SOME RECENT INVESTIGATIONS RELATIVE TO CELL-CONTENTS.

ADDRESS

BY

GEORGE L. GOODALE,

VICE PRESIDENT, SECTION F,

BEFORE THE

SECTION OF BIOLOGY,

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,

AT THE TORONTO MEETING,

AUGUST, 1889.

From the PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, Vol. XXXVIII.

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WITH THE COMPLIMENTS

OF THE AUTHOR.

CAMBRIDGE, MASS.

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BY

PROFESSOR GEORGE L. GOODALE,

OF HARVARD UNIVERSITY, CAMBRIDGE, MASS.,

VICE PRESIDENT, BIOLOGICAL SECTION.

SOME RECENT INVESTIGATIONS RELATIVE TO CELL-CONTENTS.

IN the Department of Biology, there are three subjects of transcendent interest, namely: protoplasm, or living matter, development and adaptation. In fact the interest in some phases of these subjects is now so general and deep, that the special students in this department feel that they have to a great extent the sympathy and coöperation of the public at large. This interest renders possible the construction of such commodious laboratories as this, the latest acquisition of the University of Toronto, in which we are now permitted to meet. The generous halls and adequate equipment of this laboratory and other biological laboratories throughout our country and Europe, testify to the existence of a wide-spread belief that the New Natural History has much to learn and very much to teach in regard to the great problems of life.

In the annual gatherings of the members of our section, for the exchange of views and for better fellowship, it has been found expedient for us to look at one or the other of these three subjects at the outset of our work, in a somewhat broad and yet special manner.

Your chairman for the present year asks the privilege of selecting as his topic for the introductory address, the first of the subjects mentioned. You are invited to examine the more recent additions to our knowledge of protoplasm, restricting the examination to discoveries in the field of botany.

Whether we consider protoplasm, or the living-matter of plants and animals, from the point of view of physics, of chemistry, of physiology or of philosophy, we have before us a topic which has received and which continues to receive the most assiduous attention. Hence its literature, though comparatively recent, is appallingly voluminous, and any attempt to treat the subject, or any considerable part of it exhaustively within the limits properly imposed upon introductory addresses, would result in annoyance to you and utter discomfiture for me. Apropos of this, I am reminded of a series of experiments upon protoplasm, conducted in a German laboratory, which will illustrate the embarrassment which the case presents. The study to which I refer was with regard to certain organisms of very low grade. At a given period in the life of these organisms, their microscopic masses of protoplasm become confluent in such abundance that sufficient material can be procured for experiments on a large scale. In the special investigation referred to, a considerable quantity of protoplasm, obtained in this way, was subjected to enormous pressure. You can anticipate the result; there remained behind only a shrunken residue of what we may call, without figure of speech, the most juiceless and the dryest of husks.

This natural result of extreme compression has stared me in the face during the preparation of the present address. A similar result is more than likely to follow my attempt to bring within very narrow limits the subject which I have chosen for your consideration.

The word protoplasm was coined by Hugo von Mohl in 1846 to designate certain active contents of the vegetable cell. We shall gain in clearness of vision by letting our glance rest first on the results of investigating vegetable cells and cell-contents, anterior to von Mohl's time, in order that we may see some of the steps by which this term was reached by him.

The compound microscope was not applied seriously to the examination of the structure of plants until about fifty years after its discovery by Drebbel. In 1667 Robert Hooke of England published an account of his investigations of minerals, plants and animals under the microscope, and gave excellent illustrations of what he thought he saw. His first reference to the structure of plants is in his description of charcoal, and this is followed by a good account of common cork. In these brief and fairly accurate descriptions, the author makes use of the word "*cell*," applying the term to the cavities in charcoal and in cork.

