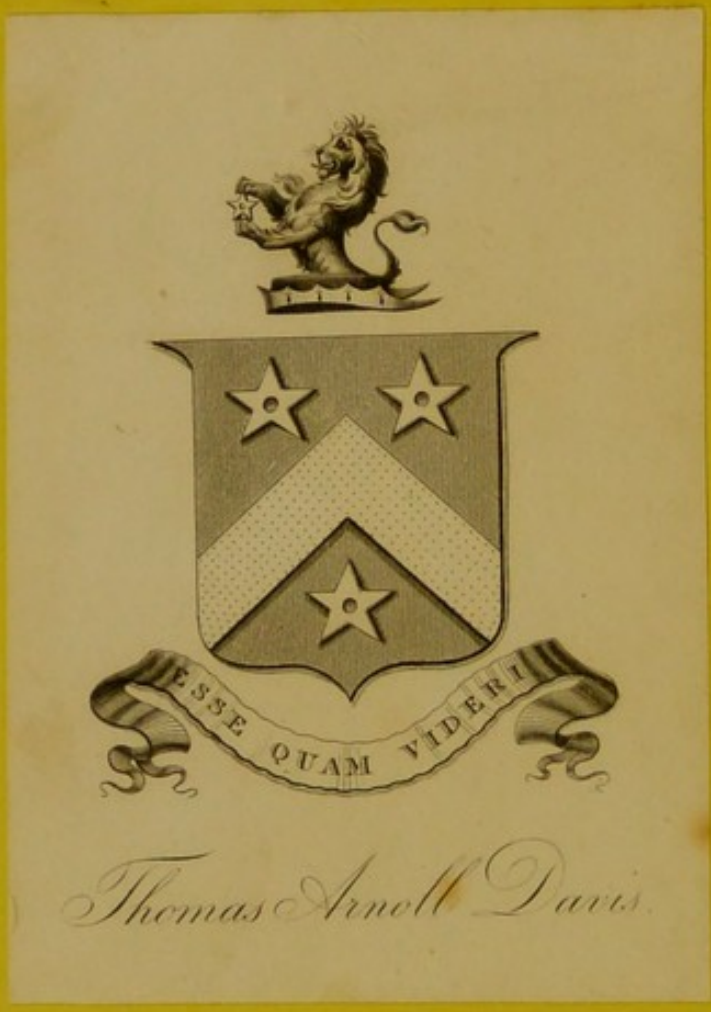
The actual process of nutrition in the living structure demonstrated by the microscope; and the renewal of the tissues and secretions, with the phenomena and products of inflammation, illustrated and established / [William Addison].

ADDISON'S PHYSIOLOGICAL RESEARCHES



J. H. Davis. with the
kind regards of his.
Old Shipmate.
Jno Parker

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THE

PROCESS OF NUTRITION

DEMONSTRATED IN THE

LIVING STRUCTURE.

BY THE SAME AUTHOR,

EXPERIMENTAL RESEARCHES,

(First Series,)

ON INFLAMMATION,

AND ON

THE ORIGIN AND NATURE OF TUBERCLES IN THE LUNGS.

THE ACTUAL

PROCESS OF NUTRITION

IN THE

LIVING STRUCTURE

Demonstrated by the Microscope;

AND THE

RENEWAL OF THE TISSUES AND SECRETIONS,

WITH THE

PHENOMENA AND PRODUCTS OF INFLAMMATION,

ILLUSTRATED AND ESTABLISHED.

(SECOND SERIES OF EXPERIMENTAL RESEARCHES.)

BY WILLIAM ADDISON, F.L.S.,

MEMBER OF THE ROYAL COLLEGE OF SURGEONS OF LONDON, AND SURGEON TO H.R.H. THE DUCHESS OF KENT, MALVERN.

LONDON:
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1843.

TO

SIR J. F. W. HERSCHEL, BART., M.A., K.H., D.C.L., F.R.S.L. & E., &c.,

AND

MICHAEL FARADAY, D.C.L., F.R.S., &c.,

THIS VOLUME OF EXPERIMENTAL RESEARCHES ON THE

PROCESS OF NUTRITION & THE FUNCTION OF STRUCTURE

IS RESPECTFULLY DEDICATED,

AS A TRIBUTE OF ADMIRATION OF THEIR HIGH SCIENTIFIC ATTAINMENTS, AND OF GRATITUDE FOR THE BENEFITS DERIVED FROM THE

"DISCOURSE ON THE STUDY OF NATURAL PHILOSOPHY,"

AND THE

"EXPERIMENTAL RESEARCHES IN ELECTRICITY:"

THE FIRST PLACES WITHIN THE REACH OF ALL MINDS

THE PRINCIPLES OF THE

INDUCTIVE PHILOSOPHY OF LORD BACON;

THE OTHER EXEMPLIFIES THEIR APPLICATION IN THE INVESTIGATION OF THE DEEPER QUALITIES OF NATURAL BODIES.

PREFACE.

In arranging the following or second series of "*Experimental Researches*" on the blood and nutrition for publication, it was found that there were still certain points, such, for instance, as the place of origin and the structure of the red corpuscles, with the relation existing between them and the colourless ones, upon which differences of opinion prevail among microscopical observers.

The determination of these questions can have but little or no influence upon the views advocated in this paper. Both the red and the colourless corpuscles or cells circulate in all the capillary blood-channels of the human body; and the object of the following pages is to trace the several stages through which *the latter* pass in their progress through the tissues, to describe the visible or physical characteristics of their contents, and to investigate the probable result of their final dissolution.

The coagulation of the buffy coat of the blood is a *glaring instance* of an elastic, compact, fibrous, and colourless tissue, resulting from the fibrillation and incorporation of the colourless elements of the blood: the experiment related (p. 4) in the following chapter is a *glaring instance* of the actual formation of this tissue, in which we see how the colourless blood corpuscles and the molecules are included in and incorporated with the fibres; and, lastly, the accumulation of the colourless blood corpuscles in the capillary vessels in the web of the frog's foot after immersion in warm water, their adhesion to the walls of the vessels, and their situation first between the red current and the tissue, and then among the fibres of the latter, is a *glaring instance* of the process of nutrition. The views and theories hereafter set forth are deduced from these Baconian *glaring instances.*

In passing from the confines of the visible to those of the invisible domain of matter, we must bear in mind that the latter or the invisible is quite as important as the former or the visible; for all objects become invisible long before we arrive at the end of their composition.

The ultimate atoms or forms of oxygen, nitrogen, carbonic acid, and water, as they surround us, and as we inhale or exhale them, cannot be rendered visible by the most powerful microscope; hence, therefore, we may conclude that the smallest visible molecule, forming part of an organized structure,

is a compound of several atoms. Moreover organisms, at least twenty times smaller than the blood-cells, may be seen by the microscope in decomposing animal infusions, moving rapidly about from place to place, darting to and fro, and exhibiting properties of a peculiar order. These have members, and are composed of several parts; therefore we must prepare ourselves to consider the blood-cells, with reference to living beings below them in the scale of magnitude, as *large and complicated structures*, probably composed of various parts, and containing various products.

"The knowledge of man hitherto," says Bacon, "hath been determined by the view or sight; so that whatsoever is invisible, either in respect of the fineness of the body itself, or the smallness of the parts, or of the subtlety of the motion, is little inquired; and yet these be the things that govern nature principally, and without which you cannot make any true analysis and indication of the proceedings of nature."

The observations hereafter related in detail were made, as before, with a magnifying power of 250 diameters only, and with the light of a bright sky, so that refraction can scarcely be supposed to have had any influence in producing erroneous results. This moderate power has been found sufficient to show the effects of water, dilute acetic acid, and *liquor potassæ* on colourless blood, mucous, and pus

cells; to exhibit their compound structure and the molecules and the fibres which result from their disintegration; to render visible the molecules and fibrous structure of mucus, and of the buffy coat of the blood; and to show the active voluntary movements of the *monadina* and *vibrionia*.

The use of this comparatively low power admits, in the simply constructed microscope I have used, of the application of re-agents to the objects without interfering with the continuance of the observation, and without fear of injury to any brass work of screws and adjustments.

It would be useless to speculate how far the facts contained in these and my former researches accord with the results obtained by other observers; one example, in proof of their general accuracy may however be mentioned, namely, that the disintegrating power of liquor potassæ on the polygastric animalcules was not discovered by accident—it was expected and *looked for*, from the effect previously witnessed from its application to blood, pus, and exudation cells.

To some persons, microscopical, or indeed any other minute anatomical researches, may appear better left in the hands of those who profess to follow only such pursuits, than to occupy the time and attention of others actively engaged in the practical duties of the medical profession; nor should I indeed have taken so large a share in

them had I not anticipated results likely to place these practical duties on a somewhat more satisfactory foundation.

Hydropathy and mesmerism on the one hand, and homœopathy and emotional or mind cures on the other, appeared to me to require some more scientific explanation or answer than that usually returned by those who cultivate medical science. How far I may have succeeded in indicating a more satisfactory foundation for the *rationale* of these cures, and for medical practice generally in a large and important class of diseases, I leave others to judge for themselves, when they shall have been in possession of, *and have read,* the whole of my researches.

If any one should form a different opinion, or question the accuracy of some of the minor points of microscopical details, I cannot say that in correcting any such *supposed* errors I shall be induced to abandon those practical views which are supported by the "*glaring instances*" just mentioned, which give a reasonable explanation to the empirical results of enlightened medical experience, and moreover enable me to satisfy my own mind as to what I have to do, or ought to attempt to do, in the treatment of disease ; unless, indeed, having proved *me* to have taken a decidedly wrong course, *they* are able also to support and establish on better grounds a more satisfactory explanation.

The great importance of the *colourless* corpuscles of the blood in the nutrition of the structures of man is already beginning to be fully acknowledged; every new observer of the beautiful process of fibrillation in the liquor sanguinis wonders that *that* had never been studied before; and the *theory of nutrition* developed in the following pages throws a new and a very high interest around that remarkable exhibition of the Divine creative power, which since the discovery of the microscope has excited the wonder and astonishment of thousands.

It is not presumed that the following researches have materially abated the difficulties which surround all physiological investigations; but they have, as it were, shifted the ground of the difficulty, and thereby enabled us to see *why* things, apparently so different as perspiration and exercise, ablution and friction of the surface of the body, counter-irritation, purgatives, and bleeding, *must* all, in different ways, concur in modifying or accelerating the nutritive changes of the tissues, and thereby alter the condition of the blood; and *how* change of air, change of diet, and change in the nature of the liquids received within the body, by varying the nutritive elements presented to the living structures in, or which are to form, the blood, *may* either produce or cure diseases.

Liebig has justly remarked that "the most exact anatomical knowledge of the structure of the tissues

cannot teach us their uses; and from the microscopical examination of the most minute reticulations of the vessels we can learn no more of their functions than we have learned concerning vision from counting the surfaces on the eye of the fly."

The most successfully injected anatomical preparations, exquisite and beautiful as they are, can be compared only to deserted houses; we can learn no more of the processes of secretion and nutrition from them than we could of the habits or movements of the inhabitants by wandering through the streets of a deserted city. But if we turn the microscope to the study of other objects—the more perishable elements of the structure—then it is probable that we may, again to use Liebig's words, "arrive at conclusions calculated to give us a more profound insight into the essence of the vital processes."

The rapidity of the decomposition (of the changes) of the elementary structures of the body is in a direct ratio to their importance in the functions of nutrition, secretion, and life; and all the future advancing steps of physiological and pathological anatomy will be accomplished by those who will carry with them the microscope and the test-tube to the dissecting room, and seize upon the objects which adhere to and leave their stain upon the bright blade of the scalpel.

All natural science is progressive; some branches advance with great rapidity, from the facility with

which observations may be made and facts accumulated; others make slower progress, from the intrinsic difficulties of the subject. Chemistry, which has to do with the qualities and properties of matter generally, is an example of the former; Physiology, which embraces the peculiar powers and properties of living structures, of the latter kind.

The *practice* of medicine is founded on experience and observation, on a long series of verified and established facts; but the *science* of medicine is based on chemistry and physiology; it must advance when they advance, or remain stationary when they are so. It is easy, therefore, to foresee the embarrassment of medical science, should one of these essential supports make a considerable and rapid progress while the other remains behind. Chemistry, for example, makes a rapid stride by a series of brilliant experimental results, offering to the medical philosopher an alluring and seductive course; while the sister science, struggling with almost insuperable difficulties, seems barren and profitless. Under such circumstances it is the duty of the medical *practitioner* to pause before he relinquish the more difficult, and embark in the more prosperous course. Physiology with him ought to stand before chemistry; and should he be constrained to make a choice, it would, at least, be more dignified to wait a little, and make some effort

to remove the obstructions lying in the path of physiology, before he adopts an exclusively chemical theory and explanation.

Fortunately, the great excellence to which the microscope has been brought, and the many philosophical observers, commencing with Schleiden and Schwann, who have now for some years been accumulating facts, seem at least to promise a rich harvest for physiology, and tend to place her as much in advance of chemistry as she has hitherto, for a long series of previous years, been behind. The result will be to establish the science of medicine upon a surer and more philosophical foundation, and thereby enable us to extend our remedies and to suggest new *physiological* methods of treatment for the diseases of mankind.

A great deal, however, remains to be accomplished: the new facts must be verified, and conclusions must be sifted and examined before they can be adopted and established; the soundings have commenced—the safe and navigable channel has yet to be buoyed out.

Since writing the above, *The Principles of Medicine,* by Dr. C. J. B. Williams, has been placed in my hands, and I hail the publication as the first systematic application of the new facts of physiology to the science or principles of medicine. At p. 213 I find in the wood-cut, and in the accompanying explanatory note, a representation and graphic de-

scription of a fact mentioned by me, p. 29, in the following chapter on nutrition; and I feel much gratified by having the learned professor's authority for an essential feature of my observation.

At the end of this volume I have placed, in a series of additional notes, several remarks and some new observations having relation to the matter contained in it.

GREAT MALVERN,
December 2nd, 1843.

A few months ago Messrs. Powell and Lealand fitted one of their very best one-eighth-object glasses to my microscope, and I have latterly frequently employed it in verifying my former observations and in extending my researches.

Before finally passing this preface through the press I wish to relate an important observation made with this object-glass, in combination with one of my own original eye-pieces, giving a magnifying power of 700 diameters linear. With this combination I can see in the interior of several of the mucous globules found in a clear transparent drop of saliva, myriads of molecules in the most active state of motion, almost reminding one of the busy scene of an ant-hill. The globules in which this

remarkable appearance presents itself, are always perfectly circular and have an uniform molecular aspect, free from any conspicuous granules, nuclei, or discs. This observation has directed my attention more particularly to the cause of the innumerable and various appearances presented by pus globules; and I now believe that the irregularity in shape and outline, and the appearance of conspicuous granules, nuclei, or discs, either in these globules or in mucous globules, is connected with the cessation of the active movements of these minute molecules. The perfectly circular and uniformly molecular mucous globule is a living cell; while those globules presenting the characters which have hitherto been considered characteristic of pus globules are, in my opinion, dead ones.

The reader of these and of my former researches will find many occasions on which I have described certain active movements of the molecules in the interior of cells; I can now fix upon a particular class of objects in which these observations may be repeated so as to satisfy the minds of other observers; and I state it without hesitation, as the result of numerous observations, that with a magnifying power of 700 diameters, having a clear and good definition, several mucous globules, (or, as I should be disposed to term them, saliva-cells,) filled with the most minute molecules in an energetic state of movement, may be seen in every drop of clear

saliva. It may be proper at the same time to remark, that with a deeper eye-piece, giving a higher magnifying power of 900, I should have failed to *discover* these motions, because the definition is not to my eye so good as with the eye-piece originally in my possession ; nevertheless, having once seen it, I can now readily perceive with this deeper eye-piece the molecules or dark points shifting their positions within the cell. These mucous globules, with a magnifying power of 700 linear, have an apparent diameter varying from the *one-third* to the *one-fourth* part of an inch ; their real magnitude, therefore, will be from the $\frac{1}{2100}$ to $\frac{1}{2800}$ part of an inch.

Active movements of an analogous kind may be admirably seen in myriads of minute objects contained in certain cells situated between the two laminæ of the *Peziza cochleata ;* and in much larger granules situated at either extremity of the *Closterium acerosum* and *turgidum.* (*Vide* Pritchard's *General History of Animalcules,* plate 1, figures 65 and 66, where the molecules are well shown.) These movements are quite different from those molecular motions which may be generally observed in the minute objects distributed on the field of a microscope having an object glass of high power ; they involve an entire change of situation and a total alteration in the relative positions of the various objects.

