To
Prof. Foz
with the Authors
kind regards

ON THE

FORMATION OF SO-CALLED CELLS

IN

ANIMAL BODIES.

BY

EDMUND MONTGOMERY, M.D.

LATE DEMONSTRATOR OF MORBID ANATOMY AT ST. THOMAS'S HOSPITAL.

"The formation of the elementary shapes of organisms is but a crystallization of substance capable of imbibition."—SCHWANN.

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CONTENTS.

ON THE

FORMATION OF SO-CALLED CELLS

IN

ANIMAL BODIES.

NATURAL FORMATION OF "CELL"-SHAPES.

OBSERVATIONS.*

Manipulation.—The minute structure of many animal tissues is so exceedingly delicate and unstable as to make it absolutely necessary to use in their microscopical investigation the gentlest possible handling. The least alteration in the conditions by which, in the living body, these soft mutable textures are surrounded and sustained, is apt entirely to change their morphological appearance, to give rise to artificial shapes bearing little or no resemblance to the natural state.

Therefore, in the following observations, great care was taken to transfer the tissues from the body to the microscope, with as little change in the normally existing conditions as was practicable under the circumstances.

This cautious method—evidently the only one fit

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* Most of the observations described in this paper were made from November, 1860, to May, 1863, during which time I held the office of Demonstrator of Morbid Anatomy at St. Thomas's Hospital.

to disclose properly the secrets of morphology—was scarcely at all in use when these investigations were first commenced. But it has become more generally employed since, and is rapidly regenerating the old science, which, it must be confessed, based its results, to a great extent, on specimens obtained by very coarse though elaborate modes of preparation.

The textures which revealed the facts here detailed, were separated from the body during life, or immediately after, were then at once placed under the microscope, bathed, if possible, in their natural juice, or else immersed in clear fresh serum, which was kept at a temperature of about 100° F. The temperature of the glass-slides upon which the preparations rested, was also maintained at about 100° F.

The microscope employed in these studies was one of Smith and Beck's largest. The powers chiefly used were the one-fourth and the one-eighth inch, with the lowest eyepiece.

Many thousand observations were made, all helping more or less to form or to confirm the view here put forward, concerning the mode of production of so-called organic cells. For the sake of conciseness and perspicuity, however, only those few facts shall be here communicated which are of chief importance in the elucidation of the main result, to which all the observations have led.

Imbibition-phenomena in "cells."—It was in examining cell-containing tumours, according to the above-stated method, that I was struck with some appearances of which I had never heard before, and which, nevertheless, formed a very prominent feature in the sights displayed under my eyes.

Entire dissolution of "cells."—Sometimes, namely, on the addition of a little warm distilled water to the natural juice through which the object was viewed, the "cells" would all of a sudden rapidly swell out to an immense size—three or four times their original diameter,—growing paler as they expanded, and at last often vanishing altogether. In various instances the nucleus would participate in this change, also growing larger and fainter till it was lost sight of. At other times, however, it alone remained unaltered, whilst the surrounding cell-constituents were diffusing themselves into the adjacent medium.

This curious phenomenon can be regulated with regard to its rapidity by adding the water very slowly and in small quantities.

It is thus capable of being closely watched. There is no bursting of cell-membrane, with pouring out of contents. The whole globule gradually swells out and fades away, with perfect uniformity, disappearing at last without leaving the slightest visible trace of its former existence.

This surprising phenomenon yielded positive proof of the non-existence of any cell-membrane and fluid contents.* It seemed clearly to indicate that the globules under view consisted of some viscid material capable of imbibing more or less water; of imbibing sometimes so much that the original viscosity of the mass was ultimately overcome by its increasing liquefaction.

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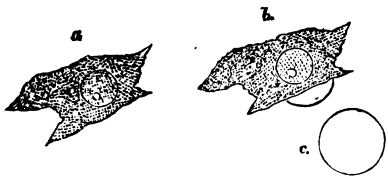
* When I first made this observation, in December, 1860, the cell-membrane was still almost universally believed to be an indispensable constituent of a true cell. It is chiefly through the endeavours of Max Schultze that science has been since freed from this great error.

These instances of entire dissolution of distinct "cell"-shapes were, however, only the extreme manifestation of a process which is often at work against various more limiting obstacles.

Imbibition giving rise to globular formations.—Nuclei in growing tissues, when isolated from the mother-texture, are often surrounded by an irregular shred-like granular mass. Out of this would bulge, on the addition of water, a clear bright segment of a globule, increasing more or less rapidly till it became full-orbed, when it would detach itself, and float away an independent body.

FIG. 1.



a. Nucleus, with its shred-like appendix. *b*. A clear globular segment bulging from it on imbibition. *c*. The same, full grown and detached.

In this occurrence, which I have very frequently observed, it would seem that some imbibing viscid material was mixed up with another cohesive substance incapable of imbibition. On the addition of water the former alone expands, being thus drawn out of its connexion with the latter until it forms a separate body. Such bodies, as I take it, are not mere albuminous drops, but globules formed by the uniform expansion of a viscid imbibing material. The nucleus, with its shred-like enclosure, remains behind, often apparently unaltered.

But this is not what always happens under similar conditions. I have occasionally seen a much more

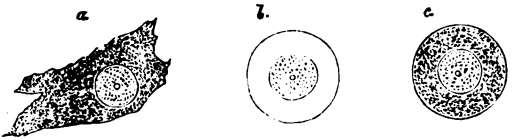
interesting result. At times, namely, the clear imbibing material does not separate from the shreddy granular substance. But the whole mass begins to swell out together, altering its irregular shape, till it has formed itself into a beautiful globule. Nothing could possibly surpass the perfect "cell"-appearance which is hereby produced. The nucleus, which was formerly the only regular shape amidst an unfashioned flake of granular stuff, becomes now, as by magic, surrounded by a splendid clear-cut sphere, formed from that self-same amorphous matter, merely by the addition of water. Shapes are hereby produced differing nowise from fully formed "cells" in other parts of the growth. In these cases the cohesiveness of the non-imbibing substance was probably not great enough to resist the expansion of the imbibing ingredient with which it was mixed up.

FIG. 2.

a. Nucleus with shred-like appendix. *b*. The same after imbibition.

These component parts, imbibing and non-imbibing, which make up the mass that is seen to encompass the nuclei, though they become at times so widely differentiated as entirely to separate from each other

FIG 3.



a. Nucleus, with shred-like appendix. *b*. The same after imbibition, the granules having disappeared. *c*. The same after a time, when the granules had reformed.

on the addition of water; they must, nevertheless,

closely resemble one another as regards their chemical nature. The following observation renders it even highly probable that they are but one and the same substance under different physical conditions. In some rare instances, namely, the granules of the shreddy material were completely dissolved by the action of the water. The resulting globule shone, at first wholly pellucid. Soon, however, the granules began to reform, showing molecular motion. Ultimately the entire mass of the globule seemed to undergo coagulation, making up a solidified sphere round the nucleus.

Unequal coagulation would be sufficient in itself to produce such a differentiation in the shreddy mass, as was shown in the above-related case to result in the emanation of a separate translucent globule.

It will be found that this fact of unequal coagulation, and alternate liquefaction and solidification of the same material, will afford the most intelligible explanation of some other striking phenomena, which will be described in this paper. I will state another very interesting observation nearly related to the last.

Not only single nuclei, with their appendix of shapeless material, are seen floating about—in the juice of some cancer, for example;—but also clusters of two, three, or more, each such imbedded in a proportionately large mass of granular material. Now it happens sometimes that, on the addition of water, the whole non-nuclear mass of such a cluster swells out, blending into one huge sphere, which encloses two, four, or more nuclei, as the case may be.