Hooke's interesting treatise was soon followed by two remarkable memoirs, one by an Italian, the other by an Englishman. Malpighi of Bologna sent to the Royal Society of London in 1670 a work entitled *Anatome Plantarum.* The published volumes bear the dates 1675 and 1679. At the period these volumes were in the hands of the Royal Society, Nehemiah Grew, Secretary of the Society, was engaged in work almost identical with that of Malpighi, but there is no good reason to believe, as was formerly intimated, that he was indebted to Malpighi for any of the statements which he published as his own. It is, however, best for us to consider these two works together. By Grew the term "cell" appears to have been applied to the cavities in what we may term the softer tissues of the plant. To him, cells were much like the cells of a honey-comb, and he does not at any time seem to have suspected that cells could be modified into other histological elements.[1] There are, to be sure,

[1] "Next to the *cuticle*, we come to the *Parenchyma* itself, the *part* through which the "*Inner Body*, whereof we shall speak anon, is disseminated; for which reason I call it the "*Parenchyma.* Not that we are so meanly to conceive of it, as if (according to the "stricter sense of that word) it were a meer concreted *Juyce.* For it is a body very cu-"riously *organized*, consisting of an infinite number of extreme small *Bladders*, as in "Tab. 1 is apparent."—*The Anatomy of Plants* by Nehemiah Grew, M. D., 1682, page 4.

"I shall conclude this discourse with a further illustration of the *Texture* of the *Pith*, "and of the whole *Plant*, as consequent thereupon. I say therefore, (and I have given "some account hereof in the *Anatomy of Roots*) that as the *Vessels* of a *Plant*, sc. the *Aer-"Vessels* & the *Lymphæducts*, are made up of *Fibres;* according to what I have in this "Discourse above said; so the *Pith* of a *Plant*, or the *Bladders* whereof the *Pith* con-"sists are likewise made up of *Fibres*, which is true also of the *Parenchyma* of the "*Barque*, and also of the *Insertions* in the *Wood.* Yea, and of the *Fruit*, and all other "*Parenchymous Parts* of a *Plant.* I say, that the very *Pulp* of an *Apple*, *Pear*, *Cucumber*, "*Plum*, or any other *Fruit*, is nothing else but a *Ball of most extreme small transparent "Threds* or *Fibres*, *all wrapped & stich'd up* (though in divers manners) *together.* And "even all those *Parts* of a *Plant*, which are neither formed into visible *Tubes*, nor into "*Bladders*, are yet made up of *Fibers.* Which, though it be difficult to observe, in any "of those *Parts* which are closer wrought and principally in the *Insertions* of some "*Trees*, yet in the *Pith*, especially of some *Plants*, which consisteth of more open *Work*, "they are more visible, which introduceth the observation of them in all other *Paren-"chymous Parts*, so in the Pith of a *Bulrush* of the *common Thistle* & some other "*Plants;* not only the *Threds* of which the *Bladders*, but also the single *Fibers* of "which the *Threds* are composed, may sometimes, with the help of a good *glass*, be "distinctly seen. Yet one of those *Fibres* may reasonably be computed to be a Thou-"sand times smaller than a *Horse-Hair.*"

"The *Fibrosity* of the *Parenchyma* is also visible in some *Woods*, in which it is appa-"rently mixed with the *Lignous Parts*, not only by *Insertions*, but *per minimus Partes "organicas.* That is to say, the *Parenchymous Fibres*, like smaller *Threds*, are either "*wrapped round about* both the *Lignous & the Aer-Vessels* or at least *interwoven* with them, "and with every *Fiber* of every *Vessel;* as in *White Ash* or *Fir-Wood*, with an advanta-"gious posture & light, may be observed.

"Whence it follows that the whole *substance*, or all the *Parts* of a *Plant*, so far as "*Organical*, they also consist of *Fibres.* Of all which *Fibres* those of the *Lymphæducts*, "run only by the *Length* of the *Plant*, those of the *Pith*, *Insertions* & *Parenchyma* of the "*Barque*, run by the *breadth* or horizontally: those of the *Aer-Vessels* fetch their cir-"cuit by the *Breadth*, and continue it by the *Length.*"—*The Anatomy of Plants by Nehemiah Grew*, 1682, pp. 120 & 121.

a few ambiguous expressions which might indicate that both he and Malpighi held a somewhat different view, but a strict construction of their text compels us to believe that they did not regard the vegetable cell as in any true sense a unit of structure: furthermore it is almost certain that neither Malpighi nor Grew recognized as we can now the multifarious forms of vessels, fibres, long cells and the like, as referable to a common source. There is always a strong temptation to read in an old text some meaning which squares with our own notions, and one is greatly tempted to think that these assiduous investigators, Grew and Malpighi, detected the relationships which we know exist between the different elements of vegetable structure. But after giving them the benefit of every doubt, one fails to find in their writings any recognition of such affinities. On the contrary, these investigators were engaged in a study which naturally led them away from such conceptions: they were busy with descriptive work, outlining the arrangement of tissues in all organs of the plant which their knives could reach. They did not even break up the tissues into elementary parts, but they described and delineated with great skill the tissues as they were displayed in sections. Is it not incredible that these first works on vegetable structure, prepared only a few years after the earliest application

