.

Notwithstanding the difficulties attendant on the study of the more delicate tissues, the compound achromatic microscope provided anatomists with an instrument of great penetrative power. Between the years 1830 and 1850 a number of acute observers applied themselves with much energy and enthusiasm to the examination of the minute structure of the tissues and organs in plants and animals.

CELL THEORY.

It had, indeed, long been recognized that the tissues of plants were to a large extent composed of minute vesicular bodies, technically called cells (Hooke, Malpighi, Grew). In 1831 the discovery was made by the great botanist, Robert Brown, that in many families of plants a circular spot, which he named areola or nucleus, was present in each cell; and in 1838 M. J. Schleiden published the fact that a similar spot or nucleus was a universal elementary organ in vegetables. In the tissues of animals also structures had begun to be recognized comparable with the cells and nuclei of the vegetable tissues, and in 1839 Theodore Schwann announced the important generalization that there is one universal princi-

ple of development for the elementary part of organisms, however different they may be in appearance, and that this principle is the formation of cells. The enunciation of the fundamental principle that the elementary tissues consisted of cells constituted a step in the progress of biological science, which will forever stamp the century now drawing to a close with a character and renown equalling those which it has derived from the most brilliant discoveries in the physical sciences. It provided biologists with the visible anatomical units through which the external forces operating on, and the energy generated in, living matter come into play. It dispelled forever the old mystical idea of the influence exercised by vapors or spirits in living organisms. It supplied the physiologist and pathologist with the specific structures through the agency of which the functions of organisms are discharged in health and disease. It exerted an enormous influence on the progress of practical medicine. A review of the progress of knowledge of the cell may appropriately enter into an address on this occasion.

STRUCTURE OF CELLS.

A cell is a living particle, so minute that it needs a microscope for its examination; it grows in size, maintains itself in a state of activity, responds to the action of stimuli, reproduces its kind, and in the course of time it degenerates and dies.

Let us glance at the structure of a cell to determine its constituent parts and the *rôle* which each plays in the function to be discharged. The original conception of a cell, based upon the study of the vegetable tissues, was a minute vesicle enclosed by a definite wall, which exercised chemical or metabolic changes on the surrounding material and secreted into the vesicle its characteristic contents. A similar conception was at first also entertained regarding the cells of animal tissues; but as observations

multiplied, it was seen that numerous elementary particles, which were obviously in their nature cells, did not possess an enclosing envelope. A wall ceased to have a primary value as a constituent part of a cell, the necessary vesicular character of which therefore could no longer be entertained.

The other constituent parts of a cell are the cell plasm, which forms the body of the cell, and the nucleus imbedded in its substance. Notwithstanding the very minute size of the nucleus, which even in the largest cells is not more than $\frac{1}{500}$th inch in diameter, and usually is considerably smaller, its almost constant form, its well-defined sharp outline, and its power of resisting the action of strong reagents when applied to the cell, have from the period of its discovery by Robert Brown caused histologists to bestow on it much attention. Its structure and chemical composition ; its mode of origin; the part which it plays in the formation of new cells, and its function in nutrition and secretion have been investigated.

When examined under favorable conditions in its passive or resting state, the nucleus is seen to be bounded by a membrane which separates it from the cell plasm and gives it the characteristic sharp contour. It contains an apparently structureless nuclear substance, nucleoplasm or enchylema, in which are embedded one or more extremely minute particles called nucleoli, along with a network of exceedingly fine threads or fibers, which in the active living cell play an essential part in the production of new nuclei within the cell. In its chemical composition the nuclear substance consists of albuminous plastin and globulin ; and of a special material named nuclein, rich in phosphorus and with an acid reaction. The delicate network within the nucleus consists apparently of the nuclein, a substance which stains with carmine and other dyes, a property which enables the changes, which take place in the network in the production of young cells, to be more readily seen and followed out by the observer.

The mode of origin of the nucleus and the part which it plays in the production of new cells have been the subject of much discussion. Schleiden, whose observations, published in 1838, were made on the cells of plants, believed that within the cell a nucleolus first appeared, and that around it molecules aggregated to form the nucleus. Schwann again, whose observations were mostly made on the cells of animals, considered that an amorphous material existed in organized bodies, which he called cytoblastema. It formed the contents of cells, or it might be situated free or external to them. He figuratively compared it to a mother liquor in which crystals are formed. Either in the cytoblastema within the cells or in that situated external to them, the aggregation of molecules around a nucleolus to form a nucleus might occur, and, when once the nucleus had been formed, in its turn it would serve as a center of aggregation of additional molecules from which a new cell would be produced. He regarded therefore the formation of nuclei and cells as possible in two ways : one within pre-existing cells (endogenous cell-formation), the other in a free blastema lying external to cells (free cell-formation). In animals, he says, the endogenous method is rare, and the customary origin is in an external blastema. Both Schleiden and Schwann considered that after the cell was formed the nucleus had no permanent influence on the life of the cell, and usually disappeared.