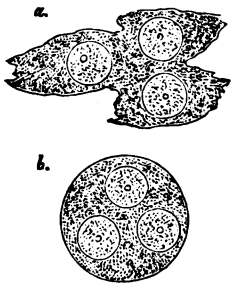
This appearance, so simply produced under

one's very eyes, is at once recognized to be identical in shape with some of the mysterious beings which have become so celebrated under the name of mother-cells.

It must be confessed that at all these most distinct sights, a flood of doubt is felt to rush in, threatening to sweep away the fondly-nurtured belief, which is contained in that most pregnant formula:

"Omnis cellula e cellulâ."

FIG. 4.



a. A group of nuclei, with their shred-like appendix. *b*. The same after imbibition, forming a "Mother-cell."

Here, at all events the progeny was clearly seen to be of older age than the parent, and all "cell"-constituents, as such,—with the exception of the nuclei—were watched shaping themselves under the microscope.

But the nuclei also will be shown to be produced merely by chemical and physical processes, and there will then remain nowhere within the "cells" a specific resort for the so-called vital forces.

"*Cells*" *are taken in theory for a kind of vital atoms.*—Since Schwann, the great endeavour has been to establish a living elementary constituent of all organic bodies; a vital unit, as it were, occupying in the science of life a similar position to that which the "atoms"—those inferential creatures of chemists and physicists—are made to fill in the fabric of the inorganic world. All morphological appearances of animal textures, however widely they were seen to differ from each other, nevertheless were made to bend in the interpretation of their development at

least, to the unit-standard thus assumed. If not actually "cells," they must needs be cells transformed.

Luckily, perhaps, for the sway of the "atoms," there is no fear of their being summoned up from their ever-receding, ever-impenetrable distance, and forced to disclose their secret individual properties in visible nearness. But it is far otherwise with the "cells." These real, distinct, large bodies, are not merely seen in all their stable characteristics; but they can also be watched in their very formation, and may be even induced, by various means, to give clear evidence of their real nature.

A uniformly viscid imbibing material must form a globule.—It has already been shown that a viscous material, when imbibing water, may form a perfect globule. It is easy to understand that this must always be the case—provided there be no impediments in the way—so long as the viscosity of the imbibing mass is not overcome by dilution.

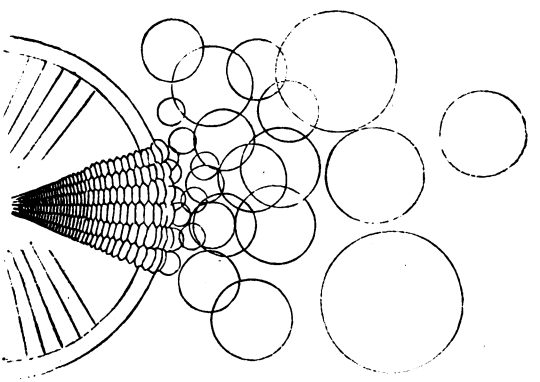
There are viscid materials which form globules of a definite size only.—But there exists another fact which is not quite so self-evident. The size, namely, of the globules formed by the imbibing viscous material is determined, not by the accidental quantity of that material, but by properties specific to its nature. In other words: a large homogeneous mass of certain viscid materials will, on the addition of water, not expand equally throughout its entire bulk, but particles of a definite size will be emitted from it, forming so large a number of separate globules as the accidental quantity of observed substance may yield. This is a most important truth, for it helps to explain why "nuclei" or "cells" formed in one and the

same tissue, under the same conditions, are found to be of similar size; why, in fact, such tissues are at all differentiated into so many separate bodies.

Formation of equal-sized globules in the crystalline lens on imbibition.—A very beautiful display of these size-regulating powers is seen, under certain circumstances, in the crystalline lens of many young animals. Mr. Rainey was the first to observe and to describe the facts. But his interpretation of this splendid phenomenon is given from an entirely different point of view. As the experiment is very little known, and as it may stand as a capital illustration of the present subject, I will give my version of it.

The lens of a very small young fish, for instance, is placed entire under the microscope, and, after the

FIG. 5.



Crystalline lens of a small young fish after imbibition. The so-called lens-fibres have become striped. The capsule has burst. The material between each pair of stripes becomes converted into an expanding globule.

addition of distilled water, is watched there for a con-

siderable time. The mere imbibing of water by the viscid material of the lens will soon produce a wonderful transformation. When some of the radiating striæ of the lens, some of the so-called fibres, are brought under the focus, their homogeneous substance will be seen to become densely transversely striped, the closeness of the stripes increasing towards the centre of radiation. Thus cleavage takes place in an apparently homogeneous substance, whilst still enclosed in a dense capsule. But when, at last, from over-tension the capsule bursts, then a very tumult of formation supervenes. At the ruptured spot, each particle of material contained between two transverse stripes near the margin of the radiating striæ, is rapidly transformed into a clear bright globule, which swells out and floats away, making room for successive layers to run through the same process. And so, on and on, till a dense crowd of such globules is seen pouring forth from the opening of the capsule. At first the globules are of nearly equal size. But they continue growing, some more, some less, till the largest measure at least twelve times their original diameter. And ultimately—like the tumour-"cells" described at the beginning of this paper—some are completely dissolved into the surrounding medium, whilst others maintain their spherical shape.

Nothing could be more surprising and suggestive than the impetuous formative activity here witnessed if it were not still more curious and instructive that the phenomenon, in its essential features, can be artificially reproduced. It will be shown, in the second part of this paper, that the interpretation here given

of the processes observed in natural tissues can be put to the test of experimental verification; that substances, chemically prepared, may be made to assume most of the "cell"-appearances here described.

Other examples of the size-limiting property.—There are many other striking examples of this remarkable size-regulating quality. Homogeneous embryonic tissues, such, for instance, as the serous membranes, or capsules of organs, will emit throughout the whole extent in which they come into contact with water globules of nearly equal size. If put flat under the microscope, there will rise on the covered surface of such tissues globules at equal distances. These come into contact with each other as they grow, forming at last a beautiful hexagonal non-nucleated epithelium. The production of globules of this kind is so profuse in embryonic tissues, that the observer is apt to get confused by it. Presupposing the formation of "cell"-shapes always to be due to a specific act of generation, he will readily misinterpret such appearances. They have been taken, by some, for the result of a process of budding; by others they have been thought to be the fundamental units, from which some ultimate tissues were derived.

That this sudden phenomenon, however, is not caused by any preformed shapes, but is merely the result of imbibition, can be well observed at the margin of any of the hyaline tissues. Segments of globules will there arise all along, will bulge more and more, till they have become fully spherical, when they will detach themselves and float away, leaving clear space for successive productions. Of course embryonic textures, in all stages of globular

differentiation, exist normally in abundance. The preformed shapes of these undergo, on the addition of water, the most varied changes, in proportion to their greater or smaller imbibing capacity.

Blood corpuscles no cells, but uniformly viscid.—It is astonishing what labour is sometimes devoted to the purpose of ranging the most diverging and incompatible manifestations under the domain of one single preconceived general notion. What immense work, for example, has been bestowed by numbers of observers on the task of trying to make the blood corpuscles accurately fit into the type which had been settled by Schwann and others for all possible "cells." Some of the changes which occur in these little bi-concave discs, when they are removed from their normal state and acted upon by foreign agents, were eagerly seized as proofs of their cellular nature, or even of their cellular life. Thus they were seen to have a distinct cell-membrane; to possess fluid contents within that membrane; to multiply by budding; or actually to propagate by means of fissiparous division.