"By which means, the said *Parenchymous Fibres*, in fetching their *horizontal circles*, do "thus *weave*, and make up the *Bladders* of the *Pith* in *Open Work*. And the same *Fibres* "being thence continued, they also *weave* & make up the *Insertions*, but in *Close-Work*. "Betwixt which *Insertions*, the *Vessels* being likewise transversely interjected, some of "the same *Fibres wrap* themselves also about these; thus *tying* many of them together "and so making those several *Conjugations & Braces* of the *Vessels*, which I have form-"erly described. And as some of these *horizontal Fibres* are *wraped* about the *Vessels*, so "also about the *Fibres* whereof the *Vessels* are composed. By which means it is, that all "the *Fibres* of the *Vessels* are *tacked* or *stitched* up close together into one coherent Piece. "Much after the same manner, as the *Perpendicular Splinters* or *Twigs* of a *Basket* are "by those that run in and out *Horizontally*. And the same *Horizontal Fibres*, being "still further produced into the *Barque*, they there compose the same *work* over again "(only not so *open*) as in the *Pith*.

"So that the most unfeigned & proper resemblance we can at present make of the "whole *Body* of a *Plant*, is to a piece of *fine Bone-Lace*, when the Women are working "it upon the *Cushion*. for the *Pith*, *Insertions & Parenchyma* of the *Barque*, are all ex-"tream Fine & Perfect *Lace-Work;* the *Fibres* of the *Pith* running *Horizontally*, as do "the *Threds* in a Piece of *Lace;* and bounding the several *Bladders* of the Pith and *Barque* "as the *Threds* do the several *Holes* of the *Lace*, and making up the *Insertions* without "*Bladders* or with very small ones, as the same *Threds* likewise do the *Close* parts of "the *Lace*, which they call the *Cloth-Work*. And lastly both the *Lignous* and *Aer-Ves-*"*sels* stand all *Perpendicular*, and so cross to the *Horizontal Fibres* of all the said *Pa-*"*renchymous Parts*, even as in a Piece of *Lace* upon the *Cushion*, the *Pins* do to the "*Thred*. The *Pins* being also conceived to be *Tubular* and prolonged to any length, "and the same *Lace Work* to be wrought many Thousands of times over & over again "to any thickness or hight according to the hight of any *Plant*. And this is the true *Text-*"*ure* of a *Plant* and the *general composure* not only of a *Branch*, but of all other parts "from the *seed* to the *seed*.—*The Anatomy of Plants, by Nehemiah Grew*, 1682, p. 121.

of the compound microscope to the study of plants, should have remained for almost one hundred and fifty years the only comprehensive treatises on the subject? But the most charitable inquirer fails to find during that long period any other works of importance on vegetable anatomy.

Near the close of the last century, at a period characterized by activity in many departments of speculative inquiries, the subject of vegetable structure again excited considerable attention, but little substantial advance was made. In 1804, the Royal Society of Sciences at Göttingen[1] proposed for competition, certain questions relative to the structure and the mode of growth of tissues. The chief contestants for this prize were Link, Rudolphi, and Treviranus. The memoirs of the first two received prizes, that of the latter, honorable mention. The names of others should be referred to as having worked at or about this time, in the same field, namely, Bernhardi, Mirbel and Moldenhawer, the latter making a great advance in certain directions. But to all of these whom I have mentioned, including the winners of the prize, the important questions seemed to be, how are the structural elements distributed, rather than how they are related to each other in manner of growth and as respects their origin. With the cell-contents they had comparatively little to do; they were busy with the constituents of the framework.