In the last number of the *British and Foreign Medical Review* there is an article in which, referring to my researches, the author states that there is something too specific in the character if not in the appearance of pus globules, for him to adopt the conclusion that they are altered colourless blood corpuscles. Now, the only possible way that I am aware of, in which pus globules can present a sensible character, is through the medium of the microscope; if this be true, then it appears to me impossible to separate, as regards these minute objects, *a character* from *an appearance;* but probably I am unable exactly to understand the passage, and must therefore leave the further consideration of the objection until these characters, which the writer evidently considers as distinct from appearances, are more fully explained. In the same article reference is made to Dr. Carpenter, and it appears that the writer coincides with him in opinion, that pus globules have the same relation to the *liquor puris* that the colourless blood corpuscles have to the *liquor sanguinis;* and this opinion, as far as it goes, exactly agrees with my conclusions.

January 17th, 1844.

Fig. 1.

Fig. 2.

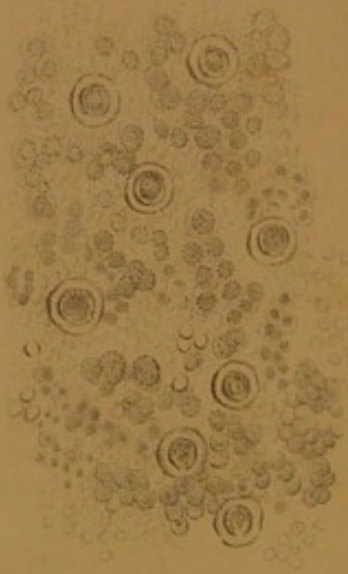


Fig. 3.

Fig. 4.

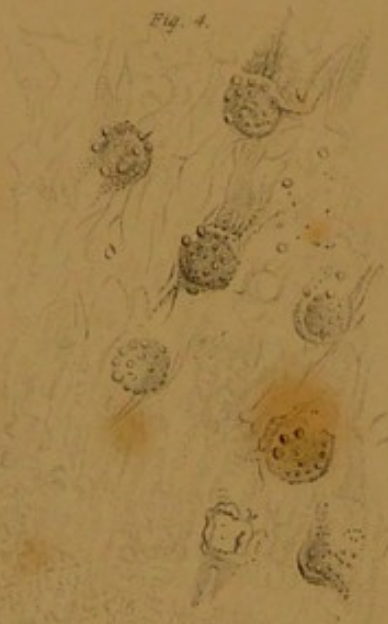
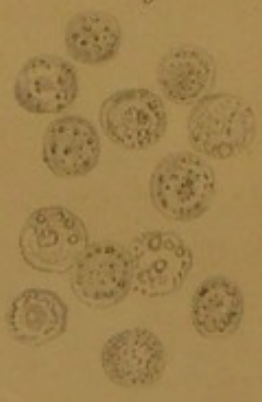


Fig. 5.

Fig. 6.

a

b



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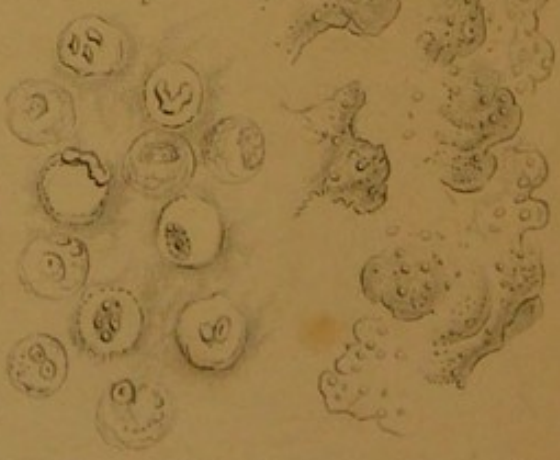


EXPLANATION OF THE PLATES.

PLATE I.

FIG. 1.—Red and colourless blood corpuscles; *the former* banded together; *the latter* preserving their figure, and standing alone.

FIG. 2.—Red and colourless blood corpuscles *immediately* after the addition of a drop of water; *the former* become fainter, granular, and smaller; *the latter* enlarge, showing a dark molecular centre, surrounded by a bright circumference or ring.

FIG. 3.—Colourless blood corpuscles *five minutes* after the addition of water; they are still larger, lose all appearance of a distinct central portion, and appear filled with dark molecules, some of which are more conspicuous than the rest.

FIG. 4.—Colourless blood corpuscles *fifteen minutes* after the addition of water; the outer envelope partially ruptured, and the molecules escaping.

FIG. 5.—A blood-vessel in the transparent membrane of a fœtal hare; showing altered colourless blood corpuscles, incorporated with the fibres forming the walls of the vessel.

FIG. 6.—(*a*) Colourless blood corpuscles; (*b*) the same after the addition of water, and resembling mucous globules; (*c*) their appearance, with granules, discs, or nuclei, after the addition of diluted acid, and resembling many of the common forms of pus globules; (*d*) the effect of a weak alkaline solution; the corpuscles first pass through the stage (*b*), and then burst open, discharging their contents.

PLATE II.

Fig. 1—Represents, theoretically, the normal process of nutrition. The colourless blood corpuscles first adhere to the walls of the capillaries; they then contribute to form the walls, and pass through the altering tissue, being evolved upon the nearest free surface in the form of a secretion, epithelial scales, or mucous epithelium.

Fig. 2—Represents, theoretically, an abnormal process of nutrition. The colourless blood corpuscles are in much greater numbers, passing through the altering tissue, and thrown off in the form of pus globules or imperfect epithelial cells.

Fig. 3.—(*a*) Colourless corpuscles shrivelled, from a tear collected at the corner of the eye; (*b*) the same corpuscles *two minutes* after the addition of a drop of water; they resemble in all respects colourless blood corpuscles treated in the same way; (*c*) the same corpuscles *five minutes* after the addition of the water; (compare this figure with fig. 4, plate 1); (*d*) the same corpuscles *twenty minutes* after the addition of the water; they display a complicated structure, with a corrugated central matter; the outer integument in some of them has burst open, and molecules and granules are escaping; (*e*) the same corpuscles after the addition of a little weak liquor potassæ; the outer integument has burst open, and become variously contorted, the molecules and granules escaping; (*f*) epithelial scales, of various forms, from a tear.

Fig. 1.

Fig. 2.

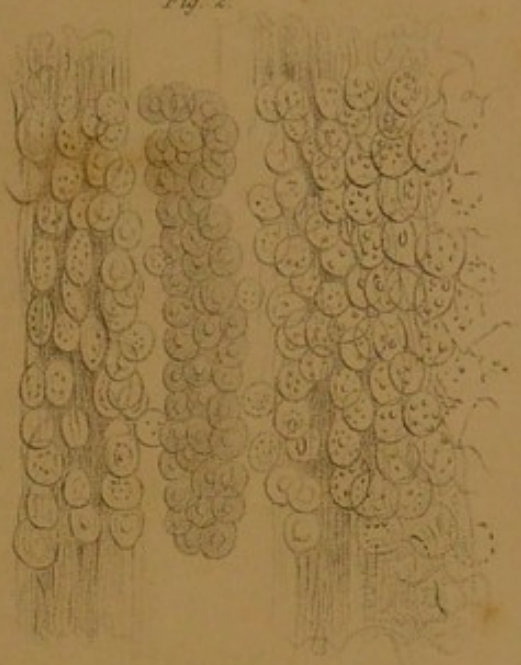
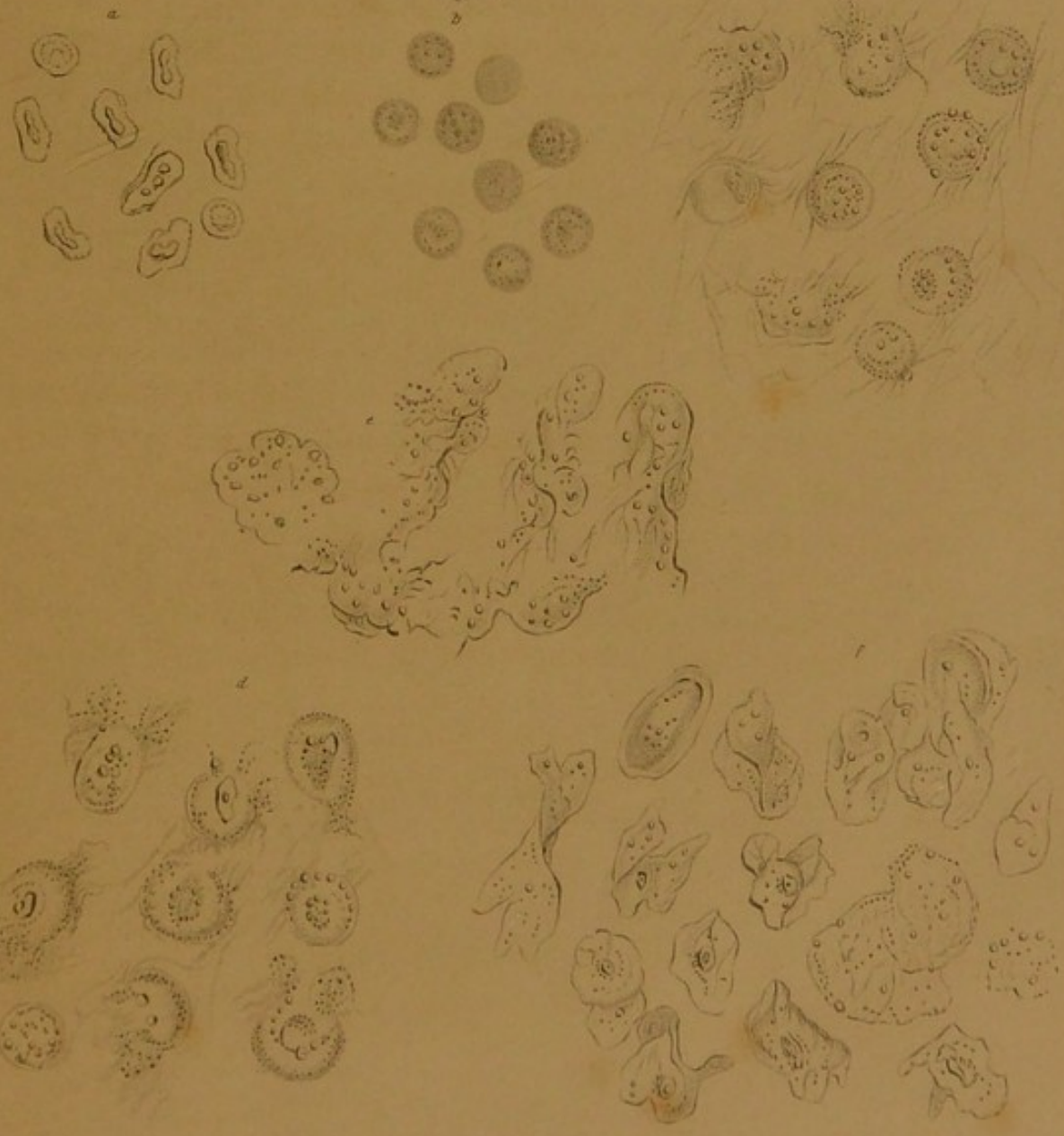


Fig. 3.



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"We have hope, and wish, that the nobler sort of Physicians will advance their thoughts, and not employ their time wholly in the sordidness of cures, neither be honoured for *necessity* only; but that they will become coadjutors and instruments of the Divine omnipotence and clemency in prolonging and renewing the Life of Man. It will be a token of God's favour towards us in our journeyings through this world's wilderness to have our shoes and garments (I mean those of our frail bodies) little worn or impaired."—Lord Bacon.

"The testimony of natural reason must of necessity stop short of those truths which it is the object of revelation to make known; but, while it places the existence and principal attributes of a Deity on such grounds as to render doubt absurd and atheism ridiculous, it unquestionably opposes no natural or necessary obstacle to further progress. The character of the true philosopher is to hope all things not impossible, and to believe all things not unreasonable."—*Preliminary Discourse on the Study of Natural Philosophy.*

"Is there not, then, great reason to hope and believe that, by a closer *experimental* investigation of the principles which govern the development and action of electricity, we shall be able to comprehend the harmony which doubtless governs electrical excitation by friction, by chemical means, by heat, by magnetic influence, by evaporation, and even by the living being. It is probable that every effect depending upon the powers of inorganic matter, and perhaps most of those related to vegetable and animal life, will ultimately be found subordinate to it."—*Experimental Researches in Electricity.*

CHAPTER I.

EXPERIMENTAL RESEARCHES ON THE PHYSIOLOGY OF SECRETION.

Three years ago I published* several cases demonstrating the existence of great numbers of colourless corpuscles in the buffy coat of the blood: they were detected by the aid of a Coddington lens merely; and their nature and characteristics, with their relation to the red corpuscles on the one hand and to the tissues on the other, were at that time quite unknown to me. In two subsequent numbers of the same periodical† I first published the fact of the lymph globules being seen accumulating in the irritated vessels of the frog's foot; and I also *then* stated that a thin film of the coagulated fibrine from the surface of inflammatory blood had all the structural characteristics and physical properties of fibrous or membranous tissue.‡

* *Medical Gazette*, December, 1840.

† *Ibid.* January and March, 1841.

‡ *Medical Gazette*, vol. i., pp. 477–690; vol. ii., p. 14, 1840 and 1841.

At the period these observations were thus incidentally recorded, the object I had in view was to find out the nature and origin of tubercles in the lungs, and the normal structure of these organs therefore came under my review. The prevalent opinion with regard to the termination of the minute bronchial sub-divisions did not appear to me to be borne out by my dissections; I therefore entered upon a series of experiments, for the purpose of discovering what these terminations really were, and their results formed the subject of a paper, published in the *Philosophical Transactions*.* The investigation into the normal structure of the lungs necessarily occupied some months; and at its conclusion I found the facts I had previously published had but very slightly attracted the notice of microscopists.

The memoir on "The Air Cells of the Lungs" was finished in March, 1842; and in the following month† I described the very remarkable process of *fibrillation* in the liquor sanguinis, whereby the tough and elastic membrane or tissue I had before noticed is formed.

This observation appeared to me at that time, when connected with my previous results, to form a "*collective instance*" in Bacon's classification; and I commenced a series of *experimental researches*, with the full expectation of ultimately arriving at a higher induction or generalization, as regards nutrition and secretion, than had hitherto been attained.

* "On the Ultimate Distribution of the Air Passages, and the Formation of the Air Cells of the Lungs."

† *Medical Gazette*, April 15, 1842.

It was not long before I was enabled to devise a method of demonstrating the existence of numerous colourless corpuscles in the blood at all times, however minute the quantity might be; and I always found them more conspicuous and abundant in blood drawn from vessels whose calibre was increased by *inflammation,* or which were administering to an accelerated process of nutrition; hence the investigation, which had been primarily directed to the buffy condition of the blood, and to the origin and nature of a morbid deposit in the lungs, was now by insensible degrees turned into the wider sphere of nutrition, secretion, and disease in general.*

By the application of several re-agents, and by comparing their effects upon the colourless blood corpuscles with those resulting from their application to pus globules, I came to the conclusion that lymph and pus globules, exudation cells, and epithelium, originate from the colourless corpuscles. This conclusion was strengthened by the fact that the fibrine of the liquor sanguinis was never seen during the progress of fibrillation to give origin to a corpuscle or globular particle of any kind. The chief difficulty in establishing this conclusion arises from the doctrine that all the blood vessels have *permanent tubular parieties.* My object on the present occasion is to show the nature of these tubular parieties; the changes they undergo; and to point out how the colourless blood corpuscles are included in their structure.

* *Vide* "Experimental Researches," published in vol. xi. of the *Transactions of the Provincial Medical Association;* and also separately by Mr. Churchill.

That the buffy coat of the blood is neither more nor less than elastic fibrous tissue may be readily verified by breaking down and washing away all the lower coloured portion of the clot. The process by which it is formed, and the numerous molecules and corpuscles included in the interstices of the fibres, may be demonstrated in the following manner :—

EXPERIMENT.—Provide six or eight slips of glass, such as are usually employed for mounting microscopical objects, and as many smaller pieces. Having drawn blood from a person with rheumatic fever or any other inflammatory disease, place a drop of the colourless liquor sanguinis before it fibrillates, on each of the large slips of glass ; cover one *immediately* with one of the smaller slips, and the others one after another *at intervals of thirty or forty seconds ;* then, on examining them by the microscope, *the first* will exhibit colourless blood corpuscles in various conditions, and numerous minute molecules distributed through a more or less copious fibrous network ; and *the last* will be a tough, coherent, and very elastic membrane, which cannot be broken to pieces nor resolved into smaller fragments, however roughly or strongly the two pieces of glass be made to rub against each other.* This is a "*glaring instance*" of a compact, tough, elastic, colourless, and fibrous tissue, forming from the colourless elements of the blood, and the several stages of its formation may be actually seen and determined. Numerous corpuscles may be observed in all these preparations to have resolved themselves,

* *Medical Gazette*, March 26, 1841, p. 14.

or to have fallen down into a number of minute molecules, which are spread out over a somewhat larger area than that occupied by the entire corpuscles; and although still retaining a more or less perfectly circular outline, yet refracting the light at their edges in a manner very different from that in which the corpuscles themselves are seen to do. It is from these and various other larger and more irregular masses of molecules or disintegrated corpuscles that the fibrinous filaments shoot out on all sides as from so many centres; or frequently the filaments are more copious in two opposite directions.