Now, whoever has watched with an unprejudiced eye these most mutable elastic bodies as they are floating on the glass slide in their own serum, or as they are speeding along, with the heart's impulse, through a network of capillaries, accommodating themselves most readily to every slightest requirement of space; now being pulled out to twice their usual length, whilst wriggling through narrow passages round corners; and then again, at the first chance springing back into their original form; whoever has thus witnessed their almost boundless sup-

pleness and pliability will scarcely hesitate to look upon them as tiny lumps of a uniformly viscous matter.

And they can easily be proved to be really such.

If a blood corpuscle be divided into two portions, the mass being torn asunder at any point, each part will rapidly form into a separate globule, perfectly homogeneous, and rounded in itself. This surely is an unmistakeable evidence of their uniformly viscous nature.

Sometimes the separation does not entirely succeed. There remains a more or less narrow bridge between the two halves. Then we have the celebrated hour-glass or biscuit form; the individual caught in the very act of fissiparous division.

On the addition of a very little water, a clear, pale globule will often begin to swell out from one of the concave surfaces of the disc, just as we have described emanating from viscous substances on several previous occasions. This is what, from the vitalistic point of view, has been interpreted as a process of budding.

Blood corpuscles emit globules of equal size on imbibition.—In spite of these occurrences so conformable to my views, I was somewhat disconcerted at always experiencing that, on the addition of more and more water, the blood corpuscles would merely grow smaller and fainter, without emitting new shapes, would gradually dissolve without much evidence of imbibition. I expected that they would act like other lumps of viscid material—that they would give off globules under favourable circumstances. On the 20th June, 1861, however, I came across a specimen which exhibited most beautifully what I had

anticipated. It was the blood of a fœtal kitten. Each single corpuscle divided, on the addition of water, into three or four; *i.e.* from the original globule there emanated rapidly a second globule of almost equal size, but much paler; then a third, and sometimes even a fourth. Ultimately the four could scarcely be distinguished from each other, as they all lay closely grouped together.

This observation is somewhat difficult, on account of the great sudden crowding that takes place on the addition of water. But it is possible to get only a very few globules separated into a quiet corner, and then the phenomenon is seen with ease. I have since repeatedly observed the same phenomenon in different kinds of blood.

I believe that these various examples, though many more might be cited, are sufficient to teach that certain viscous substances, when imbibing water, will form globules of a definite size. This, as I have already stated, we must bear in mind as a most important fact, for in the light of it many otherwise unintelligible appearances will become clear.

So-called nuclei are formed by imbibition of viscid materials, possessed of the size-limiting property.—It will scarcely be denied that only the most implicit faith in the tenets of the cell-theory can lead observers to take for granted that the profusion of equal-sized, equal-shaped, equally interspersed nuclei, which is often found in growing tissues, is really the result of procreation—that in fact they are all the progeny of one single parent. Nowhere in these cases can there be detected the least proof for this *à priori*

assertion. All appearances, on the contrary, speak against it.

Nuclei in cancers form in chemically transformed fibrous tissue.—For instance, in many cancerous growths, the most recently formed portion consists of fibres. If these be traced from the newly developed surface to deeper older layers a stratum will often be reached where the fibres begin to become "nucleated." Within the fading fibres, very elongated narrow oval bodies will be seen at regular intervals. In penetrating still deeper where the mass gets more and more soft, the oval of the "nuclei" grows broader and broader till in some cases it becomes a full sphere.

Evidently there is here a slow chemical process going on, which is by degrees transforming the fibrous substance into a viscid material. The consequence is that globules strive to form as soon as this material begins to imbibe the surrounding juice. At first these globules are much compressed by the lateral resistance due to the fibrous texture in which they are still enclosed. But in proportion as the latter softens they go on expanding. Sometimes, however, they get fixed by coagulation in some stage or other of their oval existence. Thus the "nuclei" are formed, during chemical differentiation, from a primary imbibing portion of the transformed fibrous substance. The remaining portion, the internuclear part, becomes, as we have already seen, also viscous in its turn, and ends by enclosing the preformed nucleus as a secondary globule, the whole forming together the complete typical "cell."

It will easily be conceived that the size of the "cells" which ultimately fill the so-called brood-

spaces, is to some extent dependent on the room which is left between the nuclei in their first formation. In different cancers all possibilities occur, from "nuclei," with very large surrounding globules, to such as have no surrounding globule at all, in which latter case the cancer is said to consist of free nuclei.

It is not the purport of these researches to explain the chemical changes which so differentiate a uniform mass of fibres that globules arise only at certain distances from each other, that within these globules a granule or two, known under the name of nucleoli, are very constantly manifested. It suffices for the present purpose, to show that in these cases it is just the reverse of what is generally accepted, which actually occurs; that the fibres are not transformed "cells," but the "cells" rather transformed fibres; that there is no specific act of generative vitality at work, but merely formative chemical and physical processes; that the shapes in question are not individuals endowed with a peculiar life, but merely the physical expression of chemical changes; that the noxiousness of these morbid products is to be sought in the nature of their raw material, and not in a malignancy connected with the mysterious life of their forms.

It is of immense importance, not only for the building up of biological science, but also for the sake of practical applications, that the meaning of these elementary appearances should become perfectly clear.

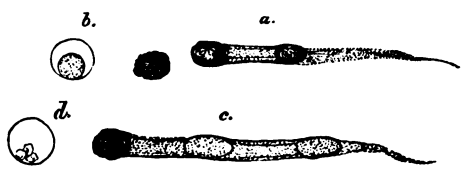
Nuclei in an inflamed pleura.—Another very good example of fibres being transformed into "nuclei" and "cells" is afforded by highly inflamed serous-membranes.

A pleura, for instance, the surface of which is yielding pus, will be found to consist in its deeper layers of densely "nucleated" fibres. Just as in the above-cited cancer cases the oval of the "nuclei" is more or less elongated according to the depth of the layer in which they are embedded. The "nuclei" close to the surface are perfectly globular, and it is these which detach themselves and float away as granulation- or pus-corpuscles.

Granulation- and pus-corpuscles.—It is curious that such great mystification still prevails with regard to granulation- and pus-corpuscles. Yet they are comparatively simple formations.

Each preformed "nucleus," as it gets freed by the breaking down of the surrounding material, assumes the spherical shape. It then looks like a more or less opaque ball of a very soft material. And it is only when it comes into contact with water or other fluids that one portion of its substance swells out by imbibition; the remainder being enclosed within it, and forming thus the "nucleus," or "nuclei," as the case may be.

FIGS. 6, 7.

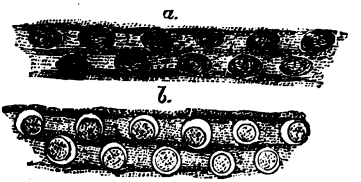


a. A fibre from an inflamed pleura. *b.* The corpuscle at the surface transformed into a granulation corpuscle on imbibition with water. *c.* Another fibre. *d.* The corpuscle at the surface transformed into a pus-corpuscle on imbibition.

That this statement corresponds to a positive fact,

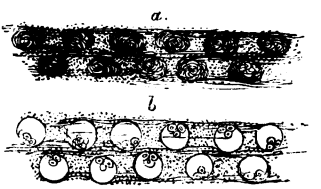
and is no mere inference, can be proved without difficulty. By tearing up the fibres of such an inflamed pleura, it happens that the "nuclei" contained in one or the other of the softer shreds will form perfect granulation- or pus-corpuscles, under the observer's eye as soon as water is added. Twenty or more such corpuscles are often seen in this way still adherent to their connective substance.