There seems to have been a strong suspicion on the part of some botanists during that period, that all this study of the skeleton of the plant failed to go to the bottom of the question. The only wonder is that with their scanty and untrustworthy chemical appliances and with their very imperfect lenses they accomplished so much. May I remind you that the element iodine which is the most important reagent in the examination of the contents of vegetable cells was not employed until the year 1812; and, further, that no good achromatic and aplanatic lenses, of even moderately high power, were constructed until 1826.[2]

Noting the more important discoveries of the next period in their order, we come first upon that of the nucleus of vegetable cells by Robert Brown in 1833, and one mode of cell-division by Mohl in 1835. In 1838 the eccentric Schleiden published his contributions to Phytogenesis in which he states substantially that

[1] Königliche Gesellschaft der Wissenschaften zu Göttingen.

[2] Æpinus and Van Deyl had nearly succeeded more than twenty years earlier.

cells of plants can be formed only in a fluid containing as chief ingredients, sugar and mucus ("schleim"). By this latter term he designated the nitrogenous matters taken collectively. At his touch all disguises fell, and for the first time the vegetable cell was distinctly recognized as a unit of structure always serving as the common basis for the formation of the innumerable shapes of the structural elements.

Next comes the master, Mohl. Armed with the best optical appliances procurable, familiar with the use of the chemical reagents then at command, and accustomed to accurate research, he reviews his own earlier work and that of his contemporaries, making rapid advances in the knowledge of the contents of the cell. In 1844 in a paper on the circulation within vegetable cells, he speaks of the living mass in each active cell, and distinctly recognizes it as that which is the treasury of stored energy and the vehicle of energy under release. He describes it as that which builds shapely forms out of unformed matter and at first hands. This substance he names *protoplasma*.[1]

If we look at the handbooks of botany just before this date of the early forties, we find references to "coagulable" matters (Treviranus) and the like. The chemical instability of the substance within cells was suspected of having much to do with its activity, but almost all of the notes, as well as those upon the same subject found here and there in philosophical writings of the latter part of the last century, are based on pure speculation. The scientific recognition of a physical basis of vital activity must be credited to Schleiden and Mohl.

The term protoplasm was at once adopted by Schleiden as a good substitute for the indefinite and misleading word *schleim* which he had employed to designate essentially the same substance, and it became thoroughly established in scientific terminology. In 1850, Professor Cohn (and Unger in 1855) showed that the protoplasm of vegetable cells is identical with what had been described

[1]"Da wie schon bemerkt diese zähe Flüssigkeit uberall, wo Zellen entstehen sollen, den ersten, die künftigen Zellen andeutenden festen Bildungen vorausgeht, da wir ferner annehmen müssen dass dieselbe das Material fur die Bildung des Nucleus und des Primordialschlauches liefert, indem diese nicht nur in der nächsten räumlichen Verbindung mit derselben stehen, sondern auch auf Jod auf analoge Weise reagiren, das also ihre Organisation der Process ist, welcher die Entstehung der neuen Zelle einleitet, so mag es wohl gerechtfertigt sein, wenn ich zur Bezeichnung dieser Substanz eine auf diese physiologische Function sich beziehende Benennung in dem Worte Protoplasma vorschläge."—*Bot. Zeit., 1846*, p. 75.

in 1835, in animal structures, as *sarcode*, by Dujardin, and this prepared the way for the exhaustive treatise by Max Schultze in 1858. From that date on, work in the contiguous fields of botany and zoölogy has made no physical or chemical distinction between the living-matter in animals and plants. Investigators in the two fields have been mutually helpful.

Mohl, in his treatise on the vegetable cell, published in 1851,[1] gives the following account of protoplasm.

"If a tissue composed of young cells be left some time in alcohol, or treated with nitric or muriatic acid, a very thin, finely granular membrane becomes detached from the inside of the walls of the cells, in the form of a closed vesicle, which becomes more or less contracted, and consequently removes all the contents of the cell, which are enclosed in this vesicle, from the wall of the cell. Reasons hereafter to be discussed have led me to call this inner cell the *primordial utricle* (*primordialschlauch*). . . . .

"In the centre of the young cell with rare exceptions rises the so-called *nucleus cellulæ* of Robert Brown ("Zellen-kern;" "Cytoblast" of Schleiden). . . . .

"The remainder of the cell is more or less densely filled with an opaque, viscid fluid of a white color, having granules intermingled in it, which fluid I call *protoplasm*."

We must now pass without notice numerous contributions to the subject made about this time, and consider Hofmeister's description of protoplasm given in his Vegetable Cell, published in 1867.