It is highly probable that the molecules and the plastic fibrillating liquid are both derived from the interior of the colourless blood corpuscles.

Experiment.—Blood was taken from the back of the hand by a puncture; it was pressed into a thin film, and its appearance under the microscope is delineated in plate 1, fig. 1; the red corpuscles are banded together, the colourless ones, eight in number, preserving their figure and standing alone. A drop of water was added at one of the edges of the upper glass; immediately both the red and the colourless corpuscles changed their aspect: the former broke up and separated from each other, becoming granular and smaller, but not all in the same degree; the latter became larger, with a very bright border surrounding a dark molecular centre. (Plate 1, fig. 2.) In five minutes further changes had ensued; the red corpuscles were very faintly visible, disintegrating and dissolving away, leaving minute filaments and ruptured integuments upon the field;

the colourless corpuscles were very much enlarged by imbibition, the outline of the central portion was no longer visible, and they appeared to be filled with molecules. (Plate 1, fig. 3.) In ten minutes the outer integument of many of the colourless corpuscles had partially given way, molecular matter and filaments appearing outside or on the exterior of the corpuscles. In a quarter of an hour or twenty minutes the corpuscles were evidently surrounded by a copious deposit of molecules and filaments, and had assumed the aspect shown in plate 1, fig. 4. Several other experiments of a similar kind yielded the same result; and when a very dilute solution of the liquor potassæ was added to those few corpuscles which were still entire, they were seen to burst, and several filaments and numerous molecules were evident among their discharged contents.

The fluid in which pus corpuscles are found frequently fibrillates: a fibrous network may almost always be found in the serous fluid of a blister; and lymph globules float in a liquid which forms fibres, as does the liquor sanguinis.

These facts appear to me to lead to the following explanation of the formation of the buffy coat of the blood in all those cases in which its presence is connected with disordered function or disease. In pregnancy, and doubtless in other normal conditions of the body, the blood may exhibit a more or less obvious buffy coat, still in these cases the explanation I am about to offer will apply; for any circumstances increasing the amount of colourless corpuscles in the blood will produce it, but to apply the *rationale* to

disease. From sundry causes the process of nutrition, or what amounts to the same thing, the function of secretion, is disturbed or diminished, and the colourless corpuscles therefore accumulate in the blood. When a vein is opened a greater number than usual flow out; from the sudden change of temperature to which they are exposed, or from other causes, many of them burst or become ruptured, and discharge their contents, consisting of liquor sanguinis and molecules. After standing a short time the liquor sanguinis rises to the surface, drawing up not only the molecules which were associated with it in the interior of the corpuscles, but also all those colourless corpuscles which have preserved their integrity amid the changes to which they have been exposed; here it very shortly fibrillates and forms tissue, as it would have done in the living vessels had the contents of the corpuscles been appropriated to the purposes of nutrition.

Accordingly neither the fibrinous element nor the serum circulate in the blood as part of the fluid in which the red corpuscles are suspended in the living vessels; they are both inclosed within, and form, incorporated together, an essential ingredient of the interior contents of the colourless corpuscle. Hence, therefore, the fibrine can no more be said to be elaborated from the albumen than the stone or kernel of a peach can be said to be elaborated from the fruity pulp—they both grow together; so likewise the fibrinous element and the albuminous element grow or are elaborated from other sources: if they bear a due proportion to each other the corpuscle or cell will be normal, and its subsequent function

will be healthy; but if one element preponderate over the other, the reverse of this must happen. What, then, it may be asked, is the nature of the liquid in which the corpuscles move when in the living vessels? It is impossible to determine; for it cannot be procured for experimental examination without being mingled with corpuscles, nor, according to these views, without some of them bursting and mingling with it their own contents.

There are several remarkable analogies between the liquor sanguinis at the surface of buffy blood and mucus. The former is a plastic fluid, containing numerous molecules and colourless blood corpuscles; and when the fluid fibrillates it incorporates the molecules and unruptured corpuscles, forming tissue. The latter is a glairy semi-fluid tissue, containing numerous molecules and colourless (mucous) globules. Mucus frequently exhibits a copious and distinctly fibrous character or structure, and always does so when a little dilute acid is added to it—an addition which cannot *form* the fibres.

It is probably owing to this peculiar, though sometimes invisible fibrous structure, that mucus is so tenacious and elastic—two remarkable physical properties placing this animal product between the more solid and visibly fibrous structures and the more completely fluid parts of the body.

Experiment. (*Mucus.*)—A transparent drop of glairy mucus from the nose was placed upon a slip of glass; it was lightly pressed into a thin film, and examined by the microscope. Numerous corpuscles

were seen, various in shape and magnitude, and filled with molecules and granules. The mucus, although perfectly transparent, had here and there an evident fibrous structure; and the corpuscles were in many places elongated and lying close together, side by side; many of them had evidently expended themselves, or had contributed their interior fluid contents to form the fibrous tissue-like matter of the mucus, leaving visible nothing more than little elongated masses of molecules, enveloped in and connected together by the almost invisible fibres. On adding a drop of the dilute acetic acid, and mingling it with the mucus, it became whitened, and its fibrous character or structure was rendered very evident; at the same time the mucous globules experienced a remarkable change: their uniform molecular appearance was altered, the interior contents were, with the molecules, drawn up together, forming two or three larger granules, (nuclei, or discs?) leaving the outer transparent integument of the globule of the same dimensions as before the addition of the acid. These results occur with all kinds of mucus.

Experiment. (*Pus.*)—A drop of white and opaque healthy pus was placed on a slip of glass, and well mingled with a drop of liquor potassæ: it entirely lost its opaque character, and became clear and transparent, resembling mucus. The fluid was now exceedingly tenacious, glairy, and elastic; it could be drawn out with the point of a needle into strings or filaments, six or eight inches long. A drop placed between two slips of glass and examined by the microscope was seen filled with molecules

and granules, but there were now no corpuscles remaining entire, they had all of them been ruptured by the alkali. On mingling another drop with a little diluted acetic acid it shrank up, would not mingle with the acid, but resumed somewhat of its former opaque white aspect ; and now on submitting it to an examination by the microscope, pressed into a thin film, it exhibited as copious a fibrous structure or character as the fibrillated liquor sanguinis. A drop of partially opaque muco-purulent secretion was treated in the same way, with the same results.

This experiment, which may easily be made, and requires no microscope, except to verify the existence of globules in pus before, and their total absence after the addition of the alkali, sets at rest the question of the difference between pus and mucus ; for if opaque pus can be changed into transparent mucus by bursting the pus globules, the inference naturally is, that the transparent parts of mucus and the isolated molecules have the like origin. The experiment, therefore, confirms the identity of mucous and pus globules, and corroborates the conclusion as to the origin of the molecules and the fibrillating liquor sanguinis of buffy blood.

Experiment. (*Liquor Sanguinis.*)—Three or four drops of the liquor sanguinis from buffy blood were placed, before the fibrillation of the fibrine, on a slip of glass. The fluid appeared of a straw or buff colour, and nearly opaque from the multitude of colourless blood corpuscles. It was well mingled with a drop of liquor potassæ, and gradually it became quite clear, transparent, and colourless, in

consequence of the rupture of all the corpuscles by the alkali. The mixed materials were now almost semi-solid, and resembled a glairy mucus.

Experiment. (*Blood.*)—A drop of recent blood was placed on a slip of glass and a drop of liquor potassæ beside it; on bringing the two together and mixing them, the effects were very singular and striking: ultimately, when they are well mixed, there results a transparent, gelatinous, or mucus-like liquid of a brownish tint. The phenomena here are owing to the rupture of the red blood corpuscles by the liquor potassæ, the result being a transparent brownish liquid, resembling, in several respects, ordinary mucus. On subsequently mingling a drop of the diluted acetic acid with these mucus-like liquids, they are rendered opaque, and the opaque portions under the microscope display a more or less evident fibrous arrangement according to the varying circumstances of the experiment.*

There have been many instances during the progress of these researches, in which I have stated that the colourless blood corpuscles imbibe water and increase considerably in size, the outline of the central portion disappearing, the corpuscles assuming a globular figure filled with molecules. The

* These experiments may be varied thus:—Place in a four-ounce phial a quantity of muco-purulent fluid or pus, so as to about one-third fill it; then add a like quantity of liquor potassæ, and shake them well for some minutes. The mucus or pus becomes nearly or quite transparent, by rupture of the corpuscles; then, before the froth at the top has all gone off, fill the phial with dilute acetic acid, pouring it in gently, so that it shall swim at the top, when the opaque white fibrous tissue-like matter may be seen copiously by the eye alone.

following experiment demonstrates their extreme susceptibility to the influence of acids and alkalis :—

Experiment.—Having added to an ounce of pure water two or three drops of dilute acetic acid, and to another ounce of water two or three drops of Brandish's liquor potassæ, I found that neither the acid nor the alkaline solution had any taste; it was impossible to distinguish in this way between the one and the other, or between either of them and pure water; litmus paper wasbarely perceptibly reddened by the acid, and turmeric paper gave but slight indication of the alkali. I then took twelve ounces of blood from a patient suffering from dropsy after scarlet fever; and having placed a drop of the colourless layer of the liquor sanguinis before fibrillation on a slip of glass, I added to it a drop of water, mixing them well together; the corpuscles enlarged gradually to three times or more their former size, and were filled with molecules or granules. In a quarter of an hour they were as large as, and could not be distinguished from mucous globules. I now mingled with these altered corpuscles a drop of the weak acid solution, and in a few seconds *I saw* the central matter or the interior of the corpuscles *collapse* and separate from the outer transparent integument, appearing in its interior in a variety of forms, sometimes as a single one, or as two or three oval or circular shaped objects (discs?) or as a circle composed of three, four, or more bright granules. Sometimes the outer transparent integument, which remains of the same dimensions as prior to the application of the acid, is so faintly perceptible that

it requires close attention to perceive it. This alteration is precisely the same as that which takes place in mucous and in pus globules from the same re-agent. I then took another drop of the liquor sanguinis, and first placing it in focus under the microscope, I added to it a drop of the weak alkaline solution ; the first effect of this application was to cause the corpuscles to alter their appearance, and to enlarge in the same manner as if water only had been added ; but in the course of a very short time, I observed them one after another explode with considerable force, discharging a quantity of molecular matter mingled with some filaments, and a multitude of molecules and granules, the fluid resulting from their disintegration being glairy and tenacious like mucus. The changes and alterations I witnessed are delineated in plate 1, fig. 6.

(*a.*) The colourless blood corpuscles.
(*b.*) The same objects after the addition of the water, and resembling mucous globules.
(*c.*) Their appearance on adding the weak acid solution after the water, and resembling pus globules.
(*d.*) The effect of the alkaline solution after the corpuscles had passed through the stage (*b*), the resulting fluid resembling mucus.*

It is evident from this experiment that the colourless corpuscles of the blood are immediately altered by the acid or alkaline quality of the fluids with

* Some of these results have long been published, *vide Medical Gazette*, April 15, 1842, p. 148, but I did not at that time know how best to show and explain them.

which they become associated; and there can be little doubt that the vital properties and chemical arrangement of the particles of matter within the corpuscles must be modified by the nature (the chemical nature) of the fluids they imbibe, otherwise there would be no alteration in their visible appearances; and hence, when they discharge their contents, these will have different qualities, according to the circumstances in which the corpuscles have been placed. These results appear to me to have some, though as yet perhaps an obscure, relation with the phenomena and treatment of two very distinct and opposite classes of disease, in one of which acids and all things tending to produce acidity in the body are scrupulously avoided, and in the other they are very urgently required and liberally allowed.

From the various appearances presented by pus corpuscles, I conclude that they are frequently subjected to similar influences; the fluid in which they exist sometimes becoming slightly acidulous, either from chemical change, or from having been originally of this nature, so that all the unruptured corpuscles assume the aspect shown in plate 1, fig. 6, *c*; but if the fluid be ever so slightly alkaline, they are seen in a more disintegrated state, mingled with a far larger number of minute isolated molecules, and with the outer integument extremely attenuated, very much resembling in appearance, except colour, the bile vesicles from the liver.

These remarks and observations show that it is necessary to attend to the qualities of the fluid used to separate pus globules from each other for

microscopical purposes, or for the examination of the changes in blood corpuscles ; if it be pure water there is a series of alterations and changes due to it ; if there is the slightest degree of acidity present there will be a different series of appearances ; and if, again, there be any alkalinity, the corpuscles will be found undergoing totally different changes from that source. From these experiments I draw the following conclusions :—

1st. That the plastic fibrillating liquid, denominated liquor sanguinis, exists as a fluid within the colourless blood corpuscles, and that when it escapes from them it forms an elastic fibrous tissue, the serum being the residual liquid.

2nd. That mucous and pus globules are altered colourless blood corpuscles, and that the glairy fluid termed mucus is nothing more than an altered state of the fibrillating liquor sanguinis, the change from the one to the other being coeval with the changes which characterize the microscopical aspect of the corpuscles. Hence, if we take the red portion of the buffy clot, and the red blood corpuscle, to represent blood, then the colourless layer of liquor sanguinis with the colourless blood corpuscle will represent the first remove from blood, and mucus or pus, with the mucous or pus globule, will be the next. And it would appear generally, that the nearer the corpuscle is to, or the fewer the stages of its removal from the circulating fluid, the more nearly it resembles the colourless blood corpuscle, and the more decidedly and visibly its fluid contents, when they escape, fibrillate ; whereas the further the corpuscle is, or the greater the number

of stages of its removal from the circulation, the larger it is, the more it is filled with molecules, and the less perfectly do the fluid contents fibrillate. Now, if it be admitted, of which I have myself no doubt, that the fibrillating liquor sanguinis is changed into mucus in the interior of living cells, then there can be no difficulty in admitting that similar living cells, by a different mode of elaboration, may form not only sundry kinds of fibrous or mucous tissue, but the tears, saliva, milk, or bile.

EXPERIMENT.—A woman applied for relief from pain and irritation in the eye, brought on by a drop of hot water which had accidentally got into it: there was very little injury done; the conjunctiva was red, and there was considerable lachrymation. I took a perfectly transparent tear from the corner of the eye, and spreading it out a little I examined it, without any covering, by the microscope, and found great numbers of colourless corpuscles, varying in figure; they appeared shrivelled. (Plate 2, fig. 3, *a*.)* I added a drop of pure water, and stirred them well together. In two minutes they presented the appearance shown in plate 2, fig. 3, *b*, and resembled exactly colourless blood corpuscles treated in the same manner. In five minutes I found that several had burst and had emitted molecular matter, the half-emptied integuments still containing molecules and bright granules; others had increased more in magnitude; molecules and granules were variously distributed within them, and in some of them there was a collapsed interior

* Also plate 2, fig. 20, in the first series of these "Researches;" *Transactions of the Provincial Medical and Surgical Association*, vol. xi.

portion, having all the characteristics of that body which has been denominated the nucleus of a cell.* (Plate 2, fig. 3, *c.*) After the lapse of fifteen or twenty minutes, further alterations had taken place: there were several corpuscles which had preserved their integrity, displaying a highly complicated structure, and in most of them there was the same collapsed and more or less divided central matter. In close contact and connected with these corpuscles on their outside, there were numerous molecules and a molecular base, which had evidently been emitted from their interior. (Plate 2, fig. 3, *d.*) I now added to these corpuscles a drop of dilute alkali, and the bursting open of their integument, the singular contortions it underwent, and the discharge of the molecules and granules, were very remarkable. (Plate 2, fig. 3, *e.*) Now these highly organized vesicles or cells are not likely to be mere exudation corpuscles, according to the definition and mode of origin usually assigned to these objects; on the contrary, it is much more probable that they were *tear-vesicles,* hurried through the stages of their growth or development by an abnormal nutrition—colourless blood corpuscles, in fact, in the primary stage of their special existence.

Experiment.—A child four years old, in perfect health, began to cry. I collected and examined a tear by the microscope, and the objects seen in it are delineated in plate 2, fig. 3, *f.* They are evidently epithelial scales, (the collapsed and empty integuments of epithelial cells,) except the oval object at the top of the group on the left hand, which

* *Vide* the experiment, pp. 5 and 6, *ante.*

appeared as I have sketched it, tense and full. Now the question is, whether these collapsed epithelial tunics belong to the mucous epithelium of the lids and eye-ball, or whether they originate from the tissue which, from the analogy of all other secretions, may be presumed to give origin to the tear-cell. Attached to most of these, as indeed to all perfect epithelial scales, there was a little kernel or nucleus, which is shown in some of the figures; but as the term nucleus has been indiscriminately applied to the altering particles of blood and other corpuscles, as well as to these permanent and fixed objects attached to the integument of epithelial cells, I have forborne the use of the term in these researches.