Under the teaching principally of Henle, the famous Professor of Anatomy in Göttingen, the conception of the free formation of nuclei and cells in a more or less fluid blastema, by an aggregation of elementary granules and molecules, obtained so much

credence, especially amongst those who were engaged in the study of pathological processes, that the origin of cells within pre-existing cells was to a large extent lost sight of. That a parent cell was requisite for the production of new cells seemed to many investigators to be no longer needed. Without doubt this conception of free cell-formation contributed in no small degree to the belief, entertained by various observers that the simplest plants and animals might arise, without pre-existing parents, in organic fluids destitute of life, by a process of spontaneous generation ; a belief which prevailed in many minds almost to the present day. If, as has been stated, the doctrine of abiogenesis cannot be experimentally refuted, on the other hand it has not been experimentally proved. The burden of proof lies with those who hold the doctrine, and the evidence that we possess is all the other way.

MULTIPLICATION OF CELLS.

Although von Mohl, the botanist, seems to have been the first to recognize (1835) in plants a multiplication of cells by division, it was not until attention was given to the study of the egg in various animals, and to the changes which take place in it, attendant on fertilization, that in the course of time a much more correct conception of the origin of the nucleus and of the part which it plays in the formation of new cells was obtained. Before Schwann had published his classical memoir in 1839, von Baer and other observers had recognized within the animal ovum the germinal vesicle, which obviously bore to the ovum the relation of a nucleus to a cell. As the methods of observation improved, it was recognized that, within the developing egg, two vesicles appeared where one only had previously existed, to be followed by four vesicles, then eight, and so on in multiple progression until the ovum contained a

multitude of vesicles, each of which possessed a nucleus. The vesicles were obviously cells which had arisen within the original germ-cell or ovum. These changes were systematically described by Martin Barry so long ago as 1839 and 1840 in two memoirs communicated to the Royal Society of London, and the appearance produced, on account of the irregularities of the surface occasioned by the production of new vesicles, was named by him the mulberry-like structure. He further pointed out that the vesicles arranged themselves as a layer within the envelope of the egg or zona pellucida, and that the whole embryo was composed of cells filled with the foundations of other cells. He recognized that the new cells were derived from the germinal vesicle or nucleus of the ovum, the contents of which entered into the formation of the first two cells, each of which had its nucleus, which in its turn resolved itself into other cells, and by a repetition of the process into a greater number. The endogenous origin of new cells within a pre-existing cell and the process which we now term the segmentation of the yolk were successfully demonstrated. In a third memoir, published in 1841, Barry definitely stated that young cells originated through division of the nucleus of the parent cell, instead of arising, as a product of crystallization, in the fluid cytoblastema of the parent cell or in a blastema situated external to the cell.

In a memoir published in 1842, John Goodsir advocated the view that the nucleus is the reproductive organ of the cell, and that from it, as from a germinal spot, new cells were formed. In a paper, published three years later, on nutritive centers, he described cells, the nuclei of which were the permanent source of successive broods of young cells, which from time to time occupied the cavity of the parent cell. He extended also his observations on the

endogenous formation of cells to the carti-
lage cells in the process of inflammation
and to other tissues undergoing patholog-
ical changes. Corroborative observations
on endogenous formation were also given
by his brother Harry Goodsir in 1845.
These observations on the part which the
nucleus plays by cleavage in the formation
of young cells by endogenous development
from a parent center—that an organic con-
tinuity existed between a mother cell and
its descendants through the nucleus—con-
stituted a great step in advance of the views
entertained by Schleiden and Schwann, and
showed that Barry and the Goodsirs had a
deeper insight into the nature and functions
of cells than was possessed by most of their
contemporaries, and are of the highest im-
portance when viewed in the light of recent
observations.