"The substance Protoplasm, whose peculiar behavior initiates all new development, is everywhere an essentially homogeneous body. It is a viscid fluid, containing much water, having parts easily motile, capable of swelling, and possessing in a remarkable degree the properties of a colloid. It is a mixture of different organic matters among which albuminoids and members of the dextrine group are always present. It has the consistence of a more or less thick mucus and is not miscible with water to any great extent."

From these and other accounts of the same date, we see that the following points were regarded as established:— (1) All of the activities of the vegetable cell are manifested in its protoplasmic contents. (2) Protoplasm consists chemically of a nitrogenous

[1] The English translation in 1852.

basis. (3) Protoplasm has no demonstrable structure. (4) The protoplasmic contents in one vegetable cell are not connected with the protoplasmic contents in adjoining cells. (5) The nucleus and other vitalized granules in the vegetable cell are formed by differentiation from amorphous protoplasm.

It is now our duty to see in what manner these views have been modified during the last twenty or rather ten years. In describing the changes of opinion, time will not suffice for us to allude to most of the observers; a few only can be mentioned by name.

The first thesis, namely, that all of the activities of the vegetable cell are manifested in its protoplasmic contents, may be regarded as firmly established. It is at this point in our present examination when, if we had time, we should take up, one by one, the terms which have been applied to some specialized or localized parts of what Mohl and Hofmeister knew as protoplasm. We can only glance at them in passing:—thus *cytoplasma* is understood to be the mass exclusive of the granular contents of all kinds; *hyaloplasma* is the outer hyaline layer; *polioplasma* is the grayish granular part. To these terms may be added others, such as *paraplasma*, etc.

The second thesis, viz.:—protoplasm consists chemically of a nitrogenous basis, remains unchanged. But instead of regarding the protoplasmic basis as simple or one, it is now known to be exceedingly complex, and to contain numerous allied proteids, some of which can be identified in the basic mass, others in the nucleus and others still in the vitalized granules.

Researches respecting this thesis must be considered also with reference to work by two diligent investigators, Pfeffer and de Vries. The former has shown the conditions under which active protoplasm reacts in the presence of certain chemical excitants; the latter has demonstrated the relations of a part of this irritability of protoplasm to its physical constitution. But as a result of all these recent studies it becomes more and more clear that the chemical relations of the protoplasmic activities are still veiled in mystery. Botanists are receding from a position held by many only a few years ago, namely, that it is safe to use the words albuminoids and protoplasm interchangeably. Nowadays the latter term is generally restricted to morphological and physiological conceptions; the former keeps its wide chemical significance.

Just here, come also the chemical studies of protoplasm; by

Rodewald and Reinke on a large scale, by Loew and Bokorny, and by Schwarz under the microscope. All of these results compel us to recognize in protoplasm a substance of bewildering complexity of composition and constitution. Moreover, you all know how wide this field of research has suddenly become by the discovery that different microbes (which are essentially minutest masses of protoplasm) not only give rise to such diverse products, but present such diverse chemical reactions.

Protoplasm is no longer regarded by any one in any sense as a comparatively simple substance.

The third thesis, namely, that protoplasm has no demonstrable structure, has been modified in a striking manner as a result of improved appliances for research. By better methods of staining and by the use of homogeneous immersion objectives the apparently structureless mass is seen to be made up of parts which are easily distinguishable. There has been, and in fact is now, a suspicion that some of these appearances under the influence of staining agents are post-mortem changes and do not belong to protoplasm in a living state. But it seems to be beyond reasonable doubt that protoplasm is marvellously complex in its morphological and physical as well as its chemical constitution. One statement of the case is as follows:—

Under ordinary circumstances, protoplasm is composed of a mesh of inconceivable fineness, in which mesh are entangled the more liquid interfilar portions (paraplasma); so that the dry husks left in Reinke's experiment may be regarded in fact as the residue of network from which all the moisture has been expelled. But this conception of protoplasm as a mass composed of a network of minutest fibres enclosing in its meshes another substance presents, as has been well shown by some critics, great difficulties, especially when we endeavor to explain the movements within the cell. It is also very difficult to explain in any way the so-called wandering of protoplasm outside the cell wall or into intercellular spaces.