When making the experiment described in my former researches,* with blood taken from the skin of a patient with scarlet fever, two, three, or four colourless corpuscles may usually be seen in several places in the field of the microscope in close contact with each other; and when they are put in motion there is evidently some structural union between them; for although they still retain their figure, they all move together and do not separate from one another. Pus globules generally adhere together, forming a species of friable tissue; they can rarely be satisfactorily examined by the microscope without being well stirred previously with a little water or serum, to disentangle them from each other; and as I have seen them, they have had, as frequently as the contrary, filaments

* *Transactions of the Provincial Medical and Surgical Association*, vol. xi. p. 237.

and molecular matter attached to their irregular external integument, and rendered very obvious when the globules were put in motion by touching the upper piece of glass. Moreover I am, I believe, constantly seeing cells forming transitions from red to colourless corpuscles, from colourless corpuscles to pus and mucous globules, and from pus globules to tissue and epithelium, in the purulent and lymph discharges from cuts, sores, and fungous excrecencses on the hands or fingers. Now definitions are all very well in their proper place, very necessary, and highly useful ; but they have always tended to obstruct rather than facilitate minute investigations. There are no visible or sensible broad lines in nature, and therefore all definitions must necessarily fall short of what they are intended to accomplish if too strictly applied. The more accurately and minutely we scrutinize the physical and vital phenomena so profusely scattered before us, the more difficulty we find in framing or using definitions, unless in a large, comprehensive, and liberal sense. We may readily frame a definition that shall distinguish a tree from an elephant or a man, and yet we cannot frame one to distinguish the vegetable from the animal scale of creation ; so likewise we may see a great difference between a red blood corpuscle and an epithelial cell, and yet a very little investigation will discover to us objects forming a connected series between them.

Finally, then, these investigations have confirmed the conclusions which were drawn from my previous "Researches," that the colourless corpuscles of the

blood are very highly-organized cells, within which the special tissues and the secretions are elaborated; and it appears that the renovation of these tissues and secretions from the blood, does not take place by the cells discharging their contents into the general mass of the circulating current, to be separated therefrom by some peculiar transcendental and purely hypothetical selective process of exudation, through a structureless and transparent tissue; but by being themselves attached to, incorporated with, and performing their special function in the structure.

The facts upon which the above conclusions are grounded, render it to my mind not only very probable, but certain, that the progress of the colourless blood-cells in administering to the maintenance of the living body is not, as I should term it, *back again* into red corpuscles, but *onward* into the higher forms of organized fibrous tissue and epithelium. This view of their nature and destination makes it exceedingly doubtful whether the molecules and granules seen in the liquor sanguinis and in the interior of the colourless blood-cells, be really "young cells," as is supposed by Dr. Barry; and these doubts were indicated in the "Researches" before referred to.*

It now appears to me that the blood-cells have their origin in the chyle, and that every step, by which they multiply or increase in numbers, is progressive, carrying them higher in the scale of organization, until at length they acquire colour by passing through the capillary vessels of the lungs; they then again become colourless by

* *Loc. cit.*, pp. 261, 265, 273, &c.

further elaboration or nutritive changes, and in this condition are prepared to enter upon what may appropriately be termed a higher and more special state of existence, *i. e.*, into the composition of the tissues.

To suppose the molecules in the interior of the colourless blood corpuscles to be objects destined for the reproduction of blood-cells, would be, I think, to admit of their descending in the scale of organization; whereas, according to the view I take, there is a gradual rise and progression, without the slightest break or interruption, from the primary colourless cells in the intestinal villus, through sundry generations, up to the red blood-cells; and from these again to the more complexly organized colourless blood-cells, which form the foundations of the tissues and the special secreting cells—the link between the blood and the more solid structures, the unity from which the pluralities arise. If, therefore, the colourless blood corpuscles be termed "parent cells," they must be considered as pregnant with the embryo materials of the tissues and secretions, and not with "young blood-cells." According to this view of the entire dependence of secretion upon the nutritive process, neither milk, mucus, nor the bile, are derived from the blood as such; on the contrary, they are each elaborated in the interior of cells which were previously colourless blood cells, *the change from a blood to an epithelial cell being the sum of the process of secretion; and milk, mucus, and bile, are the visible fluid results of the final dissolution of the cells.* Hence, therefore, a secretion is the result of the last stage of the process

of nutrition ; and hence, also, it is by the special vital activity of individual cells, and of all the visible particles composing their structure, that the secretions are produced, just as in the party-coloured petal we may see a yellow or a pink cell, not only contiguous to, but in close contact and structurally connected with a blue, a purple, or a white one. The conclusion therefore is, that the molecules in the interior of the colourless blood cells are analogous to those in the interior of the coloured cells of the petal, and to those so remarkably conspicuous in the interior of the cells of the leaf of the *Sedum acre*, or of any other leaf, which have never been considered as reproductive. They are active vital objects essential to the peculiar contents of the various cells. These opinions are borne out, not only by the countless myriads of molecules in pus, in the hepatic and in all other epithelial cells, but also throughout every part of the structure of all organized beings. These molecules have never been supposed to be reproductive objects, yet the argument is as strong in their favour as it is for the reproductive function of the molecules of the colourless blood cells.*

Again, the experimental results before related, where, upon the addition of dilute acetic acid to the colourless blood corpuscles *after* water, the interior contents of the corpuscles were seen to corrugate or coagulate and to be drawn up more closely together, seem to require a few further remarks. Dr. Barry, in his " Memoirs on the Cor-

* *Vide* " Experimental Researches," *loc. cit.*, pp. 263–4, &c. ; plate 3 and 4, figs. 28 to 35.

puscles of the Blood,"* does not make any very clear or decided distinction between the red and the colourless corpuscles; and he constantly refers to the use of the dilute acetic acid, speaking of it as requisite to remove the colouring matter, and thus enabling the observer to perceive the objects which he calls "discs." In a subsequent paper he recognises in the colourless blood corpuscles his "parent cells."† Now, according to my experiments, these "discs" have no existence in the colourless corpuscles, *as such*, until the addition of the acid; they cannot be seen in the corpuscles in their natural state, nor are they perceptible in them when enlarged by the imbibition of pure water; but the slightest possible degree of acidity in the water, whether intentionally or accidentally present, will produce the "discs," which, according to the results of my experiments, are formed by the corrugation or contraction of that interior matter of the corpuscles which before the presence of the acid appeared filled with minuter molecules. Hence, therefore, from the result of this experiment alone, I should have been led to doubt the *parental function* which Dr. Barry assigns to the colourless corpuscles of the blood.

* *Philosophical Transactions*, 1841–2.

† "On Fibre," in the *Philosophical Transactions*, 1843.

CHAPTER II.

EXPERIMENTAL RESEARCHES ON THE PROCESS OF NUTRITION.

It is impossible to frame any conception of the process of nutrition in the higher orders of the animal kingdom that shall harmonize with the results of recent observations, and at the same time leave undisputed the received doctrine that the capillary blood vessels have permanent tubular coats; without in fact supposing that the walls of these *channels*, in those places at least where nutrition is actually going on, partake in a more or less rapid alteration. The facts contained in these "Researches," with others which have for some time been accumulating from other sources, are quite incompatible with the doctrine that all the blood vessels have *permanent tubular coats*. The appearances seen in the irritated vessels of the web of a frog's foot, the well-known adhesion of the colourless blood corpuscles to their walls, and the

situation of these corpuscles among the fibres composing them; the mixture of fibres and corpuscles in the walls of the vessels in the transparent membranes of the embryo (plate 1, fig. 5*); and, lastly, the fibrous structure of the buffy coat of the blood and mucus, with the numerous molecules and corpuscles which they contain, negative this doctrine, and lead to the following explanation and *theory of the process of nutrition*:—

Nutrition may be normal or abnormal.

In normal nutrition the colourless blood corpuscles adhere to the tissue forming the boundary of the blood channels; they pass into and contribute to form the tissue, *i. e.*, the parietes of the capillaries, and are afterwards evolved or thrown off from the nearest free surface—a follicle, crypt, or duct, constituting epithelial cells; the mucus, or the secretion given out by the follicles or flowing through the ducts, being the result of the final dissolution of the cells and tissues. (Plate 2, fig. 1.)

In abnormal nutrition the colourless blood corpuscles adhere to the parietes of the capillaries in much greater abundance; they pass out among the fibres of the tissue, which is now much less fibrous and coherent, and are subsequently thrown off from the nearest free surface—a pyogenic surface, as lymph, pus, exudation, or imperfect epithelial cells. (Plate 2, fig. 2.)

According to this statement of the process of nutrition, the fibrous walls of the capillary vessels

* *Vide* also *Gerber's General Anatomy*, plate 20, fig. 103.

are formed by the fibrillation of the liquor sanguinis contained in the interior of the colourless blood corpuscles, some of the corpuscles being employed or expended in forming the fibrous tissue, others passing through it in the interstices of the fibres for further elaboration into epithelium. If the corpuscles congregate in unusual numbers, and be hurried through the stages of their growth by an abnormal nutrition, they come under observation as lymph, pus, or exudation cells; the various appearances presented by these objects, and the quality of their contents, being referrible to the period of their growth, to the special function of the tissue, and to the chemical action of the fluids with which they are associated.* Hence the buffy coat of the blood has a relation to the lower coloured portion of the clot, analogous to that which the parietes of the capillary vessels have to the blood passing through them; and the gradual contraction of the fibrinous fibres in the former, whereby it consolidates and diminishes in size for hours, indicates very sufficiently in how short a period the latter may have their walls consolidated, forming a more compact tissue after death.

I have called the preceding statement of the process of nutrition "a theory," because it involves some *hypothetical* considerations; and as all medical or physiological theories are justly viewed with great doubt and suspicion, it will be advisable to recapitulate the facts, in order to show how far the demonstration goes, and how much is left for the hypotheses to fill up. The *facts* are these:—

* *Vide ante*, pp. 12, 13, &c.

1st. Great multitudes of colourless corpuscles are at all times circulating in the blood ;* they are particularly abundant in vessels actively engaged in nutrition ;† they are seen attaching themselves to the inside of the vessels in the web of the frog's foot, and their number is very much increased when the tissue has been irritated ;‡ they contain in their interior a number of minute molecules, and a peculiar plastic fluid, which fibrillates or forms fibres.§

2nd. Colourless corpuscles and little masses of detached molecules are found incorporated among the fibres in all growing membranes ;‖ in the fibrous walls of the blood vessels ;* in the buffy coat of the blood ;† and in mucus.‡

3rd. There is a gradual transition between the colourless blood corpuscles in the interior of the blood vessels ; and the lymph and pus globules, the exudation and epithelial cells on their exterior.§

The *hypotheses* necessary to complete the theory are—that some of the colourless blood corpuscles adhering to the walls of the minute vessels form these walls by the fibrillation of their fluid contents ; that others are included in the interstices of the altering tissue, pass bodily through it and grow into epithelium ; and, lastly, that if the nutrition be hurried or abnormal, they form pus and exudation

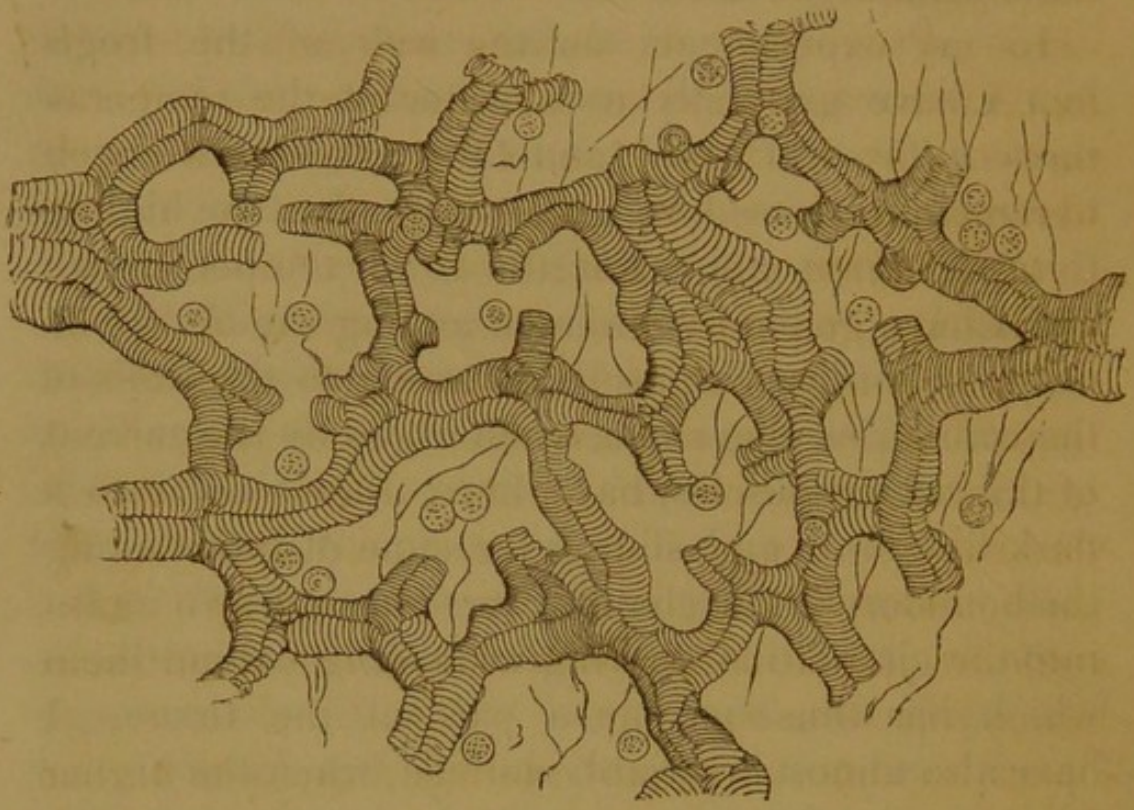
* "Experimental Researches," *loc. cit.*, p. 237.
† *Loc. cit.*, page 260.
‡ "Experimental Researches," *loc. cit.*, p. 257, &c., plate 3, fig. 27.
§ Page 4, 14, &c., *ante*.
‖ Plate 1, fig. 5, *ante*.
* Plate 3, fig. 27, *loc. cit.* ; and plate 1, fig. 5, *ante*.
† Page 4, *ante*.
‡ Page 8, *ante*.
§ "Experimental Researches," *loc. cit.*

cells. Meanwhile we are compelled to resort to some form of hypothesis, because the actual growth of the objects and their movements through the tissue cannot be seen.

In my experiments on the web of the frog's foot I have generally used water at the temperatures of 95°, 100°, 105°, and 110°, allowing the web to remain immersed from *thirty seconds* at the higher, to *two or three minutes* at the lower temperatures; and I have generally observed among the multitude of the colourless corpuscles adhering to the walls of the capillaries, that some, when urged by the current of the red corpuscles, have been drawn out into a flask-like form, and, sliding for some distance along the boundary of the channel, have been drawn again into the circulation, leaving *something* behind them which has thus become a part of the tissue. I have also almost invariably noticed, when the higher temperatures have been applied, that the red corpuscles adhere to the tissue as well as the colourless ones; and this, in my opinion, is one of the characteristics distinguishing the normal nutritive process, or an accelerated nutrition, from inflammation.

I have in the former series of these "Researches" remarked that the red blood-cells have a peculiar and very characteristic disposition to cohere, and to lose their figure by the slightest lateral pressure, but that the colourless ones have no such disposition to cohere; they stand alone and preserve their circular form against pressure. Hence we may readily estimate the relative numbers of the firm colourless corpuscles; they are generally seen in the spaces between, and along the margins of the lines formed

by the cohering red cells, as shown in the subjoined figure, which represents the appearance of a drop of blood drawn from a pimple on the skin.



In blood drawn from any inflamed surface, or taken from the skin of a patient in scarlet fever, these firm colourless cells are equally numerous and conspicuous.

Now it may be necessary, since the colourless corpuscles are supposed by me to be such important agents in the nutrition of the structures, and in the elaboration of the secretions, to offer some explanation why, in this experiment, they are not seen in greater numbers, in a proportion more nearly equalling that of the red corpuscles.

This is, I think, accounted for by their strong disposition to adhere to the tissue, so that they are not disposed to flow out when a puncture is made;

whereas the red-cells, from the readiness and rapidity of their motion, flow out immediately, and in preference. Hence, the number of colourless corpuscles seen, is no valid criterion whereby to judge of their actual amount, though an increase of this amount may be indicated by the greater numbers observed in blood drawn from one spot over that drawn from another situation. That this is not altogether supposition appears from this: I have frequently seen thousands of colourless blood corpuscles adhering to the walls of the vessels (capillaries, veins, and arteries) in the frog's foot, after immersion in warm water; and yet, when a puncture was made for the purpose of obtaining these corpuscles, their amount, relatively to the red-cells, has not been at all greater than is shown in the above figure.