In 1841 Robert Remak published an ac-
count of the presence of two nuclei in the
blood corpuscles of the chick and the pig,
which he regarded as evidence of the pro-
duction of new corpuscles by division of the
nucleus within a parent cell ; but it was
not until some years afterwards (1850 to
1855) that he recorded additional observa-
tions and recognized that division of the
nucleus was the starting-point for the mul-
tiplication of cells in the ovum and in the
tissues generally. Remak's view was that
the process of cell division began with the
cleavage of the nucleolus, followed by that
of the nucleus, and that again by cleavage
of the body of the cell and of its membrane.
Kölliker had previously, in 1843, described
the multiplication of nuclei in the ova of
parasitic worms, and drew the inference that
in the formation of young cells within the
egg the nucleus underwent cleavage, and
that each of its divisions entered into the
formation of a new cell. By these observa-
tions, and by others subsequently made, it
became obvious that the multiplication of
animal cells, either by division of the

nucleus within the cell, or by the budding
off of a part of the protoplasm of the cell,
was to be regarded as a widely spread and
probably a universal process, and that each
new cell arose from a parent cell.

Pathological observers were, however, for
the most part inclined to consider free cell-
formation in a blastema or exudation by an
aggregation of molecules, in accordance
with the views of Henle, as a common
phenomenon. This proposition was at-
tacked with great energy by Virchow in a
series of memoirs published in his 'Archiv,'
commencing in Vol. I., 1847, and finally
received its death-blow in his published
lectures on ' Cellular Pathology,' 1858. He
maintained that in pathological structures
there was no instance of cell development
de novo; where a cell existed, there one
must have been before. Cell-formation
was a continuous development by descent,
which he formulated in the expression
omnis cellula e cellulâ.

KARYOKINESIS.

Whilst the descent of cells from pre-exist-
ing cells by division of the nucleus during
the development of the egg, in the embryos
of plants and animals, and in adult vege-
table and animal tissues, both in healthy
and diseased conditions, had now become
generally recognized, the mechanism of the
process by which the cleavage of the nu-
cleus took place was for a long time un-
known. The discovery had to be deferred
until the optician had been able to con-
struct lenses of a higher penetrative power,
and the microscopist had learned the use
of coloring agents capable of dyeing the
finest elements of the tissues. There was
reason to believe that in some cases a direct
cleavage of the nucleus, to be followed by
a corresponding division of the cell into
two parts, did occur. In the period be-
tween 1870 and 1880 observations were
made by Schneider, Strasburger, Bütschli,

Fol, van Beneden and Flemming, which showed that the division of the nucleus and the cell was due to a series of very remarkable changes, now known as indirect nuclear and cell division, or karyokinesis. The changes within the nucleus are of so complex a character that it is impossible to follow them in detail without the use of appropriate illustrations. I shall have to content myself, therefore, with an elementary sketch of the process.

I have previously stated that the nucleus in its passive or resting stage contains a very delicate network of threads or fibers. The first stage in the process of nuclear division consists in the threads arranging themselves in loops and forming a compact coil within the nucleus. The coil then becomes looser, the loops of threads shorten and thicken, and somewhat later each looped thread splits longitudinally into two portions. As the threads stain when coloring agents are applied to them, they are called chromatin fibers, and the loose coil is the chromosome (Waldeyer).

As the process continues, the investing membrane of the nucleus disappears, and the loops of threads arrange themselves within the nucleus so that the closed ends of the loops are directed to a common center, from which the loops radiate outwards and produce a starlike figure (aster). At the same time clusters of extremely delicate lines appear both in the nucleoplasm and in the body of the cell, named the achromatic figure, which has a spindle-like form with two opposite poles, and stains much more feebly than the chromatic fibers. The loops of the chromatic star then arrange themselves in the equatorial plane of the spindle, and bending round turn their closed ends towards the periphery of the nucleus and the cell.

The next stage marks an important step in the process of division of the nucleus. The two longitudinal portions, into which each looped thread had previously split, now separate from each other, and whilst one part migrates to one pole of the spindle, the other moves to the opposite pole, and the free ends of each loop are directed towards its equator (metakinesis). By this division of the chromatin fibers, and their separation from each other to opposite poles of the spindle, two star-like chromatin figures are produced (dyaster).

Each group of fibers thickens, shortens, becomes surrounded by a membrane, and forms a new or daughter nucleus (dispirem). Two nuclei therefore have arisen within the cell by the division of that which had previously existed, and the expression formulated by Flemming—*omnis nucleus e nucleo*—is justified. Whilst this stage is in course of being completed, the body of the cell becomes constricted in the equatorial plane of the spindle, and, as the constriction deepens, it separates into two parts, each containing a daughter nucleus, so that two nucleated cells have arisen out of a pre-existing cell.

A repetition of the process in each of these cells leads to the formation of other cells, and, although modifications in details are found in different species of plants and animals, the multiplication of cells in the egg and in the tissues generally on similar lines is now a thoroughly established fact in biological science.