FIG. 8.



a. A soft shred from an inflamed pleura. *b*. Each corpuscle transformed into a granulation-corpuscle on imbibition.

FIG. 9.



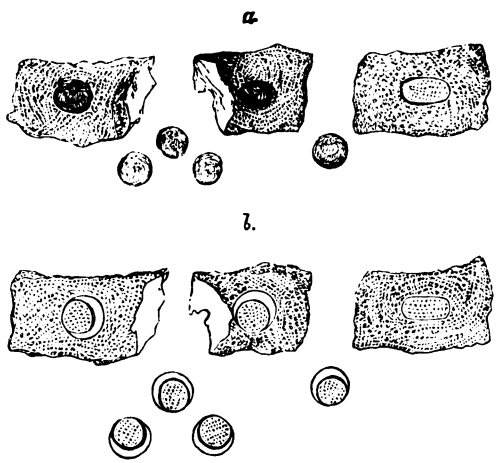
a. Another shred. *b*. Each corpuscle transformed into a pus-corpuscle on imbibition.

Formation of mucus- and pus-corpuscles within epithelium-scales.—A still more striking example of this kind of "cell"-formation can be watched within the epithelium of mucous-membranes or the skin. In the mucous-membrane of the mouth or the nose, for instance, there will be seen side by side with scales of epithelium containing faint oval "nuclei" and clusters of minute opaque balls, numerous epithelium-scales more or less transformed. They

are evidently undergoing liquefaction; for some are already dissolved to a considerable extent. In these the "nuclei" have become much more distinct than they are in the perfect scales. In some they even form balls exactly like those other free ones that are scattered about. It is often possible to make these balls swell out with water and form perfect mucus-corpuscles while they are still contained within the epithelium-scales.

Thus we obtain "cells" enclosed within other "cells," but here rather the result of death than of any vital process.

FIG. 10.



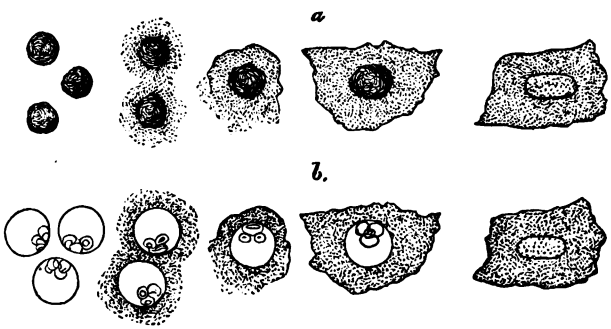
a. Epithelium scales in various stages of disintegration, and mucous-corpuscles unexpanded. *b.* The same after imbibition, mucous-corpuscles having formed within the scales.

Saliva-corpuscles.—Sometimes the partly dissolved, partly softened scale forms with its remaining portion a secondary globule round the nucleus. We have then a saliva-corpuscle, frequently showing molecular motion.

The same thing, as shown in Fig. 10, occurs with

regard to pus-"cells" in recent abscesses of the skin. In such cases the formation of pus-corpuscles can be watched with great ease. Each pus-corpuscle is formed from the pre-existing "nucleus" of an epithelium-scale. They can be seen in their most typical state, still enclosed within the scales.

FIG. 11.



a. Epithelial scales in various stages of disintegration in an abscess of the skin. *b.* Formation of pus-corpuscles within the scales.

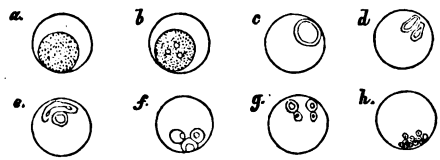
The nuclei of pus-corpuscles the results of decay and not of growth.—It is quite intelligible that, from a certain point of view, pus should have been looked upon as a product of highest vital activity, as the abortive issue of over-fecundity; the generative powers having run wild, as it were, and overdoing their task. But it is scarcely conceivable how the wretched, irregular, half-oily granules, which have all marks of decay stamped on their features; these mere corrugations, which come best into view within the pus-corpuscles by the help of acetic acid; how these all but amorphous particles have been greeted as a clear evidence of the correctness of the above supposition.

One need only carefully compare various pus-corpuscles to become aware that those very appearances which are said to be nuclei in the act of fissiparous division are mere expressions, of decay.

The series here given as an example was taken from one and the same specimen of pus produced on a granulating surface. It was observed on the 27th of November, 1861.

It will be seen that the homogeneous clear-cut "nucleus" of granulation-corpuscles is here traced through all stages of disintegration. The first appearance in the scale is the one in which pink spots become visible in the otherwise uniform surface of the central globule,

FIG. 12.



A series of pus-corpuscles taken from the same pus, showing the various stages of disintegration of the nucleus.

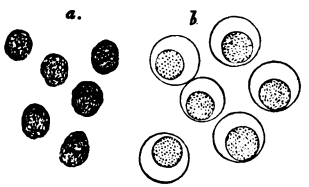
two, three, four, and more. These pink spots constitute the centre of the granules which are ultimately formed by the entire breaking up of the globule. The most instructive shape for our purpose is *c*, in which there is only one large pink spot filling the whole centre of the nuclear globule and giving rise to the formation of a more or less narrow ring, an appearance often met with in decomposing brain substance.

If, however, after the foregoing exposition, the subject should still remain doubtful, the following observation, made on the 17th June, 1862, will probably suffice to dispel the uncertainty.

Serum was taken from a blister. To one portion pure distilled water was slowly added. Thereupon the little balls contained in the serum began to swell out. They soon formed beautiful mucus- or granulation- or exudation-corpuscles, or whatever one may choose to call the appearance produced by one clear-cut sphere surrounding another. These bodies are derived, as we have seen, from transformed pre-existing "nuclei" of epithelium-scales.

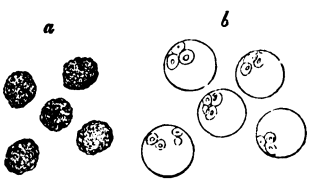
A second portion of the same serum was treated with water and a little acetic acid, upon which all the balls were converted into the most typical pus-

FIG. 13.



a. Globules in serum of a blister. *b.* After imbibition.

FIG. 14.



a. Globules of the same serum as Fig. 13. *b.* After imbibition.

"cells," *i.e.*, the nuclei of the resulting shapes were stunted, irregular, and multiple, instead of large, bright, and single, as had been the case when water alone was added.

The experiment was several times repeated, and yielded each time a similar result.

The acetic acid had here the same effect outside the body which other agents sometimes produce within.*

There remains, however, one thing still to be urged

* This observation is to my mind conclusive, and the arguments brought forward by Reinhardt "Virch. Arch.," vol. i. p. 528, seem to me ineffective against the conclusions drawn from it.

in favour of the generative view:—It was the acetic acid which stimulated the dying cells to a last desperate effort of procreation.

I will not here argue the point, but will merely state that corpuscles with all the various microscopical characteristics of pus-"cells" can be artificially produced. This will be shown in the next section of these researches, which is devoted to the experimental verification of the views put forward in this first part.

ARTIFICIAL PRODUCTION OF "CELL"-SHAPES.

EXPERIMENTS.

General inference from observations.—The manifold experiences which have been briefly related in the first section of this paper, along with many others that have not been here communicated, were steadily pointing—through all the profusion and diversity of configurations which make up complex organic bodies—to one single general fact. It is true that this fact concerns only those of the shapes that would be called cells in an untransformed state. But then it is asserted and generally accepted—whether rightly or wrongly is not at present the question—that all organic textures, indiscriminately, are essentially composed of such cells; that these textures are every one of them a mere aggregation of organic individuals, the life-endowed offspring of that single original parent cell, the ovum.