But it may be urged, as an objection to the theory of nutrition, that as we *can see* the colourless corpuscles in the irritated web of a frog's foot adhering to the tissue, why *do we not see* them passing through it and forming fibres or epithelium? To this I answer, that the nutritive changes or processes are too slow in this example for us to follow, from beginning to end, all the actual stages of nutrition; the corpuscles go on congregating in the irritated tissue for an hour or two. Nevertheless the epithelium of the web, and the walls of the capillaries have their visible characters gradually changed during the observation; and numerous corpuscles, more or less altered in shape, may be seen mingled with or buried in the fibrous tissue. This is as far, perhaps, as we are able to go in *seeing*

the process of nutrition ; and yet if the part were patiently watched for a sufficient length of time, it is very possible that still more of the process might be seen. Moreover, that the great accumulation of the lymph globules or colourless blood corpuscles in the capillary channels of the web of the frog's foot after immersion in warm water, their adhesion to and incorporation with the tissue, is a "glaring instance" of an acceleration of the normal process of nutrition, is, in my opinion, substantiated by the fact, that in the course of a day or two after the application of the warm water, the cuticle or epithelium of the web, composed of pentagonal or hexagonal cells, with their well-known nucleus in the centre, looking like a lymph globule, peels off in large flakes, an event perfectly according with the theory, as it would not have happened so speedily except from the application of the irritant.

The truth of the theory may be tested by the phenomena of any well-marked specific disease—scarlet fever, gout, or rheumatism. Let us take for an example scarlet fever : this disease has a specific character, probably arising from a peculiar poison imbibed by or affecting the blood corpuscles ; whether so or not, at all events, the function of nutrition is more or less obviously disturbed, the secretions are diminished or disordered, and the colourless blood-cells consequently accumulated in the circulating fluid. In the milder and favourable cases of the disease, these cells are specially determined to the epithelial surfaces of the skin, for the purpose of being eliminated from the body, forming an excess or an additional layer of epi-

thelium, which peels off at the termination of the disease. In the severer and more formidable cases, they congregate in the vessels of some one or more of the internal epithelial surfaces, causing muco-purulent discharges, or the formation of abscess, so that a person may have the disease termed scarlet fever without any redness of the skin. If there has been no exfoliation of the cuticle, nor any critical discharge, we may conclude that the abnormal corpuscles have not been at all, or only partially and imperfectly eliminated. The patient, under these circumstances, may perhaps for a little while appear to be getting well; but these appearances ought not to be trusted, for the diseased corpuscles are still present in the circulation, insidiously perhaps, by an abnormal nutrition, locating themselves in some of the internal glandular structures, laying the foundation of future scrofulous disease, or forming tubercles in the lungs. If none of these events are taking place, their presence will probably be speedily proclaimed by symptoms of dropsy, or of an acute inflammatory or greatly accelerated and abnormal nutrition in the kidneys, the phenomena of which exemplify the truth of the theory; for the disintegrated tissues and the red corpuscles of the blood are voided in the urine.

These views of the phenomena which frequently mark the course of scarlet fever, explain why it happens that those cases presenting the mildest primary type are so frequently followed with the graver lesions afterwards. It also points out the necessity of scrupulously attending to the exfoliation of the cuticle, or watching for some other more or

less obvious critical discharge, before we finally dismiss, as cured, a case of scarlet fever, or pronounce it to have terminated satisfactorily. But to try the theory by another test: what are the remedial measures it suggests, where the natural cure—the elimination of the abnormal corpuscles—has been interrupted or impeded?

1st. Bleeding, for the purpose of diminishing the total amount of the colourless blood corpuscles; and by lessening the volume of the blood, to recall, if possible, into the current of the circulation some at least of those which have become stationary, oppressing and loading the tissues.

2nd. A more or less active purgation, or accelerated nutrition upon all the available epithelial surfaces, so that by speedily removing the worn-out or unhealthy epithelium, a stimulus may be given or space afforded for the more rapid growth of the new.

It is not to be concluded that I am advocating the operation of bleeding in all or even in the majority of those cases, either of scarlet fever or any other specific disease, in which the surface of the blood assumes the colourless aspect; I merely adduce the particular example of dropsy or inflammation of the kidneys, after or during scarlet fever, to show that the theory or *rationale* of the process of nutrition, here set forth, suggests the employment of those remedial measures which enlightened medical experience has approved as very frequently essential to the cure of the disease. But the theory does more: it indicates *two very different modes of withdrawing blood*—one by the lancet, leeches, &c., where both the red and the colourless corpuscles

are discharged; the other, by establishing an accelerated nutrition—an eruption on the skin, a blister, an issue, or a seton—where the colourless corpuscles only are selected and thrown off. Thus, then, the judicious employment of bleeding and purgation is the nearest approach to natural cures; for a critical abscess has often put a period to a long and tedious illness, and a critical hæmorrhage has as frequently saved a valuable life.

Moreover, the great and admitted principles of medical practice, slowly accumulated by experience, are illustrated and explained by the theory. The various modes in which these principles can best be carried out must ever depend upon the temperature of the climate, the social habits, the diet, the moral condition, and the education of the people. That pure air, early rising and exercise, abstraction from mental anxiety, and a more rational routine of diet and sleep, are at this moment, and in this country particularly, essential elements of the cure of numerous chronic diseases, is exceedingly evident and clear; the disorders produced by intemperance, indulgence, and indolence, will be cured by sobriety, frugality, and exercise, in the way that sleep cures fatigue; bread, hunger; and water, thirst. But the most scrupulous attention to the apportionment of the vital stimuli, heat and cold, food and water, air and exercise, has never hitherto prevented or eradicated all human maladies; nor can it shield the body from the influence of the noxious miasmata of the atmosphere, from which a numerous and important class of diseases arise. Hence, therefore, upon these grounds, the proposal

of a water, a diet, an exercise, or indeed of any other exclusive mode of cure, applicable alike to all kinds and every variety of disease, is contrary to the order of nature, opposed to all past experience, and must be erroneous. Their doctrines cannot be otherwise than partial and deficient, and the practice to which they lead either useless and unnecessary, or inefficient, and therefore dangerous.

The preceding theory of nutrition may be applied in explanation of sundry other phenomena of disease.

The visible appearances in the web of the frog's foot after the immersion in water, at 96° or 100° F., is of the nature of a *vera causa*, explaining how the calibre of the capillary blood channels may be diminished or enlarged in diameter in brief periods of time, without calling in aid any hypothesis of active dilatation, spasm, or contraction; for the area of the channels, and the physical character of their walls, will depend upon the number of colourless corpuscles stationary upon them, or upon the quantity of tissue left behind by those which slide along them. These visible appearances are also a *vera causa*, indicating how the parietes of a whole series of capillaries may, during the progress of an accelerated or abnormal process of nutrition, be changed from *fibrous* into *friable* tissue; and how a firm, hard, and vascular tumor is converted into pus; they are also a *vera causa* accounting for the occurrence of spontaneous hæmorrhages. Finally, *in the accelerated nutritive process visible in the web of a frog's foot*, we not only see numerous colourless blood corpuscles

adhering to the walls of the vessels, *but we likewise see* that a great many of them, after adhering for some time, are driven again into the circulating current. Now the occurrence of vicarious secretions, the phenomena of *metastasis*, and the different hues or tones of colour presented by the buffy coat of the blood and the serum in different kinds of disease, the variations in the chemical elements of the blood, and several other phenomena, *required such a fact as this for their solution.* For, if the colourless blood corpuscles, being brought into contact with a particular tissue, and adhering thereto, have peculiar changes thereby determined in them, it becomes a question of time only how soon these peculiar changes commence. Reasoning from the facts, we may conclude that a temporary adhesion to the tissue of one organ is sufficient to unfit them for their normal function in another; so that when they are dislodged from their situation, and driven again into the current, they carry the changes commenced in one structure into another.

While these sheets were in progress through the press I received a communication, of which the following is an extract, from Dr. W. B. Carpenter—a name too familiar to the microscopical physiologist to require from me any comment:—"A few months ago I happened to meet with an aquatic larva, of a species I had never seen before, though I think it must have been a *Culex*, in which the circulating fluid seemed to occupy nearly the whole space between the external envelope and the walls of the intestinal canal. A large number of colourless cells

were floating in the fluid, in all respects analogous to the colourless corpuscles of human blood. On each side of the channel through which the fluid was moving, were several layers of cells, exactly resembling those which were floating in it. The layers next the fluid seemed quite loose, some of the cells being every now and then detached and carried on with the current, whilst others were drawn out of this and became adherent; but the layers nearer the parietes of the channel were evidently more fixed, and seemed undergoing alterations, by which they gradually became *fused*, as it were, into the surrounding tissue."*

Case.—On examining the body of a patient who died of the sequelæ of scarlet fever, I found a sero-purulent fluid in the cavities of the chest; hypertrophy of the heart, with fibrinous filaments and shreds adhering to its external surface; and a thick layer of sundry forms of pus globules spread over the pleura costalis. The liver was harder and whiter than usual. The lungs were crepitant and *appeared* healthy; but on cutting into them a yellow serous fluid flowed from the incisions; every section swam buoyantly in water; still the minute tissue was evidently loaded with an abnormal deposit. My attention was arrested by the *yellow* fluid; I therefore took away two or three sections and a small portion of the liver; they were carefully kept apart. On subsequently examining, by the microscope, a little of the yellow fluid taken from the interior of *a fresh incision* into one of the pieces of lung, I was surprised to find it full of large

* Dated Bristol, December 1st, 1843.

granulated cells, of a very yellow colour, having molecules in them, and not distinguishable, by the most careful comparison, from those subsequently procured from a section of the liver; I studiously avoided every source of error. Large granulated vesicles, or cells, are always found in the minute tissue of the lungs; but this is the first, and as yet the only instance, in which I have found in these organs cells resembling the bile cells of the liver.

It may be said that objects as large as these could not pass through the capillary blood channels; but it must be borne in mind that, according to the theory of the process of nutrition, the parietes of these channels are subject to various and rapid changes, resulting from an alteration or acceleration of the nutritive function. It is likewise extremely probable that cells increase in magnitude after the death of the individual. Reasoning therefore from this fact, which perfectly accords with others mentioned in these researches, and assuming that colourless blood cells, contaminated by a temporary adhesion to the tissue of one organ, may again enter the current of the circulation and find their way to another, we have a *vera causa* for the sudden origin of grave symptoms during an illness, and for the universally popular belief, which, during the long reign of an exclusive solidism in the medical world, has steadily maintained its ground, of the danger attendant upon the sudden suppression of any naturally established excretion.

Case.—A young man, residing in a family of the utmost respectability, of a full habit, living well, and taking very little exercise, applied for relief from several pimples and irritable inflamed boils

about the chin and face. I punctured one of the most perfect and recent of the little purulent heads, and squeezed out a little pus. Having added a drop of water I examined it by the microscope, and was surprized at the large size of the cells and the unusually energetic motion of the numerous minute molecules distributed over the field. I also saw in the interior of some of the cells, molecules and granules performing motions as vivid as those I have seen in objects from other structures; nor should I have entertained the slightest doubt of their nature had they been procured from a different situation.

Case.—A man applied for relief from shingles. I punctured one of the *blue*-looking vesicles, and found in the transparent fluid discharged numerous corpuscles, resembling both the red and the colourless corpuscles of the blood; on adding to them a little water they increased very considerably in size; and afterwards, on adding a little liquor potassæ, I saw them burst open and discharge an immense quantity of molecules, which exhibited very vivid and considerable motions, after passing out of the corpuscles. These results may be compared with those related in the former series of researches.*

In bringing to a conclusion what may be called a *microscopical theory of the process of nutrition*, I shall make a few remarks upon what might otherwise appear to many persons the *rival* explanations of chemistry. There appears to me to be no obstacle to prevent chemical and microscopical observations illustrating each other; on the contrary, either must be imperfect without constant reference to the other.

* *Loc. cit.*, pp. 248, 250, 267, and 276.

The chemist may analyze the secretions which are discharged under given circumstances of disease; he may discover a remarkable diminution or increase in some particular ingredient or element; and then he may advise an alteration in the diet of the patient, recommending those articles of food or drink calculated to supply the observed deficiency or remove the redundancy. But do the results answer the expectation? If not, why? Here the microscopical observer steps in and explains the difficulty, even if he does not *a priori* strongly urge the necessity of the greatest caution in admitting the validity of a practice based exclusively on chemical results. He is able to show that the nutritive elements which disappear, including the oxygen imbibed during respiration, are taken within, or consumed by, myriads of living cells; that these cells have a governing or controlling power over the nutritive changes; and that a secretion is the result (the excretion) of their cell-life. It therefore by no means follows, as a matter of course, when *their* function is disturbed and the secretion consequently altered, that the one can be restored and the other brought back to a normal standard by offering them an abundance of the principles or ingredients which a chemical examination of the secretions may show to be deficient. The mere chemical practitioner may, indeed, bring his proposed remedies to the living structures, but it does not follow that they will or can partake of the repast he offers. *There is a prior and a higher link in the complicated chain* (extraneous to his investigation) *which must be first adjusted.*

CHAPTER III.

EXPERIMENTAL RESEARCHES ON THE FUNCTION OF STRUCTURE.

In the two preceding chapters I have endeavoured to trace and follow through their several stages the primary and (to the unassisted eye) invisible vitalized forms by which the nutrition of the body is effected, and the various secretions are produced. To the superficial observer the results may appear to furnish but very indifferent data from which to reason out the phenomena of structural vitality. This, however, is far from being the case; and it remains in the following pages to point out those analogies and facts most calculated to give an insight into the means whereby the qualities or properties of the living structure are sustained by a succession of altering cells.

The general tenor of the argument, several of the illustrations, and some of the conclusions arrived at, will be found the same with those already more ably supported by Liebig, in the third part of the

Organic Chemistry applied to Physiology and Pathology. But as all the reasoning of this celebrated chemist proceeds upon the supposition that *the globules of the blood take no share in the process of nutrition*,* it is imperative to show that the origin of animal heat and vital power, with the phenomena of health and disease, may be as clearly and simply explained upon the opposite fact, that *the globules of the blood are the sole agents of nutrition*. Liebig has, indeed, led the physiologist through a vast mine of chemical wealth, and shown him all the changes that can possibly be rung upon the ultimate particles of the matter composing the structure of animal bodies; but I should be sorry to trust any friend of mine in the hands of a medical practitioner whose treatment was to be founded on his physiology and theories of disease and respiration.

The act either of fecundation or self-division is the antecedent of vitality in all living structures; it is the *appointed* means whereby an invisible power is united to a peculiar material form. We have no knowledge of the invisible power of any living thing until the structure or the material form comes within the range of our senses; and then the properties of the visible form are *exponents* of the qualities of the invisible power.

But the visible structure of the human being has a great number of qualities in common with innumerable other forms of organized and inorganic matter; and therefore it is requisite to know something of the higher qualities of matter generally.

To the ordinary observer all inanimate objects

* *Loc. citat., supra*, p. 268.

appear inert, and incapable of themselves of originating or maintaining any motion or change. If we see a table or a chair remain fixed before us, we are not apt to regard the elements of which it is composed as possessing any property to which the terms power, force, or energy, could appropriately be applied. Nevertheless, a very little investigation into the constitution and properties of bodies will show that the ultimate particles of all things have an inherent activity or force; and the phenomena which ensue during combustion are a palpable exhibition of forces of a very active kind.

There are persons who, having added nitric acid to quicksilver, gaze on the effervescence and the gradual dissolution without considering all the wonderful characters of the operation, or asking themselves how the acid has rendered invisible a mass of metal. They may even add to the acid solution a quantity of alcohol, collect the powder which falls to the bottom of the vessel, and make themselves acquainted with its powers and properties; yet they will still speak of the materials and the compounds as nothing more than *brute matter*. There are others who will watch the crystallization of a salt, observe the forms in a flake of snow, or feel an interest in the portrait painting of the sun, and be content with admiration; but if the ultimate particles of the matter which are active in dissolving the quicksilver, and those symmetrically arranged in the crystals of a flake of snow, are, as chemistry informs us, identical with those employed in building up the visible structure of living things, we cannot so lightly dismiss these striking pheno-

mena, though they be familiar and *only chemical facts*.

"The *inherent activity of matter*," says Sir J. Herschel, "is proved not only by the production of motion, by mutual attractions and repulsions of distant or contiguous masses, but by the changes and apparent transformations which different substances undergo in their sensible qualities."*

"It is certain," says Lord Bacon, "that all bodies whatsoever, though they have no sense, yet they have *perception;* for when one body is applied to another there is a kind of election to embrace that which is agreeable, and exclude or expel that which is ingrate; and whether the body be alterant or altered, evermore a perception precedeth operation, for else all bodies would be alike one to another. And sometimes this perception in some kind of bodies is far more subtle than the sense, so that the sense is but a dull thing in comparison of it: we see a weather glass will find the least difference in heat or cold, when men find it not; and this perception also is sometimes at a distance as well as upon touch, as when the loadstone draweth iron."†

"I am prepared to admit," observes Dr. Faraday, "both with respect to the attraction of aggregation and chemical affinity, that *the sphere of action of atoms or particles extends beyond those other particles with which they are immediately and evidently in union*. Thus in water a particle of hydrogen in combination with oxygen is considered as not *altogether indifferent* to other particles of hydrogen,

* *Preliminary Discourse*, p. 297; also pp. 59, &c.