In the study of karyokinesis, importance has been attached to the number of chromosomes in the nucleus of the cell. Flemming had seen in the Salamander twenty-four chromosome fibers, which seems to be a constant number in the cells of epithelium and connective tissues. In other cells again, especially in the ova of certain animals, the number is smaller, and fourteen, twelve, four, and even two only have been described. The theory formulated by Boveri that the number of chromosomes is constant for each species, and that in the

karyokinetic figures corresponding numbers are found in homologous cells, seems to be not improbable.

In the preceding description I have incidentally referred to the appearance in the proliferating cell of an archromatic spindle-like figure. Although this was recognized by Fol in 1873, it is only during the last ten or twelve years that attention has been paid to its more minute arrangements and possible signification in cell-division.

The pole at each end of the spindle lies in the cell plasm which surrounds the nucleus. In the center of each pole is a somewhat opaque spot (central body) surrounded by a clear space, which, along with the spot, constitutes the centrosome or the sphere of attraction. From each centrosome extremely delicate lines may be seen to radiate in two directions. One set extends towards the pole at the opposite end of the spindle, and, meeting or coming into close proximity with radiations from it, constitutes the body of the spindle, which, like a perforated mantle, forms an imperfect envelope around the nucleus during the process of division. The other set of radiations is called the polar, and extends in the region of the pole towards the periphery of the cell.

The question has been much discussed whether any constituent part of the achromatic figure, or the entire figure, exists in the cell as a permanent structure in its resting phase; or if it is only present during the process of karyokinesis. During the development of the egg the formation of young cells, by division of the segmentation nucleus, is so rapid and continuous that the achromatic figure, with the centrosome in the pole of the spindle, is a readily recognizable object in each cell. The polar and spindle-like radiations are in evidence during karyokinesis, and have apparently a temporary endurance and function. On the other hand, van Beneden and Boveri were of opinion that the central body of the centrosome did not disappear when the division of the nucleus came to an end, but that it remained as a constituent part of a cell lying in the cell plasm near to the nucleus. Flemming has seen the central body with its sphere in leucocytes, as well as in epithelial cells and those of other tissues. Subsequently Heidenhain and other histologists have recorded similar observations. It would seem, therefore, as if there were reason to regard the centrosome, like the nucleus, as a permanent constituent of a cell. This view, however, is not universally entertained. If not always capable of demonstration in the resting stage of a cell, it is doubtless to be regarded as potentially present, and ready to assume, along with the radiations, a characteristic appearance when the process of nuclear division is about to begin.

One can scarcely regard the presence of so remarkable an appearance as the achromatic figure without associating with it an important function in the economy of the cell. As from the centrosome at the pole of the spindle both sets of radiations diverge, it is not unlikely that it acts as a center or sphere of energy and attraction. By some observers the radiations are regarded as substantive fibrillar structures, elastic or even contractile in their properties. Others, again, look upon them as morphological expressions of chemical and dynamical energy in the protoplasm of the cell body. On either theory we may assume that they indicate an influence, emanating, it may be, from the centrosome, and capable of being exercised both on the cell plasm and on the nucleus contained in it. On the contractile theory, the radiations which form the body of the spindle, either by actual traction of the supposed fibrillæ or by their pressure on the nucleus which they surround, might impel during karyokinesis the dividing chromosome elements towards the poles of

the spindle, to form there the daughter nuclei. On the dynamical theory, the chemical and physical energy in the centrosome might influence the cell plasm and the nucleus, and attract the chromosome elements of the nucleus to the poles of the spindle. The radiated appearance would therefore be consequent and attendant on the physico-chemical activity of the centrosome. One or other of these theories may also be applied to the interpretation of the significance of the polar radiations.

CELL PLASM.

In the cells of plants, in addition to the cell wall, the cell body and the cell juice require to be examined. The material of the cell body, or the cell contents, was named by von Mohl (1846) protoplasm, and consisted of a colorless tenacious substance which partly lined the cell wall (primordial utricle), and partly traversed the interior of the cell as delicate threads enclosing spaces (vacuoles) in which the cell juice was contained. In the protoplasm the nucleus was embedded. Nägeli, about the same time, had also recognized the difference between the protoplasm and the other contents of vegetable cells, and had noticed its nitrogenous composition.