Starting from this basis, yielded by the present state of Biology, the fact which was disclosed by these studies may well be represented as of funda-

mental and general importance. It is simply this:—There exist plastic materials, viscid imbibing substances, which, by their physical properties, give rise to the formation of those shapes that have been called cells, and that are believed to be the bearers of those peculiar powers known under the name of vital.

The task was to prepare such a substance, and to demonstrate its properties.

Myeline, a viscid imbibing substance, forming definite shapes.—It was a long and tedious search till the right material was hit upon; but the success was complete. When, in March, 1862, my attention was drawn to the substance called myeline, there remained no doubt that this wonderful material possessed the required properties. If others have ever witnessed in such an exquisite manner as I have, the sight which is displayed when water is added to amorphous myeline, I am astonished that they should not have at once jumped to all the conclusions at which I have in other ways so laboriously arrived.

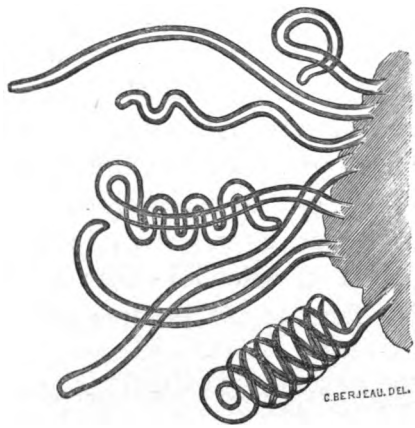
The most practical manner of preparing the material for our purpose was found to be the following:—

About 1 oz. of concentrated alcohol is added to the yelk of a fresh egg and well mixed with it. The whole is then heated till it begins to boil, when it is rapidly filtered through a cloth not too dense. The yellow fluid which filters through is left to cool and to evaporate; a sediment then remains behind, which is the substance sought for.

The least particle of this sediment will suffice to show under the microscope, on the addition of water, a beautiful spectacle.

From all the free margins of the mass there shoot forth slender tubes, more like nerve-tubes than anything else. I say tubes, because they seem to consist of two materials, a central and a peripheral constituent, divided from each other by a distinct

FIG. 15.



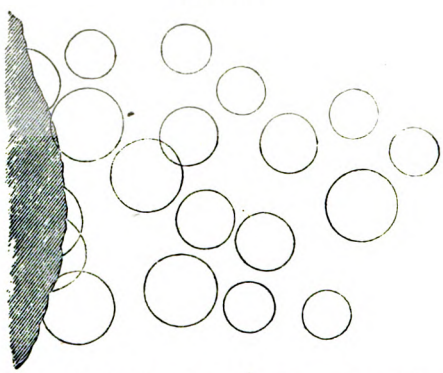
Myeline-tubes shooting forth from the amorphous mass on imbibition.

line of demarcation. These tubes grow longer and longer, maintaining their original diameter, till they sometimes stretch over the whole field of the microscope. They must be exceedingly flexible, for the free end wriggles serpent-like about, till it generally doubles upon the body of the tube, coiling then around it many times. It is remarkable to see how these shapes, which evidently consist of a very soft viscous material, nevertheless completely maintain their form; how they nowhere upon contact blend with each other, reminding one in this respect as in many others of blood-corpuscles. If this tube-forming

process be disturbed by shaking or the like, a confusion of most grotesque shapes will result. This curious substance certainly acquires on imbibition an unequalled plasticity; and it seemed very likely that, under favourable circumstances, it would form globules.

A crystalline force inferred and counteracted by the admixture of white of egg.—The rectilinear shooting forth of tubes I took for an indication of there being some crystallizing influence here at work.* To procure globules it was necessary to counteract this. The plastic substance was therefore intimately mixed with a decidedly viscous material, the white of egg; and, behold, as soon as water was added, instead of tubes, segments of splendid clear bright globules commenced to form at all the free margins. When

FIG. 16.



Globules instead of tubes formed on imbibition, after white of egg had been mixed with the myeline.

they had attained the full spherical shape, they detached themselves and floated away; new forma-

* See Appendix, p. 49.

tions rapidly succeeding. The phenomenon is very much like that exhibited by the crystalline lens under similar conditions. The complete globules could not be morphologically distinguished from each other. They behave in a similar manner to those of the lens, only, not having been formed under great pressure, they do not expand in the same way.

There is an exact proportion of white of egg which has to be mixed up with the plastic material, and which one must hit off pretty accurately if one wishes to obtain the phenomenon in its full beauty. It is difficult to measure beforehand the required quantities, as one has to deal with such very small masses. But a few trials, best made on a glass-slide, will soon teach the experimenter the right proportions.

It will be allowed that the experiment just cited turned out to be a striking demonstration of the correctness of the inferences which have been drawn from the observations on the nature of "cell"-shapes.

Here was actually found an amorphous substance which, on imbibition, formed globules of a definite size.

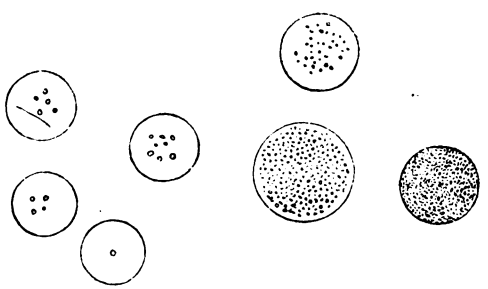
This process of individuation is, as I have already mentioned, a most important and remarkable fact. Why a uniform mass should, on the mere addition of water, divide into so many and similar shapes, is a subject well worth consideration. I have reason to believe that the occurrence is due to a crystallizing propensity.*

* See Appendix, p. 49.

Production of various globular combinations.—To proceed, however, with the main subject; I may state, that after this encouraging success in the chief point, the obtainment of all possible globular combinations seemed to me scarcely much more than a matter of perseverance. By varying the fluid medium, by mixing up the viscid material with different substances a wide field was opened for exploration. But of the many curious occurrences that were met with, only those few shall be mentioned which closely bear upon the present question.

Formation of globules containing granules, and showing molecular motion.—The clear globules produced in the manner above related, would have been more "cell"-like if, instead of being hyaline, they had had a granular appearance. This was likely to be effected by precipitating the albumen within the formed globules, and very dilute nitric acid was found to bring about the desired result. After its application the globules became filled with

FIG. 17.



Globules containing granules, and showing molecular motion, obtained by mixing myeline with blood serum.

more or less minute dots. But this artificial granu-

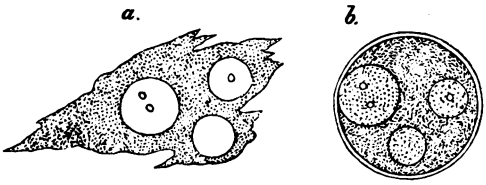
lating turned out to be of a much finer grain than is usually met with in nature. The endeavour was to imitate the natural shapes as closely as possible. It occurred to me, therefore, that by choosing for admixture a substance that would of itself coagulate on contact with the air, there might be obtained granules of a coarser kind; perhaps even molecular motion within the globules. For this purpose blood serum was procured, and intimately mixed with the myeline. The result was beyond expectation—no saliva-corpuscle could be more globular or exhibit molecular motion more vividly than many of the shapes thus produced. Some of the globules contained only one, some a few, some many more granules. But a number of them were completely crowded with most active granules. And just as has been shown to be the case with saliva-corpuscles, the molecular motion ceased also in these artificial products, when they were exposed to pressure. For this, if for no other reason, the notion of the highly complex organization of the former has to be abandoned. Moreover, in some of the most densely crowded globules the molecular motion would cease of itself, coagulation of the entire contents having apparently taken place. These latter globules were formed where the glass slide had been most thinly covered with the mixture of serum and myeline.