† *Sylva Sylvarum*, p. 171, edition 1651.

but to have an affinity or attraction towards them; and *in many cases this affinity produces effects rising into considerable importance.*"*

The "inherent activity" of Herschel, the "perception" of Bacon, the "non-indifference" of Faraday, the "elective affinity" of the chemists, or the "polarity" of electricians, are only different modes of giving expression to the very evident fact that the Creator has endowed all particles of matter with extraordinary invisible powers or qualities.†

Now the particles of matter are probably not at one time endowed with an "inherent activity," and at another deprived of it altogether; it is neither philosophical, nor consonant with the phenomena, to suppose that inert materials can invest themselves with any kind or degree of energy or activity whatever, or that when once possessing they can divest themselves of it; hence the condition of repose in which visible objects frequently appear, if it does not arise from the absence of an "inherent activity," must be referred to an equilibrium of opposing forces. As long as this equilibrium is maintained

* *Experimental Researches in Electricity*, pp. 150, 180, &c.

† It has always appeared to me that the sun has been too much neglected in our estimates of the "inherent activity" of the ultimate particles of matter. What this globe would be without the sun, or what would then be the characteristics of matter, we cannot tell; his rays are hourly rendering invisible that which in their absence again becomes visible; by the withdrawal of his influence only for a few hours water becomes solid; and thousands of instances, nay, perhaps, all the instances of activity in matter may, in a more or less remote degree, depend upon the sun. This supposition would remove the *antecedent* of the phenomena of motion and activity in matter a step further; but it would not affect the laws or general expressions deduced by observation, nor would it alter the conclusions drawn from the views taken in the text.

among their ultimate particles, bodies have fixed qualities or properties; as long as it is maintained by the mass, the body is at rest. But whenever this equilibrium is disturbed, either among the ultimate particles, or in the mass individually, then properties alter, and the phenomena of force or power begin.

A series of disturbances, of decompositions and recombinations among the ultimate elements of inorganic bodies, may be so disposed or arranged together as to render manifest a force or power, which has so far an independent character, that it may be conducted or led away from the materials in which it originates, and made to act upon bodies at a distance from its source, so as to put them in motion, to raise their temperature, and otherwise alter their sensible properties.*

In the fifth, sixth, seventh, and eighth series of Faraday's *Experimental Researches in Electricity* there are numerous facts expressly adduced by this highly-gifted philosopher to prove—

1st. That the physical power ostensibly originates from the body experiencing decomposition.

2nd. That the greater the number, or related series of decompositions and recombinations, the greater the apparent amount (certainly the greater the sensible effects) of the power.

3rd. That a peculiar order and arrangement of parts is necessary to aggregate the power, to make us sensible of it, and to render it useful.

In the order and arrangement here spoken of as necessary to give activity and effect to the physical power, there is, unquestionably, a species of struc-

* *Vide Daniell's Introduction to Chemical Philosophy*, p. 405.

ture—a methodical allocation—for the purpose of obtaining an aggregate result from the changes which take place; this aggregate result being on the one hand an invisible, energetic, and abstract power; and on the other, the visible saline compounds or fluids which have served their turn in the operation.

If I required a solution of sulphate of zinc, tinctured with copper, I should probably place the two metals and sulphuric acid diluted with water indiscriminately together; I might watch the effervescence, and content myself with the product, without having the slightest idea of any abstract power, passing away unperceived; but, if having gained a knowledge of the power, and wishing to obtain it without caring for the sulphate of zinc, then I must make a peculiar and regular order in the disposition of my materials: one system of decompositions must be separated from another, and yet they must be connected with each other; they must, in fact, form a regular structure of distinct and separate and yet connected parts. If I would vary the results to be obtained from the activity of the power, I must vary the number and size of the separate parts; increase or diminish the series; and, lastly, if I wish to render the action continuous, I must at short intervals add fresh materials and draw away the old.

Most persons greatly undervalue the results of every-day experience, and allow common events to pass without consideration; "thereby," as Daniell remarks, "neglecting the first rounds of that intellectual ladder by which the loftier heights of

philosophy must be scaled."* For example, let us observe a dancer on the tight rope : remark its bending under his weight ; its re-bounding when the weight is removed ; and the strength and elasticity it displays. Suppose we had never seen these properties before, and anxious to know in what and where they reside, proceeding to an examination with forceps, knife, and scissars, we begin by removing all the exterior fibres ; and finding that they have no apparent influence, reject them, expecting to discover a peculiar mechanism beneath. What would be our surprise to find the power or properties we search for, failing gradually under our operation, and all our labour to result in nothing more than fibres identical with those which we at first rejected, and none of which explain the whole elastic power and strength ; moreover, the further the research was carried the more perplexing the cause we seek ; for although we might discover a certain minute and fractional part of the cohesion and elasticity in each separate fibre, yet even this remnant would seemingly depart, when they are reduced to atoms, to hard inelastic particles, at some distance from each other. But now let us suppose the subject be examined in a different way : we may first remark that the rope is coiled ; that the coils are made up of smaller strands ; that these also are coiled or twisted, and composed of numerous threads ; and, lastly, that the threads contain the fibres ; it will then be evident that *numbers and structure,* or *association and arrangement*, are most important circumstances in sustaining and rendering evident the strength,

* *Introduction to Chemical Philosophy, ante,* p. 3.

cohesion, and elasticity of the rope.* Single fibres may be picked out and taken away from the rope, without any apparent diminution or alteration in its strength or power, and yet it is evident that every filament has its share in sustaining the power. If a weight were suspended over our head by *a cable*, we might, probably, be indifferent to the picking out of a few almost invisible threads; but would anybody allow this simple operation to be indefinitely continued? What, therefore, a single fibre does not do, and what it may *appear* to have no share in doing, is really accomplished by the numbers and arrangement of precisely similar fibres. Every particle of sand in the hour-glass is as necessary to the true indications of the instrument as every other; and yet, two, three, or four grains may be taken from the mass without any sensible or perceptible effect; nevertheless, the abstraction of a single grain must have its influence on the time marked by the falling of the remainder.

The following general conclusions are deducible from the preceding facts and observations:—

1st. The invisible ultimate particles of all kinds of matter are endowed with an "inherent activity."

2nd. Two or more ultimate particles, associated or incorporated together, form an aggregate or compounded element, which may or may not be visible; each compound element having peculiar qualities or properties, arising from the abstract nature and the "inherent activity" of the ultimate

* Into how many structures and to how many different uses might not an ingenious mind convert a ball of twine? In how many different ways might not the qualities of the elementary fibres be made to exhibit various degrees, phases, and conditions of power?

particles composing it; such, for instance, are atmospheric air, carbonic acid, olefiant gas, and arseniuretted hydrogen.

3rd. Several invisible ultimate particles, or several invisible compound elements, associated or incorporated together, constitute the visible forms of matter; each form having its own properties, which are determined not only by the nature or "inherent activity" of the ultimate particles, but likewise by the arrangement or allocation in which they are disposed with regard to each other.

4th. As long as the arrangement of the ultimate particles or elements, composing an invisible or a visible form of matter, remains unaltered, the qualities of the form are fixed and stable; but when the arrangement is changing or varying, the qualities or properties of the form alter, the evidence of force begins, and very striking phenomena frequently result.

5th. The power or force of a galvanic battery or a steam-engine, although originating from the matter undergoing decomposition, is, nevertheless, as we witness it—*an aggregate power, the function of a peculiar structure.*

Lastly. Although individual elements may be abstracted from a structure without visible or sensible effect, still the abstracted element may be equally as essential in maintaining the visibility of the structure, or in sustaining its aggregate power, as any of the other remaining elements.

Now, as the ultimate particles or elements of all living bodies are of the same kind or nature as those most energetic in inanimate and inorganic

bodies, so therefore they have the same "inherent activity;" and being in a constant and ceaseless state of change, throughout a series of detached, and in one sense independent, and yet connected and dependent cells, it follows (unless the contrary can be proved) that a certain amount of power or force must be the result. Also, as the secreting and all the nutritive organs of the body are structural arrangements, in which changes are going on, they can scarcely be supposed limited in their office merely to the production of what is termed "*a secretion;*" on the contrary, there being a large amount of "perception," or "susceptibility," and power, quite distinct from consciousness and volition, to account for, it is much more probable that their real function is a *dynamic function,* and that the secretions flowing from them are the visible remains of the materials which have ministered to the function. All living beings afford abundant proofs of a perception, or susceptibility, which is a quality of their structure, and upon which motion follows; it is, therefore, necessary to mark intelligibly the characteristics of consciousness and volition, the unity of thought and personal identity, as distinguished from the perceptions and powers of the altering living structure.

First, then, all voluntary movements are determined and controlled, excited and arrested, by the WILL; yet still there is *an intermediate agent,* for in paralysis the *will* to move the affected limb may be as strong as ever, yet no voluntary movement follows; secondly, in all fits or convulsions—in hysteria, chorea, and epilepsy—powerful and energetic move-

ments are performed without any consciousness or volition, and sometimes in opposition to the efforts of the *will;* thirdly, the consciousness of volition, or thought, is one and indivisible; it cannot be more nor can it be less; it has no aggregate quality; whereas the structural susceptibility and power, with the motions following therefrom, may be increased or diminished, and vary as the condition of the body varies.

Hence, therefore, the conclusion necessarily is, that there are in the living human body two distinct kinds of "perception," and two distinct kinds of "power:" the one is the simple perception of consciousness, and the single power of volition; and the other, which is a totally different thing, is the aggregate perception of the structure, and the aggregate power arising from the ceaseless changes of its elementary particles. The former constitutes personal identity; the latter is the immediate antecedent of all vital or involuntary movements, and the agent intermediate between volition and the living structure in voluntary motions.

It may, perhaps, be objected that it is impossible to conceive two distinct and totally different agents—such as the aggregate perception and power of the living structure, and the simple, not aggregate, perception and power of consciousness and volition, in one nature; but it is not more difficult than to conceive that *one* and *one* make *one*—a proposition which the chemist daily calls on us to assent to, and which is involved in all the facts and principles of the science; nor more incomprehensible than the familiar fact, that the properties of one body are

veiled in the properties of another body by combination, while the properties of the resulting compound differ *in toto* from either of its components.

There is considerable difficulty in adopting an unobjectionable phraseology upon the subject of vital phenomena. Although we have the authority of Bacon for the use of the term "perception," to express a quality of matter entirely distinct from personal consciousness—an antecedent upon which motion follows; yet as this term has been so generally limited to a far higher and totally different quality of consciousness, it is desirable to fix upon some other general expression, which shall, without fear of error, enunciate that important quality, power, or inherent activity, which is accumulated in all living structures by the nutritive changes, and in animal bodies expended by the *will*. We have, it is true, the terms irritability, organic power, vital force, and sensibility, as when we speak of the sensibility of plants and leaves to light and heat, or of seeds to warmth and moisture, and yet deny them sense; but neither of these terms fully express a power consequent on the changes in a living structure, existing in possibility as well as in act, in efficacy if not in actuality; an energy which may be in a state of induction as it were, or in operation, and which has the same relation to the altering materials of the living structure, that the physical power has to the altering materials in the generating cells of the battery; an energy which is expended in a ratio with the primary elements, or cells of the structure, by fasting, mental emotions, voluntary exercises, or intellectual employments; which is

impaired and modified in a thousand different ways, by an abnormal nutrition, by impure air, or an impoverished diet; and which is restored by pure air, invigorating food, rest and sleep.

Whatever may be the term we use to designate this energy, potentiality, or power, it is of the utmost practical importance to bear in mind its invariable ratio to the function of nutrition, on the one hand; and, in all normal conditions, its subservience to the intellectual power, or *will*, on the other.

It would be departing entirely from the object of these researches to enter upon the question, how much of a complex visible motion in the body—such, for example, as is witnessed in fits and convulsions, or in confirmed and inveterate habits—is due to the aggregate potentiality of living structure, and how much falls within the limits of the *will;* but there is a large class of disorders embraced under the term *hysteria,* in which we seem to see two opposing or conflicting powers, certain structural phenomena, which a firm and determinate resolution in volition will sometimes subdue and overcome. Here, then, our inquiry presents us with a broad practical rule, which we may venture to lay down, viz.:—

That all the visible motions and affections of the body, which are distinct from, or continued in spite of the *will,* may generally be modified or removed by altering, increasing, or diminishing the nutritive changes of the structure; and it may be affirmed generally, that the *will* having a large control over

the materials received within the body, and therefore indirectly over the nutritive changes, is responsible for the origin of many bodily diseases. There are, indeed, many interfering circumstances in the habits and occupations of life, and especially with regard to the air we breathe, whereby injurious agents gain insensibly and involuntarily an entrance within the body, and set up injurious changes; nevertheless, the affirmation or rule is true generally.

The general physiological and pathological deductions from these researches are:—

That the animal heat, the structural perceptions, and vital forces, with the motions arising therefrom, in the living body, although primarily originating from the act of fecundation, are, nevertheless, as we witness them, *aggregate consequents*, of which the unceasing nutritive changes of matter within myriads of temporary altering cells are the *antecedents*.

Every cell, and every surface upon which cells are distributed, has a share in maintaining these consequents, analogous to that which every atom of water, acid, and metal, must have in sustaining the power of a galvanic battery, or to that which every fibre has in maintaining the power and elasticity of the rope.

Health, therefore, is a very complex aggregate, vibrating as it were between innumerable points, and is dependent upon a certain amount and order of change of matter in a given time; and the almost endless forms of disorder or disease are severally departures from this amount and order of change.

If the departure or deviation, whether in excess, deficiency, or alteration, occur generally throughout the whole or the major part of the organs of the primary nutritive changes, or the blood-cells, the disorder will be of a general nature, and peculiar phenomena will mark their circulation through and their exit from the system. If, on the other hand, the departure or deviation be of a less general nature, consist of a local increase or diminution of the nutritive changes, or of cell-life, in particular organs, the phenomena will vary accordingly; and, lastly, if the nutritive changes be altogether heterogeneous to the normal tissue, then the form of the disorder will be peculiar on that account.

Finally, all the experiments and observations that I have made have tended to confirm the conclusion that it is the special office of the circulation to convey the colourless blood cells to the part, and to negative the supposition that they are produced in any way from the liquor sanguinis, or multiply by the growth of the molecules of the tissue. *Congestion,* therefore, according to my interpretation, implies a fulness of, and an increase in the calibre of the capillary, and other minute vessels, with a preternatural redness in the part, but without any increase, or acceleration in the process of nutrition, on the contrary, that may be diminished. *An accelerated nutrition* is something more than a congestion; it is a condition in which the colourless blood cells are, in a peculiar manner, accumulating and experiencing active changes in the part; entering into the composition of the tissue with unusual rapidity; the rate of

acceleration being at least one of the elements determining the physical character and the microscopical appearances of the tissue, or of the cells and their products. Increase in the bulk of the tissue, or *swelling*, will therefore be one of the chief characteristics of an accelerated or abnormal nutrition.

The term *inflammation* I would confine to a still more exalted and abnormal process of nutrition, in which the red corpuscles of the blood are not only detained in the part, but are also, with the colourless cells, entering into the composition of the tissue, adhering or sticking to the fibrous or friable walls of the capillaries, minute venous, and arterial ramifications.

This interpretation of the essential characteristics of inflammation is warranted by the results of my researches; the attendant *pain* and *heat* are the expected phenomena, arising in consequence of the red cells performing *in the tissue*, those changes and transformations which ought to have been previously perfected and concluded *in the circulation*.

According to these definitions, more than one-half of the conditions to which the term inflammation is now applied would come within the category of an accelerated nutrition. *A determination of blood* is a very general and very indefinite phrase, embracing all the three conditions just enumerated, and many others.

It occurred to me some time ago to subject the *Paramœcium Aurelia* to an experiment similar to

those described in pages 8, 9, &c., *ante*. Since the printing of the foregoing sheets I have succeeded in obtaining an abundance of these animalcules in an infusion of chopped hay in pond water, kept in a somewhat dark place; I found them, with other polygastrics, forming a white line round the glass, about a quarter of an inch below the surface of the fluid, and I obtained myriads in a single drop of the water.

EXPERIMENT. (*Paramœcium.*)—On adding to a drop of water containing a great number of these animalcules, a drop of liquor potassæ, and stirring them well together, I found all the animalcules burst open, and then nothing could be seen in the fluid by the microscope except molecules and granules.* The fluid was now extremely cohesive or glairy and tenacious; it could be drawn out with the point of a needle into long strings or filaments, and it resembled mucus; on adding a little dilute acetic acid, copious white flakes appeared, which exhibited a fibrous appearance, studded with molecules and granules, analogous to that of mucus, and to that already described as resulting from the application of the same reagent, to the transparent mucus-like fluid obtained by the rupture of the blood and pus corpuscles.†

"Among the many wonderful and beautiful objects displayed by the microscope, there are none exceeding in interest the ova and the bundles of seminal

* *Vide* First Series of "Researches," *loc. cit.*, p. 235; also pages 273, &c.