Fourth, we are to glance at the accepted statement that the protoplasmic body or protoplast, as it is called, of one cell is cut off by the cell wall from all connection with the contiguous cells. There are a few cases in which this intervening wall was formerly held to be pervious, but such cases were considered as exceptional. Now, however, as has been shown by Gardiner and others who have followed out his exact researches, there are intercommunicating threads of protoplasm of extreme fineness between adjoining cells, and these living threads maintain a connection, sometimes direct, sometimes indirect, between one protoplasmic mass and another. This has been shown to be so widely true in the case of the plants hitherto investigated, that the generalization has been ventured on, that *all the protoplasm throughout the plant is continuous.* The formation of the dividing wall in cell division is now better understood than ever before, and our knowledge of this process lends great probability to the truth of the general statement made. It is not unlikely then that all the living matter throughout each plant is continuous, a whole, shut off only partially until the time of severing from the mother plant from the body of protoplasm there, and thus making a true chain of descent.

May I ask you to observe, in passing, how this bears on the vexed subject of individuality of plants. Brücke in 1862 declared that the living protoplasmic contents of a cell formed an elementary organism, and this idea found its fullest expression in the profound work by Hanstein in 1880. In that treatise Hanstein proposed for the living protoplasmic contents of the cell, the term protoplast, in order to indicate its individuality. But these late researches show that these protoplasts are not only highly organized and of complicated structure, but each is bound by indissoluble ties to its nearest neighbors, each helping to form a united whole.

The fifth thesis has been completely controverted. Instead of believing as formerly that all the granules within the cell arise *de novo* from the protoplasm in which they are imbedded, we are now forced to regard all of them as springing from preëxistent bodies of the same character.

Hofmeister in 1867, in an exhaustive description of the contents of vegetable cells, states distinctly that the nucleus arises from homogeneous protoplasm, and that in all cell division the nucleus must first disappear, two new ones arising in its place. The nucleus, according to him, occupied a secondary place as a derivative organ, and the chlorophyll granules were believed by him and his contemporaries to be new formations from homogeneous protoplasm under certain conditions of light, temperature and food. Researches which leave no room for doubt have shown that the nucleus, in all cases hitherto examined, springs from a preëxistent nucleus by a process of division. The process of division with its marvellous sequence of formal arrangements of definite portions in meridional lines and in polar and equatorial masses, has been most carefully examined in almost every organ of the plant, and in connection with similar processes of cell-division in animal tissues. In no well marked case has a nucleus been observed to arise from homogeneous protoplasm, even a few doubtful instances having been lately explained satisfactorily.

The extraordinary manner in which the nucleus, both in common cell-division and in reproductive blending, carries ancestral characters and controls the distribution of nutritive materials, is as yet the greatest mystery in vegetable life.

We pass next to consider a very important change of view in regard to the other granules imbedded in the protoplasmic body, known as leaf-green or chlorophyll granules. Formerly, as we have noticed, it was held that all of these sprang by a process of differentiation from the shapeless mass in each exposed cell. Researches by Schmitz on some of the lower plants, and by Schimper and Meyer on the higher, have shown that these chlorophyll granules always arise by a process of division from preëxistent granules. This fact taken by itself might not possess great interest. It is, however, known that at the growing points where leaves are developed, the cells contain in their protoplasm, granules of about the consistence and color of protoplasm itself, and these granules have the power of division, much after the fashion of the cell nucleus. But the products of such division are essentially three-fold: some of the resulting granules are colorless, like the mother granules, others become true chlorophyll-granules, while others still, in those leaves which become the leaves of the flowers and the fruit, assume colors other than green. In other words we have in these associated granules, or chromatophores, a morphology which is of the highest interest. The needs of the plant bring from this common source the microscopic organs for assimilation, for storing up starch in the form of grains, for protection and attraction. This most interesting generalization, in regard to the granules taken together, adds a new zest to the study of the developing plant and the evolving species.

It has been lately claimed by de Vries of Holland, that the sap-cavities or vacuoles in protoplasm divide in much the same way as do the granules just referred to, but this part of the subject is not yet beyond all doubt. That the sap-cavities are the birth-place of most crystals, and that the aleurone grains are desiccated sap-cavities has been made out by several observers. But it is not clear that vacuoles divide as granules do.

What we do know beyond all reasonable question is this,— that all the working granules within the plant have sprung from pre-existent granules, and that there is no break here in the transmission from parent to offspring.