Formation of perfect "cell"-shapes.—It was there, too, that shapes wonderfully like those found in the organic tissues were seen to form. On the addition of water, one or a few small globules would first start into existence. These were at the time embedded in a film of granular material. By degrees this,

FIG. 18.

a. Globules surrounded by granular shred. *b*. Transformation of the shred into a globule.

FIG. 19.



a. Several globules with shred-like appendix. *b*. Transformation into a body resembling a mother-cell.

together with the globules, would get loosened from the glass slide, and float about, the whole resembling exactly those "nuclei" enclosed in granular flakes which have been described in the first section of this paper. Like these, they would sometimes subsequently assume the globular shape, forming thus the most perfect "nucleated cells" that can be imagined. To prevent the likeness from being deficient in the slightest detail, some of the inner globules had formed round a single granule, which then represented the "nucleolus." And even the narrow white border which, in the natural formations, has so often been mistaken for a cell-membrane, was always seen distinctly drawn around the outer globule.

It need scarcely be added that in this way were produced mother-"cells" as well as single "cells" in profusion.

No better imitation of the first mode according to which "nucleated cells" are formed within the living

organism could well be desired; around a pre-formed globule, (the "nucleus,") a second globule, (the "cell,") shaped itself.

Imitation of the second mode of "cell"-formation.—The next endeavour was to reproduce artificially also the second mode of "cell"-formation; that namely in which one portion only of a globular mass swells out on imbibition, inclosing then the non-imbibing portion as a separate globule.

If myeline, unmixed with other ingredients, be spread very thinly on a glass slide, there will be seen on the addition of water the beginning of such tubes as have been previously described bulge from many points of the unshapen mass. But there being not sufficient material available, and the glass, moreover, exerting its attractive power, these incipient tubes do not shoot out to any length. At first they form hemispheres, which, however, soon get enough additional material from behind to complete themselves into entire globules. These globules, like the tubes, consist of two materials, a central and a peripheral constituent. They have more the appearance of rings than double globules; for the central sphere looking much lighter, is apt at first sight to be mistaken for a break.

FIG. 20.

Ring-like shapes of myeline when thinly spread on the glass slide.

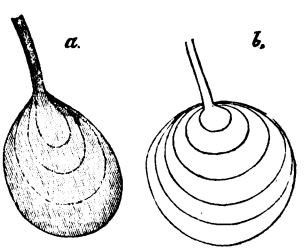
One might rest satisfied and call these bodies "nucleated cells," for essentially they are like such in appearance, one globule being enclosed within another. But the resemblance is not striking enough for conviction; nor does the mode of formation of these

bodies correspond to any known type of "cell"-formation within living organisms. Perhaps the nucleated blood-corpuscles may be found to be formed in a similar way, but there is no positive proof for this as yet.

The outer material of these curious bodies is more or less opaque and lumpy, this being probably due to the larger or smaller amount of fatty substances mixed up with the transparent viscid ingredient. All stages are met with in different specimens, from perfectly bright, pellucid-looking globules, to such as are of very dark bulky appearance.

Artificial Bird's-nest cells.—Though these bodies owe their appearance to the action of water, they become very sensibly altered by the prolonged operation of that agent. This is all the more so the more bulky they at first appear. Some of the ingredients become slowly dissolved, leaving behind clear concentric rings separated from each other by dark circles of demarcation. Sometimes there are only a few, sometimes a great many such layers. The resulting body is very much like a so-called bird's-nest cell.

FIG. 21.



a. Shape from a tumour.
b. Artificial shape.

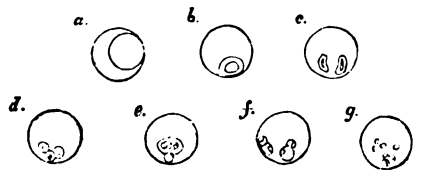
It happens sometimes that such globules are hanging on to a thread which they have dragged along with them on separating from their original matrix. These become ultimately converted by the water into forms which resemble so much some puzzling shapes of which tumours occasionally consist, that it is

worth while to draw attention to the point. They are pear-shaped bodies involved in each other, in the same way as the globules just described.

Artificial pus-cell-like corpuscles.—But these changes caused by water within these globules do not always take place symetrically throughout their entire mass. In many instances the contents break up at various irregular spots, ultimately leaving behind but a few granules with central pinkish dots. These prove to be morphologically identical with the so-called nuclei of pus-corpuscles. All possible varieties occur, even many more than are met with in real pus.

If these shapes be left to dry, and then water added for a second time, the most perfect "cell"-formation will be obtained. A clear bright globule swells out around each preformed shape, enclosing thus nuclei of various descriptions. Whole layers of the most exquisite typical pus-"cell"-like shapes are produced in this manner. Also many forms with single large bright nuclei, entirely like mucus- or granulation-corpuscles.

FIG. 22.

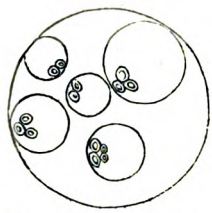


Shapes morphologically not distinguishable from pus-corpuscles.

But besides these well-known shapes, there occur others of a more complicated character. Among these some imitations of very rare natural types. A large globule, for instance, will be seen filled with

many "pus-corpuscles;" a conformation which has been described as occurring on suppurating mucous membranes. And, I am happy to say, also the most splendid examples of "cells" in all stages of fissiparous division. This latter sight being most gratifying, considering how vainly one has longed to catch a glimpse of this surmised act of propagation in natural tissues under natural conditions.

FIG. 23.



Pus-cell-like shapes enclosed in a large globule.

FIG. 24.

Bodies which might be taken for cells in various stages of fissiparous division.

I cannot feel otherwise than convinced that whoever will take the trouble to reproduce these manifold artificial shapes, watching them as they form under his eyes, the exact counterfeits of so many of the true "cell" formations, will willingly give his consent to the views put forward in this paper.

Formation of bi-concave discs.—Before concluding, I will relate one more important observation.

It has been stated at the beginning of this section that the myeline tubes remind one in some respects of blood-corpuscles. They are as flexible and as elastic as these; they also undergo a similar star-like wrinkling on exsiccation.

Moreover, when myeline which is spread out very thinly on a glass slide is acted upon by serum instead of water, bodies very much like blood-corpuscles, only generally much larger, will form in place of the

ring-like shapes. They are of homogeneous appearance, no central globule is visible, but a distinct concavity on two sides, making up a bi-concave disc.

Perhaps it will appear, at first, rather startling that one single substance, under only somewhat varied conditions, should be capable of producing such divers forms; and, moreover, that these forms should happen to resemble so exactly many of the shapes of which living organisms are built up. But one must bear in mind that, after all, every one of the shapes in question is merely some combination or modification of the spherical form. Besides, our plastic substance is actually one of the most important constituents of animal and vegetable bodies. Even the brain consists to a great extent of it. The contents of the nerve-tubes are mostly myeline. It enters largely into the composition of the spermatozoa. The crystalline lens contains it in profusion. And it is not unlikely that the blood-corpuscles, all so-called cells, and perhaps also the muscles, owe their configuration and many of their properties to it.

It is certainly a substance which deserves the highest consideration, and which is already beginning to receive it. Some valuable contributions to the knowledge of its nature have been made within the last few years, and the recent discovery of the substance named *protagon* promises to throw additional light on the subject.