† I shall endeavour to procure the aquatic *larva* mentioned to me by Dr. Carpenter, and instituting a similar experiment upon the colourless cells of that creature, I fully anticipate similar results.

animalcules of the common earth worm (*Lumbricus terrestris*); and from their size they are admirably adapted to display the singular effects of liquor potassæ. Mingled with these objects are numerous cells, containing in their interior molecules and granules, in the greatest state of activity; they are continually shifting their position within the cell, presenting exactly the same appearance as those molecules and granules which I observed in the colourless corpuscles or cells from the case of catarrh before related. On the application of liquor potassæ all these molecules and granules were quickly ejected, and their restlessness and motions, after they were discharged from the cell, were very singular; but not more remarkable than the motions of the molecules discharged from the lymph globules of the frog, or from the colourless blood corpuscles and pus corpuscles of man."*

EXPERIMENT. (*Cells of Lumbricus terrestris.*)—A drop of water mingled with the above mentioned objects is rendered white and milky; but when well mixed with liquor potassæ, it becomes transparent, glairy, and mucus-like; and when dilute acetic acid is afterwards added, there is the same fibrous appearance as is presented in ordinary mucus from this reagent.

Similar experiments have been made with the colourless blood cells of the earth worm, and with the red-blood cells of the frog, with similar results.

Now, all these colourless and coloured cells are administering to the functions of animal life, in

* "Experimental Researches," *loc. cit.*, pp. 275, &c.

some cases constituting the entire individual, as in the polygastrics; in others, sharing in the structure, and therefore they are analogous to one another, at least in this respect. The experiments just related, with others contained in the former series of "Researches," show a remarkable identity in the chemical reactions of liquor potassæ on their interior contents, as well as on their exterior integument; moreover, all the colourless cells contain myriads of molecules and granules, which may on various occasions be seen moving within the cell, and which, when discharged or forced out of the *living* cell by liquor potassæ, exhibit peculiarly vivid motions, from whatever department of the animal kingdom they may be observed.

The red colour of blood-cells in the higher orders of the animal kingdom is, in my opinion, only a phenomenon or appearance, characterizing a particular stage of their life or existence, and analogous to the colour of a petal; which is also a phenomenon marking a particular stage in the series of developments occurring between the bud and the ripe capsule or seed-vessel in some plants. The really essential structure, in both instances, is situated in the axis or centre of the coloured envelope, and, in both, it is gradually increasing in size and importance as the colour fades.

These facts appear to me to indicate a very remarkable analogy, not only in the form but in the nature of the elements of the structure of all animal beings, and to show that however different may be the Power which determines the species—the duration of the organism—the bulk and cha-

racteristics of the structure—and the mode or rate of nutrition—yet the visible manifestations of the power in the lowest and in the highest forms are maintained or supported by analogous and similar means.

To these additional remarks, I cannot forbear subjoining the following extract from Lord Bacon's *Sylva Sylvarum*, a work too well known to require from me aught of praise or commendation; but which has yet to be thoroughly appreciated by the practical physiologist :—

"The nature of *vivification*," says the noble author, "is very worthy the inquiry; and as the nature of things is commonly better perceived in small than in great, and in imperfect than in perfect, and in parts than in whole, so the nature of vivification is best inquired in creatures bred of putrefaction. The contemplation whereof hath many excellent fruits: first, in disclosing the original of *vivification;* secondly, in disclosing the original of *figuration;* thirdly, in disclosing many things in *the nature of perfect creatures* which in them lie more hidden; and fourthly, in tracing, by way of operation, some observations in the *insecta to work effects upon perfect creatures.* Note, that the word *insecta* agreeth not with the matter, but we use it for brevities, sake, intending by it creatures bred of putrefaction."*

To conclude. In every inquiry into the phenomena of life, by far the most positive fact that can be known is brought prominently under our consi-

* *Sylva Sylvarum*, cent. vii., p. 143; edition 1651.

deration : a fact which is the source whence all knowledge flows, and which must precede and accompany all our researches.

This fact, or truth, is the existence of an internal feeling of our own personal identity and unity. Neither the divisibility and qualities of matter, nor any appearances reaching us from without, can in the slightest degree weaken this conviction ; on the contrary, they rather tend to strengthen and confirm it.

In studying the phenomena of external nature, every thing exhibits a multiplicity of operations and changes, an endless divisibility of parts, and the influence of motion, numbers, and arrangement, in the production of sensible effects. But when we turn inward upon ourselves, and contemplate the feelings and consciousness of self, although we meet with great complexity and variety, yet here there is a principle of unity, an individuality in which all feeling centres. This perfect conviction of unity and identity, springing up, as it were, or maintained and supported by such a multiplicity of parts and operations, is incomprehensible to our reason, the great mystery of man's nature, and beyond the range of his inductive inquiries. After many reiterated but fruitless attempts, from Aristotle down to the present time, to reconcile the qualities and appearances of things without, with the oneness of consciousness and thought within, and to remove the veil thrown over the inscrutable union of the living body, with the intellectual power which governs and controls its movements, the effort has been found hopeless, and has been abandoned.

The primary atoms or particles of matter have their origin a long way within the precincts of the unseen world, and possibly they may experience a thousand combinations before they approach the limited circle of the human vision; how little, therefore, can we really know of matter, of the really essential elements of living structure! A person, counting as fast as possible, can enumerate twenty in five seconds; and keeping on at this rate night and day, without intermission, for *four hundred years*, he might accomplish the enumeration of the living structures in half an ounce of blood, a quantity which any one may part with without harm or detriment; yet every particle—every such living structure—is as essential to the aggregate phenomena of life as any antecedent can be to its consequent.

It is not my intention to enter into any metaphysical disquisition, yet I cannot omit here observing, that volition may properly be considered under two distinct points of view; thus a man may will to speak, or be silent, to take off or put on his hat; and he has at his command the structural power and bodily configuration to realize his wish; if he has not, he is paralytic, or his body is diseased. But if he wills to visit the moon, to fly through the air, or stay his descent when falling from a height, his will must remain a wish or a desire, for he has neither structural power nor bodily conformation to accomplish such a wish. In the former case, his inabilty is a deprivation and a loss, which may possibly be remedied; in the latter, it can hardly be

viewed in the same light, at all events it is irremediable. Corporeal or structural power, therefore, limits the *operations* of volition; but the boundary of knowledge is the only confine to our *desires*.

The Christian philosopher pursues his investigations with a settled belief that an ALMIGHTY CREATOR exists; and having in view only the discovery of those general laws, which may be deduced by the contemplation of a particular class of facts, or series of phenomena or appearances, he does not speculate on the *abstract nature* of matter or force; neither does he try to know what becomes of this or that invisible power, when, as in the example of the voltaic pile, he is able at his will to concentrate and direct, or to dissipate and annul it; nor when he heats and cools a bar of iron is he disappointed because he is ignorant of the nature of heat, and cannot tell how it comes or goes. On the contrary, he knows that in all, even in the simplest or most common cases, there must be residual phenomena or ultimate facts, quite beyond his comprehension; he, therefore, does not doubt the *possibility* of forms of power existing in a very different state, and under very different arrangements to any he witnesses here. "The possibility," to use the words of a distinguished writer, "of the occasional direct operation of the Power which formed the world, in varying the usual course of events, it would be in the highest degree unphilosophical to deny."* But belief beyond reason is based upon grounds entirely distinct from

* *Inquiry into the Relation of Cause and Effect*, by R. Brown, M.D., F.R.S.

those arising within the scope of any *experimental* research; the object of which is, in all cases, to remove the *antecedent* or the primary phenomenon as far back as possible, and to discover the combinations, appearances, and results, as they are, without questioning those which a Supreme Intelligence has willed they shall be.

Bearing in mind, then, the true aim and scope of all inductive researches, it is evident to whatever extent they may be carried, on the subject of life, or whatever may be the forms of expression which the inadequacy of language may constrain us to adopt in explaining the phenomena, we can arrive at no other conclusions than those convincing us of *our utter ignorance,* except from Revelation, *of the real origin or final destination of any form of power.*

ADDITIONAL NOTES.

NOTE TO PAGE 8.—It is not intended to deny that the fluid in which the blood cells float in their passage through the living vessels, is not, or may not be an albuminous fluid; all that is meant by the affirmation is, that it is *not serum*, though clearly it must be mingled with and form part of the bulk of this fluid.

NOTE TO PAGE 12.—The changes here described as resulting from the application of the acid, appear to be connected with the *entire* cessation of vitality in the corpuscles; for they undergo very little alteration for a long time after, and they are best preserved as microscopal preparations in this state. Every observer, who has attempted to preserve the colourless blood corpuscles in any fluid, must have experienced the difficulty there is in doing so, from the slow changes they experience. It is my opinion, now confirmed by some experience in microscopical researches, that the molecules which have formed the elements of living structure do not at once fall back to the condition of inorganic matter when the structure dies, but gradually recede through a series of descending stages, in any one of which a favourable combination of external circumstances may develope peculiar forms, both crystalline and foliaceous, chemical or vital. It is from this department of nature, where the last remnants of vital activity are struggling with the now potent and more permanent affinities of inorganic matter, that the chemist obtains many of those singular isomeric and polymeric compounds, which seem, by their number, likely to confuse rather than enlighten the practical physiologist, unless aware of the principle upon which such never-ending combinations arise.

NOTE TO PAGE 15.—The difference between the colourless blood corpuscle and the mucous globule, and between the liquor sanguinis contained within the one and the mucus contained within the other, appears to me to be this: in the former there is no vital union or combination between the fibrillating fibrine and the non-fibrillating albumen or the serum; hence the liquor sanguinis (by which I mean that element of the blood which forms the buffy coat, and from which the fibrinous clot and serum is obtained,) separates into a mass of fibres and a residual fluid; whereas in the latter a vital union or combination has taken place, forming the fluid-tissue termed mucus, and therefore it does not separate into its constituent elements, fibrine and serum.

NOTE TO PAGE 28.—On examining the circulation of the blood in the tongue of a frog, the first thing that strikes the observer is the absence of any thing like the capillary network seen in the web of the foot. The capillary divisions of the arteries take much longer courses, are variously convoluted and looped, and it is generally impossible to determine where the artery may be said to end and the vein begin. The mucous follicles are readily seen in the form of small circular depressions, lined throughout with epithelial cells; and in the centre of each follicle lie several intricate convolutions of an arterial capillary. The blood enters the follicle by an arterial capillary, which, after making five or six convolutions at the bottom, passes out to make other turns and convolutions in its progress to a venous trunk. Sometimes there are two capillary twigs making a more intricate series of turns together. The mere exposure of the tongue during the examination is generally sufficient to cause a visible accumulation of the round colourless corpuscles in these follicular capillaries, and the object of the loops and convolutions appears to be to facilitate the adhesion of these corpuscles to the tissue. If the colourless corpuscles do not readily accumulate they may speedily be caused to do so by immersing the tongue in water at 80° or 90° F. for a few seconds. My observations have been chiefly made upon the under side of the tongue; and besides the mucous follicles, the whole of this surface may be seen studded with epithelial cells, which have in many places a foliated expansion, and

are much more prominently raised in some parts than in others. The most careful observations have not enabled me detect any difference between the young or incipient mucous cells outside the vessels, and the round colourless blood corpuscles accumulated within them. If the tongue be very gently scraped, and the matter placed on a slip of glass, great numbers of these mucous cells may be seen by the microscope adhering together; and although some are much larger than others, still many of them are not to be in any way discriminated from the colourless blood corpuscles.

Note to Page 51.—"The equivalent weights of bodies are simply those quantities of them which contain equal quantities of electricity; it being electricity which determines the equivalent number, because it determines the combining force. Or if we adopt the atomic theory or phraseology, then the atoms of bodies which are equivalents to each other in their ordinary chemical action have equal quantities of electricity naturally associated with them. But I must confess I am jealous of the term *atom;* for though it is very easy to talk of atoms, it is very difficult to form a clear idea of their nature, especially when compound bodies are under consideration."—*Experimental Researches in Electricity*, p. 256. ....."From all these concurrent arguments, we seem to be justified in concluding that a limit is to be assigned to the divisibility of matter, and consequently that we must suppose the existence of certain ultimate particles, stamped, as Newton conjectured, in the beginning of time by the hands of the Almighty with permanent characters, and retaining the exact size and figure, no less than the other more subtle qualities and relations, which were given to them at the first moment of their creation. The particles of the several substances existing in nature may thus deserve to be regarded as the alphabet composing the great volume which records the wisdom and goodness of the Creator; since the characters which go to make it up, far from appearing to be thrown together by chance, and collected into unmeaning groups, as the Epicureans contended to have been the case, denote in every page, by the import they convey, the agency of mind, and speak a language, which, so far as it is intelligible to our finite faculties, is every way worthy of its divine

Author. There cannot be a sublimer subject for contemplation, or one more calculated to elevate our ideas with respect to the Divine attributes, than the correspondence which may thus be traced between the laws that pervade the whole of creation, from the ultimate particles of matter, which, by their extreme minuteness, baffle our very powers of conception, to those immense aggregates of them which compose any one of the members of our own planetary system; and as, according to the grand conception of Boscovich, the attraction of gravitation, and that of cohesion, may perhaps turn out to be the same force exerted at different distances, so the various ways in which, as we have seen, the tendency to definite proportions (if I may so express myself) manifests itself throughout the whole of nature, will perhaps be eventually traced to the same law; of which, what is called the atomic theory, comprehensive as it is, may be only one of the consequences."—*Daubeny on the Atomic Theory*, pp. 101, 107.

Note to Page 54.—With regard to the aggregate potentiality of the living structure, I may probably have failed to express myself as clearly as I wish to do. A voluntary muscle in its normal condition has *a capacity to act;* and the movement of a limb or the visible shortening of the muscle is the evidence of this capacity. But every visible muscular movement is a consequent, having many antecedents, because myriads of muscular fibrillæ must act concurrently for the motion to be apparent; hence the capacity to act, *i. e.*, the power to act sensibly or visibly, is an aggregate capacity or potentiality.

"It is seldom, if ever, between a consequent and one single antecedent that this invariable sequence subsists. It is usually between a consequent and the sum of several antecedents; the concurrence of them all being requisite to produce, that is, to be certain of being followed by, the consequent. In such cases it is very common to single out one only of the antecedents, under the denomination of Cause, calling the others merely Conditions. Thus, if a man eats of a particular dish, and dies in consequence, that is, would not have died if he had not eaten of it, people would be apt to say that eating of that dish was the cause of his death. There needs not, however, be any invariable connexion

between eating of the dish and death; but there certainly is, among the circumstances which took place, some combination or other upon which death is invariably consequent: as, for instance, the act of eating of the dish, combined with a particular bodily constitution, a particular state of present health, and perhaps even a certain state of the atmosphere; the whole of which circumstances perhaps constituted in this particular case the *conditions* of the phenomenon, or in other words the set of antecedents which determined it, and but for which it would not have happened. The real cause is the whole of these antecedents; and we have, philosophically speaking, no right to give the name of cause to one of them, exclusively of the others. What, in the case we have supposed, disguises the incorrectness of the expression, is this: that the various conditions, except the single one of eating the food, were not *events* (that is, instantaneous changes, or successions of instantaneous changes) but *states*, possessing more or less of permanency, and might therefore have preceded the effect by an indefinite length of duration for want of the event which was requisite to complete the required concurrence of conditions; while, as soon as that event, eating the food, occurs, no other cause is waited for, but the effect begins immediately to take place: and hence the appearance is presented of a more immediate and closer connexion between the effect and that one antecedent than between the effect and the remaining conditions." ..... Speaking of the *immediate cause* of death produced by metallic poisons, the same talented writer goes on to say—"When solutions of these substances are placed in sufficiently close contact with many animal products, albumen, milk, muscular fibre, and animal membranes, the acid or salt leaves the water in which it was dissolved, and enters into combination with the animal substance; which substance, after being thus acted upon, is found to have lost its tendency to spontaneous decomposition, or putrefaction. Observation also shows, in cases where death has been produced by these poisons, that the parts of the body with which the poisonous substances have been brought into contact, do not afterwards putrefy. And finally, when the poison has been supplied in too small a quantity to destroy life, eschars are produced, that is, certain superficial portions of the tissues are destroyed, which are

afterwards thown off by the reparative process taking place in the healthy parts. These three sets of instances admit of being treated according to the method of agreement. In all of them the metallic compounds are brought into contact with the substances which compose the human or animal body; and the instances do not seem to agree in any other circumstance. The remaining antecedents are as different, and even opposite, as they could possibly be made; for in some the animal substances exposed to the action of the poisons are in a state of life, in others only in a state of organization, in others not even in that. And what is the result which follows in all the cases? The conversion of the animal substance (by combination with the poison) into a chemical compound, held together by so powerful a force as to resist the subsequent action of the ordinary causes of decomposition. Now, organic life (the necessary condition of sensitive life) consisting in a continual state of decomposition and recomposition of the different organs and tissues, whatever incapacites them for this decomposition destroys life. And thus the proximate cause of the death produced by this description of poisons is ascertained, as far as the method of agreement can ascertain it. Let us now bring our conclusion to the test of the method of difference. Setting out from the cases already mentioned, in which the antecedent is the presence of substances forming with the tissues a compound incapable of putrefaction, (*à fortiori* incapable of the chemical actions which constitute life,) and the consequence is death, either of the whole organism or of some portion of it; let us compare with these cases other cases, as much resembling them as possible, but in which that effect is not produced. And, first of all, 'many insoluble basic salts of arsenious acid are known not to be poisonous. The substance called alkargen, discovered by Bunsen, which contains a very large quantity of arsenic, and approaches very closely in composition to the organic arsenious compounds found in the body, has not the slightest injurious action upon the organism.' Now when these substances are brought into contact with the tissues in any way, they do not combine with them; they do not arrest their progress to decomposition. As far, therefore, as these instances go, it appears that when the effect is absent, it is by reason of the absence of that antecedent which we had

already good ground for considering as the proximate cause. But the rigorous conditions of the method of difference are not yet satisfied; for we cannot be sure that these unpoisonous bodies agree with the poisonous substances in every property, except the particular one of entering into a difficultly decomposable compound with the animal tissues. To render the method strictly applicable, we need an instance not of a different substance, but of one of precisely the same substances, under circumstances which would prevent it from forming, with the tissues, the sort of compound in question; and then, if death does not follow, our case is made out. Now such instances are afforded by the antidotes to these poisons. For example, in case of poisoning by arsenious acid, if hydrated peroxide of iron is administered, the destructive agency is instantly checked. Now this peroxide is known to combine with the acid, and form a compound, which, being insoluble, cannot act at all on animal tissues. So, again, sugar is a well-known antidote to poisoning by salts of copper; and sugar reduces those salts either into metallic copper or into the red suboxide, neither of which enters into combination with animal matter. The disease called painter's colic, so common in manufactories of white lead, is unknown where the workmen are accustomed to take, as a preservative, sulphuric-acid-lemonade (a solution of sugar rendered acid by sulphuric acid.) Now diluted sulphuric acid has the property of decomposing all compounds of lead with organic matter and (of course) of preventing them from being formed."—*A System of Logic, Ratiocinative and Inductive.* By John S. Mill, Esq.