Such then are some of the more important changes which have taken place with regard to our knowledge of the living contents of vegetable cells. I would gladly take the time, if it could be granted, to call your attention to certain most interesting discoveries which have been made by Pfeffer relative to the absorption of coloring agents by living protoplasm, and which have been supplemented by Campbell in regard to the nucleus. But more than this allusion is now impossible.

It is an interesting coincidence that with the substituting of the crude compound microscope for high power simple lenses about 1660, came the first works on vegetable structure, and for more than one hundred years, or until the introduction of achromatic object glasses, these works were in truth the only authoritative treatises. With the introduction of water-immersion lenses came renewed activity in this field, and with the later discovery of homogeneous immersion lenses came the results which have now been detailed. Whether we have, at these stages, more than a series of interesting and very striking coincidences, or not, we have not time now to discuss. It is enough for our present purpose to observe that, with the introduction of the cedar-oil immersion objectives, a thorough reïnvestigation of certain parts of this subject began. One may be pardoned for asking whether the objectives known as apochromatics are to open up in this field new lines of research.

Can these recent discoveries relative to the continuity of protoplasm and the genetic relationship of the associated granules (including in the widest sense, the nucleus) be made to cast any light on the question of development, as they certainly do upon the kindred question of adaptation? The answer has been given us very lately by Hugo de Vries of Amsterdam.[1] This investigator, who has done very much to clear up certain obscurities in regard to the external relations of the cell, has recently revised the

[1] Intracellulare Pangenesis, Jena, 1889.

neglected doctrine of pangenesis and applied it to the question just propounded. De Vries suggests that we divide the hypothesis of pangenesis as proposed by Darwin into two parts, as follows: (1) In every germ-cell individual characters of the whole organism are represented by material particles which, by their multiplication, transmit to descendants all of such peculiarities. (2) All the cells of the organism throw off at certain periods of development material particles which flow towards the germ-cells supplying its deficiencies.

Now, de Vries asks, whether it is not high time for us to look at the first part of this hypothesis again and abandon the hindrances which the latter part imposes. If we accept his suggestion and restate the hypothesis, in view of what has been learned relative to the nucleus and other granules (the trophoplasts) within the cell, we should then read:

In every cell at a growing part are all the elements ready for multiplication. Each protoplast possesses the organs necessary for continuous transmission: the nucleus, for new nuclei; the trophoplasts for new granules of all kinds according to the needs of the plant.

De Vries reviews all theories bearing on the question, from the so-called plastidules of Elsberg to the germ-plasma of Weismann, and then applies his hypothesis of intra-cellular pangenesis to the different parts of a single plant and to the transmission of peculiarities. The active particles recognized in Darwin's hypothesis, he terms *pangens*, and, regarding them as vehicles of hereditary characters, traces them throughout their course. He is not obliged to ask for any means of transportation for these pangens, since they work, so to speak, on the spot. They are ready at hand at the points of growth.

We must look very sharply with reference to this at two points of growth in the flowering plant, namely, the bud and the seed. Each bud with its growing point, made up of cells containing in their protoplasm the divisible granules, carries with itself all the peculiarities which have been transmitted without appreciable change. In the formation of the bud there is fission, but no blending. The cells divide, and each in turn may divide until the ultimate form of the leafy branch or flower is reached. In the leafy branch new buds form, and in their turn carry forward the ancestral peculiarities. But in the flower on the other hand, with the formation of the ovule, all development is arrested (except in the rare cases of parthenogenesis and the like) unless the protoplasm of the embryonal sac receives a new impetus from material contributed by the pollen grain. And in this blending of parts which have developed under different external conditions, we see that there is a chance for variation to come in. Not only is there a blending of the nuclei but a sharing of the accompanying trophoplasts. How this can be applied to the lower plants and other organisms cannot now be referred to. It would not be right to hold de Vries wholly responsible for the application just given, but I ask you whether the hypothesis does not appear fruitful. It certainly seems, to me, to be likely to stimulate speculation and research in this important field.

In view of de Vries' work and of the results of recent study which I have endeavored to bring before you this afternoon, does not the following statement of Darwin possess new force?

"An organic being is a microcosm, a little universe, formed of a host of self propagating organisms, inconceivably minute and as numerous as the stars in Heaven."