It has not been my aim systematically to disprove one by one the facts or arguments which have been amassed in favour of the cell theory by so many observers during a long series of most busy years. I rest satisfied with having scientifically demonstrated

certain important points which have presented themselves to me during the course of my studies. These points are not only incompatible with the generally accepted notions; but they also demand, on the strength of their own significance, a reconsideration and reconstruction of the basis upon which biological science is raised.

GENERAL REFLECTIONS.

THERE can be no compromise between the tenets of the cell-theory and the conclusions arrived at in this paper; the distinction is thorough. Either the units of which organisms are composed owe their origin to some kind or other of procreation, a mysterious act of that mysterious entity, life, by which, in addition to their material properties, they become endowed with those peculiar metaphysical powers constituting vitality. Or, on the other hand, the organic units, like those of inorganic bodies, the crystals, form by dint of similar inherent qualities; form, in fact, possessed of all their properties, as necessary modes of appearance, as soon as certain chemical compounds are placed under certain physical conditions. If the former opinion be true, then we must clearly understand that there exists naturally a break in the sequence of evolution, a chasm between the organic and inorganic world never to be bridged over. If, on the contrary, the latter view be correct, then it strongly argues for a continuity of development, a gradual chemical elaboration, which ultimately re-

sults in those high compounds which, under surrounding influences, manifest those complex changes called vital.

Surely it is not a matter of indifference or of mere words, if the extreme aim of physiology avowedly be the detection of the different functions dependent on the vital exertions of a variety of ultimate organisms, and the discovery of the specific stimulants which naturally incite these functions into play. Or, on the other hand, if it be understood to consist rather in the careful investigation of the succession of chemical differentiations and their accompanying physical changes, which give rise to the formation of a variety of tissues that are found to possess certain specific properties, to display certain definite actions due to a further flow of chemical and physical modifications.

Surely it is not unessential, even for practical purposes, if pathology be believed—as it mostly is—to be the science of the heightened and depressed vitality, of the abnormal nutrition, and of the death of a vast number and variety of tiny inscrutable creatures; or, if it be clearly known to be simply the study of chemical and physical abnormity.

It has already been shown, and can be seen at a glance, how the tenure of one or the other of these opposite views will affect, for instance, the investigation of cancer. The observer ruled by the former opinion, will endeavour—with vain hope—to espy the vital manifestations of the individual units of which the mass is composed. The pathologist holding the latter view will on the contrary be induced to set to work to make out the chemical nature of the substance, the

peculiar composition of which produces the peculiar morbid effect. There will then be some hope of discovering agents wherewith to counteract its all-invading noxious influence.

The task is to trace material effects to material causes. There is, indeed, no other way of attaining a true scientific knowledge of physiological and pathological processes than by thus following up link by link the chain of causation. This is a truth which has so often been asserted to be valid for all branches of natural science, that it sounds almost like a truism to any one the least conversant with studies of the kind. Yet most biologists are far from practically carrying out this truth. They are still governed by verbal abstractions which raise an insurmountable barrier between their views and those of other naturalists, which still retard in an extraordinary degree the progress of their science.

One is easily deluded by the apparent brilliancy and explicitness of a general conception, into the belief that this very conception is actually itself the cause of the results which we thus comprehend. One takes it for granted, for instance, that life, this most complex result and notion, is itself, under the name of vital powers, or some term equivalent to it, the productive force that constructs and sustains the organism which we finally perceive as what we call living: this being but a name in which we gather together ever so many distinct effects of distinct causes.

Here in our subject we have again turning up in one of its clearest expressions the oldest of all scientific dilemmas, over which so many memorable battles

have been fought; teleological evidence encroaching upon the domain of causation; the so-called final causes assuming the part of efficient causes; analytical exposition overruling synthetical experience; logical conclusions made to stand for laws of nature; general conceptions installed as working powers; fictitious entities believed to coerce matter.

But whatever of deepest meaning may be contained in the transcendant lessons of apparent design which an all-befitting coaptation in nature seems to teach; we have nevertheless to confess that every triumph and acquisition of science is gained by the laboriously upward-working champions of causality. For it does not fall within the range of our intellectual faculties to explain how it happens that things have certain influences over each other; how a body in motion is capable of communicating motion also to another body; how oxygen and hydrogen so seize and transform each other that water results, a new agent of new influences. Still less can we understand how manifold influences, accumulating, establish foci more and more concentrative; organs more and more subtle in their special impressibility; till in the higher beings a nerve, catching up with unperceived vibration a far-wafted rhythm, will give rise to a creation in which the source of the strange influence is magically revealed; yea, till with us, in silence and darkness, the mere remembered sign for a fading trace in memory has power to stir our being's very depth.

We are steeped full-deep in this creative mystery. We, the centres of it, can but look on and marvel. In and around us we can but experience and watch

the flow of events, this ever-changing issue of combining inscrutable forces. And with our science we can do no more than fix and describe, as they present themselves to us, certain stages of being; then trace back the origin of these to parent states of which they are of necessity begotten; and, to complete our canon, classify, at last, the manifold effects and their definite causes according to their mutual affinities. This is for us securest knowledge; it affords the soundest teaching of all learnable facts, the only wholesome food for our reasoning faculties.

It is true it is but a slow and tedious method of proceeding, and we would fain find some way of understanding all at once. Thus we are induced to throw out vague guesses at things, at the nature of most complex results; fixing them with shadowy names, in which we then believe true understanding to be embodied. Since time immemorial, Truth has been in this way enwrapt in dark clouds of superstition, which are only now gradually dispersing before the light of true knowledge, revealed by Nature's supremest law, *causation*.

In science we can aim no higher than to attain a more and more extensive definite knowledge of the all-comprising woof of reality, as it is woven by *causation*, which, with time, its brain-reflected shadow, flows into infinity both ways.

POSTSCRIPT.

THE foregoing paper was read before the Royal Society, the 20th December, 1866. A very brief abstract appeared in the Proceedings of the Society. This, however, could be but an inadequate publication of the researches which I had communicated in the original. I therefore make this personal attempt of saving from oblivion a labour on which I have bestowed much time and attention. The thoughts expressed under the head of "General Reflections," were only lightly touched upon in the MS. now resting in the archives of the Royal Society.

APPENDIX.

ON LATENT CRYSTALLINITY IN THE ELEMENTARY ORGANIC SHAPES CALLED CELLS.

THE researches detailed in the main part of this paper had led me to infer that a crystallizing influence was most likely at work:

First. In that rectilinear shooting forth of the myeline tubes which takes place whenever water is added to the dry material.

Second. In that individuation of shapes which ultimately results in the formation of separate globules of definite size.

In other words, that the imbibing plastic substance called myeline probably contained an ingredient which, by its crystallizing propensities, forces, on the addition of water, the amorphous mass to divide into individual forms of definite size and shape.

In myeline extracted from the yelk of eggs or other organic substances, the content of the tubes or globules is so far soluble in water that, after a certain period of immersion, there remains behind but a very attenuated matrix, showing no trace of crystallization. I have not yet in any way succeeded in demonstrating the crystalline ingredient in the shapes obtained from this peculiar myeline.

I say "this peculiar myeline," because not merely according to my own researches, but, also according to the researches of several distinguished German chemists, there seem to exist a great variety of myeline substances, *i.e.* substances which, under certain conditions, yield the characteristic shapes known under the name of myeline-shapes.

I have observed that of these some are greatly more soluble in water than others. There was therefore a hope of obtaining a variety in which the inferred crystalline ingredient which was thought to determine the shaping of the material, should be so little soluble in water that its crystallinity might, under favourable circumstances, become evident to the senses.

The substances formed by the combination of various fatty acids with a number of bases, constitute a series of myeline varieties which differ widely from each other regarding their solubility in water. Ammonia-myeline, for instance, other conditions being equal, is much more soluble than soda- or potash-myeline.