Though the analogy with a closed bladder or vesicle could no longer be sustained in the animal tissues, the name 'cell' continued to be retained for descriptive purposes, and the body of the cell was spoken of as a more or less soft substance enclosing a nucleus (Leydig). In 1861 Max Schultze adopted for the substance forming the body of the animal cell the term 'protoplasm.' He defined a cell to be a particle of protoplasm in the substance of which a nucleus was situated. He regarded the protoplasm, as indeed had previously beeen pointed out by the botanist Unger, as essentially the same as the contractile sarcode which constitutes the body and pseudopodia of the

Amœba and other Rhizopoda. As the term 'protoplasm,' as well as that of 'bioplasm,' employed by Lionel Beale in a somewhat similar though not precisely identical sense, involves certain theoretical views of the origin and function of the body of the cell, it would be better to apply to it the more purely descriptive term 'cytoplasm' or 'cell plasm.'

Schultze defined protoplasm as a homogeneous, glassy, tenacious material, of a jelly-like or somewhat firmer consistency, in which numerous minute granules were embedded. He regarded it as the part of the cell especially endowed with vital energy, whilst the exact function of the nucleus could not be defined. Based upon this conception of the jelly-like character of protoplasm, the idea for a time prevailed that a structureless, dimly granular jelly or slime destitute of organization, possessed great physiological activity, and was the medium through which the phenomena of life were displayed.

More accurate conceptions of the nature of the cell plasm soon began to be entertained. Brücke recognized that the body of the cell was not simple, but had a complex organization. Flemming observed that the cell plasm contained extremely delicate threads, which frequently formed a network, the interspaces of which were occupied by a more homogeneous substance. Where the threads crossed each other, granular particles (mikrosomen) were situated. Bütschli considered that he could recognize in the cell plasm a honeycomb-like appearance, as if it consisted of excessively minute chambers in which a homogeneous more or less fluid material was contained. The polar and spindle-like radiations visible during the process of karyokinesis, which have already been referred to, and the presence of the centrosome, possibly even during the resting stage of the cell, furnished additional illustra-

tions of differentiation within the cell plasm. In many cells there appears also to be a difference in the character of the cell plasm which immediately surrounds the nucleus and that which lies at and near the periphery of the cell. The peripheral part (ektoplasma) is more compact and gives a definite outline to the cell, although not necessarily differentiating into a cell membrane. The inner part (endoplasma) is softer, and is distinguished by a more distinct granular appearance, and by containing the products specially formed in each particular kind of cell during the nutritive process.

By the researches of numerous investigators on the internal organization of cells in plants and animal, a large body of evidence has now been accumulated, which shows that both the nucleus and the cell plasm consist of something more than a homogeneous, more or less viscid, slimy material. Recognizable objects in the form of granules, threads, or fibers can be distinguished in each. The cell plasm and the nucleus respectively are therefore not of the same constitution throughout, but possess polymorphic characters, the study of which in health and the changes produced by disease will for many years to come form important matters for investigation.

WILLIAM TURNER.

(*To be concluded.*)

EXPERIMENTS OF J. J. THOMSON ON THE STRUCTURE OF THE ATOM.

RECENT ideas as to the stability of the chemical molecule have been much modified by the evidence that it is readily dissociated when a substance is dissolved in water.

The researches now being carried on by J. J. Thomson and his assistants on the electrical conduction of gases seem to require an even more radical and sweeping change in our conception of the structure of the atom itself.

Ordinary gases are perfect non-conductors of electricity of low electromotive force. Electricity may, however, pass through them, more or less readily, under certain conditions, viz:

1. When the electromotive force is sufficient to produce a spark.

2. When the pressure of the gas is much reduced and a sufficient electromotive force is applied; as in a 'vacuum tube.'

3. When the gas is heated very hot, or has been recently in violent chemical activity, as in the region above a flame.

4. When the negative electrode is illuminated by ultra-violet light.

5. When the gas has been very recently exposed to Röntgen rays or to the similar rays proceeding from uranium, radium, etc.

Thomson's investigations on the conduction by sparks through gases at ordinary pressures, indicated that electrolysis took place somewhat as in solutions, and that the amount of decomposition was, in several cases, essentially the same as in the decomposition of solutions. In the case of hot gases and the gases in a vacuum tube, also there was evidence that the conduction was by means of 'ions' or portions of broken-down molecules which acted as carriers for the current.

When an electric current passes through a solution, it is a fundamental law that a univalent atom of any substance carries precisely the same charge as a univalent atom of any other substance, while a bivalent atom carries just twice this charge. The exact charge carried by one atom cannot be known until we know the exact weight of the atom; but the charge carried by 1 gramme of atoms (e/m) is about 10,000 units in the case of hydrogen. For any other univalent substance, the weight required to carry this charge is greater in