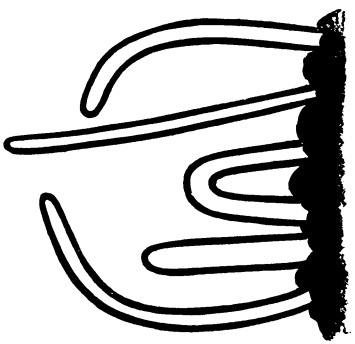
I have also found that in decomposing soaps with mineral acids, the specific nature of the mineral acid employed in the process exerts a great influence on the solubility of the myeline ultimately derived by recombining the freed fatty acids with ammonia, or some of the alkalies.

Of the various kinds of myeline produced in this way, the one which was got by decomposing soap with crystallized phosphoric acid, showed the desired phenomenon of crystallization in the most convincing and perfect manner.

The tubes shot forth as usual on the addition of water. But soon their flexibility, which was perfect at first, began to decrease, their rounded outlines at each bend became by degrees sharply angular; the soft worm-like tubular appearance thus gradually vanishing, and leaving in its place at last a rigid uniform crystalline skeleton.

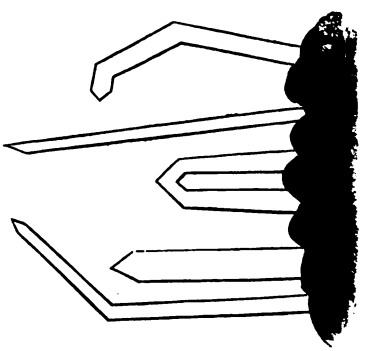
FIG. 25.

a.



a. Myeline tubes from soap decomposed with crystallized phosphoric acid.

b.



b. The remaining crystalline skeleton of the same after a period of immersion in water.

Globules, procured from the same myeline, were

transformed in a similar way. They also became sharply angular, looking at last generally like hexagonal prisms.*

Knowing that crystallization is the force which individuates inorganic matter; having, moreover, proved in the main part of this paper, that the formation of the organic individuals, called cells, is due to the physical properties of plastic substances; and being now able to demonstrate that it is a crystallizing property which determines the individuation of such plastic substances, I think I am fairly justified in concluding that the so-called cells are but modified crystals. They are modified, however, in such a way as to possess the essential characteristics of the substances which Professor Graham, in his most significant classification, has ranged under the head of Colloids. They are, from a formative point of view, crystalloid beings. But functionally they partake altogether of the colloid nature.

Crystals are not strangers in the organic world. It will be remembered that many of the highest organic compounds are capable of assuming a crystalline form under certain conditions; and a very little consideration will show how the results here detailed are, for instance, at once applicable to the blood-corpuscles, which have already been made to reveal their crystalline basis.

Mr. Rainey has shown by conclusive experiments

* I will incidentally mention that I have observed the feathery globular clusters of crystals of some fatty acid being converted on saponification into uniform clear-cut ovoid bodies, the whole soap being at last made up of such bodies, and looking very much like young cartilage.

that the shells of animals consist of globular crystals, *i.e.* mineral substances made to crystallize in a globular form by the influence of a viscid material. In these cases the crystalline ingredient preponderates over the viscid material. Just the reverse occurs with regard to the soft tissues; the viscosity overbalances the influence of crystallinity.

The experiments which I have communicated go a good way to show that a plastic imbibing material, driven into individual shapes by a crystallizing influence, is the cause of "cell" formation.

Is it not remarkable then that Schwann himself, the great propounder of the original cell-theory, thus sums up his views:—

"The formation of the elementary shapes of organisms is but a crystallization of substance capable of imbibition. The organism is but an aggregate of such imbibing crystals"?

LITERATURE.

My purpose in writing the present paper was to put into a simple and clear light a peculiar view of "cell"-formation which I had been induced to form during the course of my studies on the subject. To avoid complication, I have refrained from introducing into the text special references to the very numerous papers on cells which I have consulted. I will here, however, enumerate some of the most important writings bearing on this most interesting topic.

"CELLS."

Schleiden—"Untersuchungen über Phytogenesis." 1837.

Schwann—"Microscopishe Untersuchungen," &c. 1838-9.

Vogel—"Physiol. Pathol. Untersuch. über Eiter." 1838.

Remak—"Med. Vereinszeit," No 47. 1841.—Muller's Archiv. 1852.

Henle—"Allgemeine Anatomie." 1841.

Bergmann.—"Müll. Arch." 1841.

Virchow—Numerous important papers.

Koelliker—"Entw. der Cephalopod." 1844.—"Lehre von der thierischen Zelle Schleid. u. Nägeli's Zeitsch. f. wiss. Bot." 1845.

John and Harry Goodsir.—"Anatom. and Pathol. Observat." 1845.

Reichert—"Ueber das Bindegewebe." 1845.

Reinhardt—"Virch. Arch." 1847.

Henle—"Canstatt's Jahresbericht." 1844-56.

Kölliker—"Handbuch der Gewebelh." 1850. 5th Edit. 1867.

Huxley—"Cell-theory." British and Foreign Med.-Chir. Review, Oct. 1853.—Monthly Journal, 1853.

RAINEY—"On the Mode of Formation of Shells of Animals," &c. 1858.

VIRCHOW—"Cellular Pathologie." 1858, &c.

CLAPAREDE—"De la formation et de la fécondation," &c. Genève, 1859.

HENLE—"Jahresbericht in Zeitschrift für rationelle Medic." 1856-67.

M. SCHULTZE—"Arch. für Wissen. Anat. u. Phys." 1861.—"Das Protoplasma der Rhizopoden u. Pflanzenzellen." 1863.

BRUECKE—"Sitzungsbericht der Wiener Akademie." Vol. 44, 2, 1861.

L. BEALE—"On the Tissues," &c. 1861.

CH. ROBIN—"Comptes Rendus." Jan. 1862.—"Journal de l'Anat. et Phys." Vol. i., 1864.

E. HAECKEL—"Radiolarien." 1862.—"Generelle Morphologie." 1866.

M. TRAUBE—"Experimente zur Theorie der Zellenbildung u. Endosmose." Arch. für Anat. u. Physiol. 1867.

&c. &c. &c.

MYELINE.

DRUMMOND—"Monthly Journal." 1852.

H. MECKEL—"Berlin Charité Annal." Vol. i.

VIRCHOW—"Archiv." Vol. vi. 1854.

BENEKE—"Studien über das Vorkommen von Gallenbestandtheilen in dem thierischen und pflanzlichen Organismus." Giessen, 1862.—Archiv. für wiss. Heilk. 1865-1866-1867.—Zeitschrift für Analytische Chemie. Vol. v.

LEHMANN—"Lehrbuch der physiol. Chemie." 3rd Edit., vol. iii. p. 88.

METTENHEIMER—"Corresp. Blatts des Ver. f. Gemeinsch. Arb." Vol. xxxi.

G. LIEBREICH—"Ueber die Entstehung von myelin-formen." Virch. Arch. V. 32.—"Ueber die chem. Beschaffh. der Gehirn-Substanz." Annal. der Chem. u. Pharm. V. cxxxiv.

NEUBAUER—"Ueber Myelinformen." Virch. Arch. V. 36.

HOPPE-SEYLER—"Medic. chem. Untersuchungen," 1st H. Berlin, 1866.

BAEYER—"Synthese des Neurins." Annal. d. Chem. u. Pharm. V. cxl. 1866.

A. KOEHLER—"Ueber das Myelin." Schmidt's Jahrb. V. 134, No. 6. 1867.

THE END.