Note to Page 55.—"There is no point which seems to me of more importance than the state *of the metals and the electrolytic conductor, in a simple voltaic circuit, before and at* the moment when metallic contact is first completed. If clearly understood, I feel no doubt, it would supply us with a direct key to the laws under which the great variety of voltaic excitements, direct and incidental, occur, and open out new fields of research for our investigation. We seem to have the power of deciding, to a certain extent, in numerous cases of chemical affinity, which of two modes of action of the attractive power shall be exerted. In the one mode we can transfer the power onwards and make

it produce its action elsewhere; in the other, it is not transferred, but exerted wholly at the spot. The first is a case of volta-electric excitation; the other, ordinary chemical affinity; but both are chemical actions, and due to one force or principle. ..... Assuming it sufficiently proved that the electromotive action depends, when zinc, platina, and dilute sulphuric acid, are used, upon the mutual affinity of the metal zinc and the oxygen of the water, it would appear that the metal, when alone, has not power enough, under the circumstances, to take the oxygen and expel the hydrogen from the water; for, in fact, no such action takes place. But it would also appear that it has power so far to act, by its attraction for the oxygen of the particles in contact with it, as to place the similar forces already active between these and the other particles of oxygen and the particles of hydrogen in the water in *a peculiar state of tension* or polarity; and probably also at the same time to throw those of its own particles which are in contact with the water into a similar but opposed state. ..... I have sought carefully for indications of a state of tension in the electrolytic conductor; and conceiving that it might produce something like structure, either before or during its discharge, I endeavoured to make this evident by polarized light."—*Experimental Researches in Electricity.* pp. 283, 284, and 285.

THE END.

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THE ACTUAL

PROCESS OF NUTRITION

AND

INFLAMMATION

IN THE

LIVING STRUCTURE

Demonstrated by the Microscope.

PART II.

(THIRD SERIES OF EXPERIMENTAL RESEARCHES.)

BY WILLIAM ADDISON, F.L.S.,

MEMBER OF THE ROYAL COLLEGE OF SURGEONS IN LONDON, AND SURGEON TO H.R.H THE DUCHESS OF KENT, MALVERN.

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1845.

"He that knowes not the wayes of NATURE, how can he succour her, or turne her about."—LORD BACON.

"No man ever penetrated far into any study, but he was carried up at last into principles which are the source of all others; and no man ever studied wisely who stopped short of these depths. If you are afraid of depth; if you think that general principles are useless, because, to be stated generally, they must assume an abstract and mysterious character; if you will deal only with what shallow-minded men call *practical* questions—as if anything could be practical which is not founded on truth, or anything could be true, which, if expressed in all its fulness, would not seem a problem and a mystery—you are not a fit person to study any science." . . . . "Men are sick of the shallow, superficial, meagre speculations which these *practical* notions have engendered."—SEWELL.

INTRODUCTORY REMARKS.

SINCE the publication of the former part of this volume, the accumulation of the colourless-cells of blood in irritated and inflamed textures, and the existence of active molecules in the interior of the cells of blood, saliva, and pus, have become established physiological facts.

As questions will doubtless arise upon the nature of the motions performed by these active molecules, it is gratifying to have the support of Dr. Houston, of Dublin, for my opinion that they are vital and spontaneous. "I have repeatedly seen them," he says, "and have shown them to others, when burst from their cell-membrane, performing sundry independent and apparently voluntary evolutions in the field of the microscope, until to the eye the whole looked like a moving mass of creeping things."

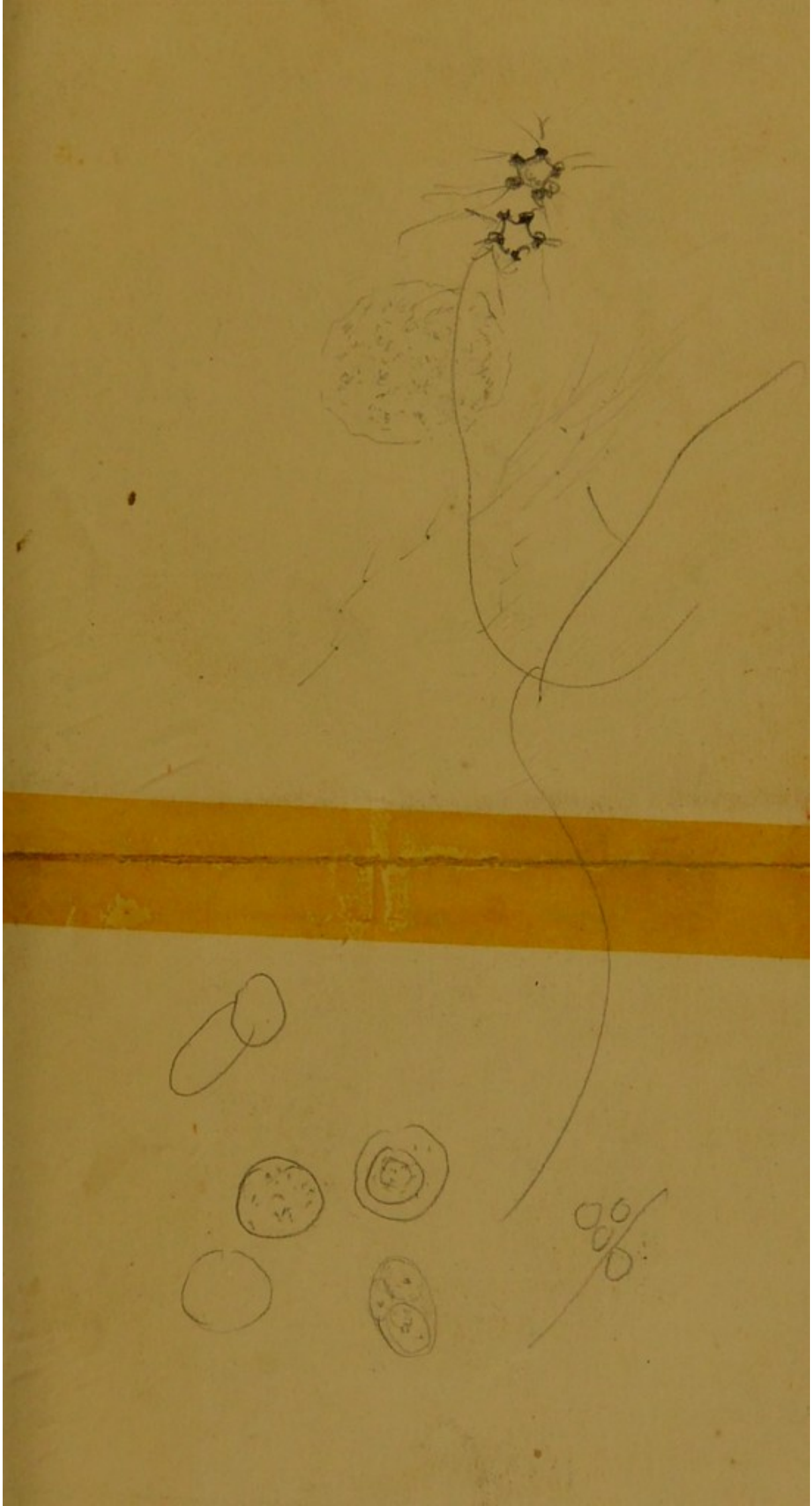
The point to which the arguments and experiments in the following pages are constantly recurring is that relating to the origin and nature of pus-cells, and necessarily so; for, according to my observation, these objects, so far from being produced by diseased action, are really the nutritive particles of the blood,

containing within them those stores of living matter from which the solid textures and the secretions are, or ought to be, reproduced. The differences between pus, fibrous tissue, mucus, saliva, and other secretions, depending on the cells; in the former case, falling short of their destined purpose, and preserving their integrity and individuality; and in the latter, completing that purpose, rupturing and discharging their contents.

The question relating to pus-cells is a very important one, for the settlement of it carries with it the settlement of those other questions relating to the process of inflammation, to a cell-genesis in the secreting and in inflamed textures.

Considerable discussion has for some time been going on, as to whether the red or the colourless-cells of blood make or elaborate fibrine. But all cells (or the active particles in their interior) make or create their own structures; and if the external covering of the red-cells of blood be, as it most probably is, of a fibrinous nature, then we must allow that red-cells make or elaborate fibrine. The question, therefore, is one only of degree; but as the interior contents of the colourless-cells fibrillate to a much greater extent than do the interior contents of the red ones, so therefore the former must contain more of the fibrinous constituent than the latter.

GREAT MALVERN,
JAN. 25, 1845.



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EXPLANATION OF THE PLATES.

PLATE I.

(900 diameters linear.)

Fig. 1.—The appearance of a drop of blood drawn from a swollen, inflamed, and painful leg:—The colourless-cells are very numerous, with conspicuous molecules in their interior; many have ruptured and discharged their contents, consisting of molecules and a plastic-element. The fibres or filaments of fibrine are very conspicuous. The red-cells are very adhesive, and many of them are singularly drawn out or elongated.

Fig. 2.—Colourless-cells of lymph, (with active molecules in their interior,) isolated molecules, and fibres of fibrine; from the transparent vesicles or watery blebs of *Herpes labialis*.

Fig. 3.—Colourless-cells of pus from a pustule of *Porrigo scutulata*, a few minutes after having been mingled with a drop of warm water:—Some of the cells have ruptured, and a plastic or mucous-element and isolated molecules are mingled with the fluid in which they float. Other cells gradually change their aspect and at length rupture; others again have active molecules in their interior.

Fig. 4.—Colourless-cells of saliva:—Some have ruptured and discharged their contents (a plastic or mucous-element and molecules); others have altered their appearance, and in others very active molecules are rapidly moving in their interior.

Fig. 5.—Colourless-cells from the nasal mucous membrane in catarrh:—Many of them are fringed with active vibratile cilia, and have active molecules in their interior.

PLATE II.

(300 diameters linear.)

The appearance of vessels in the web of a frog's foot, thirty-six hours after the application of warm water, &c.:—The red-cells have various rates of movement; and the round colourless-cells adhere in great numbers to the walls of the vessels.

For further details, *vide* p. 81.


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CHAPTER I.

ON THE MOVING MOLECULES IN THE INTERIOR OF CELLS.

EXPERIMENT I.

SWELLED LEG. *(Blood-cells.)*

A young woman in service, whose occupation kept her much upon her legs, complained of their being swelled and extremely painful; the swelling extended from the foot to the knee. There were numerous dark red spots upon the skin, and in many places the outer portions of the cuticle were cracked; the cracks gaped open, and were red, but they did not discharge any fluid. The cuticle was desquamating over the whole of the diseased surface; and on attentively examining it, several layers, one below another, could be readily distinguished; the legs felt hot, and were very tender, but the surface generally was pale. I punctured the skin where there was no redness, and received a drop of blood, not larger than a small pin's head, upon a slip of glass, it was covered with a smaller thin piece of glass and submitted to examination by the microscope, linear power 700 diameters. (*Vide*

plate 1, fig. 1.) Its appearance was extremely characteristic; the red-cells evinced a powerful adhesive quality, and many of them were singularly elongated. The colourless-cells were very numerous, and the molecules in their interior very conspicuous. The isolated molecules were moving, and many little aggregated masses of them indicated the place where the colourless-cells had disintegrated and fallen to pieces. In six minutes the vacant spaces between the cohering red-cells were overspread with a fibrinous network. The examination was made without the application of any re-agent.

EXPERIMENT II.

Erythema Nodosum. *(Blood-cells.)*

A young woman, aged 19. Patches as large as the palm of the hand on the front of each leg; of a dark, dusky, bluish red; mottled, and very tender; somewhat hard, and slightly swollen. Complains of headache, thirst, fever, and loss of appetite, with pains in the back and legs. I punctured with a lancet one of the red patches, and examined the blood with a linear power of 700. I found in it nearly as many colourless-cells as red ones. The colourless-cells were uniformly molecular, smaller than the mucous-cells in saliva; but, like them, filled with a number of minute dark objects or molecules. I added a drop of water at the temperature of 90, having one drop of liquor potassæ to the ounce. The colourless-cells gradually increased in size; and in the course of from three to five minutes, by

very careful attention, I could see, in the majority of them, very active motions among the contained molecules. I also saw some of them open and discharge myriads of minute active molecules, without any immediate alteration in their figure or appearance. The motions of the molecules remaining in the interior of the cells, however, gradually ceased after this event, and the cells slowly changed, showing large coarse granules, or discs.

At the end of four days I saw the case again; the blueness or redness of the patches on the legs had very much diminished, though still evident, and the tenderness was less. I punctured the skin in the same way, and examined the blood drawn, as before. There were now not a tenth of the number of colourless-cells.

Four days after, the redness was very nearly all gone; there was now considerable itching in the part, and the skin for a long way around looked as if powdered lightly with a white powder, and large broad white lines showed where the girl had, by scratching, raised the desquamating epidermis in her attempts to allay the itching.

EXPERIMENT III.

Erythema Nodosum. *(Blood-cells.)*

A young man, aged 26, had been ill with symptoms of pleuritis and general functional disturbance for three weeks; at the end of this period both legs, from the ankles to the knees, became nearly covered with various-sized patches of erythema, one or two

very large ones being situated on the calves of the legs. I punctured one of the darkest of the spots, and the appearance of the blood under the microscope, (700 linear,) was exactly that represented in the wood-cut, in Vol. 12, p. 268, of the *Transactions*, only that there was a greater proportion of colourless blood-cells, and more isolated molecules. After about five or six minutes the whole of the interspaces between the rows of cohering red-cells were covered by a delicate fibrinous web.

I have usually observed three facts in blood drawn from inflamed parts:—1st, an increased amount of colourless-cells; 2nd, an increased amount of isolated molecules; 3rd, a very evident web or network of fibrinous filaments in the interspaces between the cohering red-cells. It is very necessary to distinguish a *fibrillated* network from a *cellular one*. The former is seen in the buffy coat of the blood, and is composed of fibres or filaments variously interlaced, and having no regular interspaces; the latter is very different, being composed of more or less globular cells, having their walls compressed against each other, forming various polygonal meshes, with a structure or with molecules and granules within them.

EXPERIMENT IV.

Erythema Nodosum. *(Lymph-cells.)*

A young woman, aged 22, complaining of feverishness, headache, and pain in the back, showed me a slight blush of erythema on one of the legs, and

a large bulla, the size of half a walnut, resembling a bulla of pemphigus, on the other. The cuticle covering the bulla was very tense, thin, and shining, but there was not the least degree of redness in the surrounding integument. I punctured the vesicle with a point of a lancet, and instead of its discharging its contents and collapsing, as I expected, only a small drop of perfectly transparent and limpid fluid flowed out. In this fluid I found several corpuscles, or cells; some were evidently red blood-cells, others resembled, and in my opinion were, colourless blood-cells. There were, besides, sundry other forms of cells, some entire, others flattened, and altered in form, having numerous filaments of the utmost degree of tenuity attached to them. (Fig. 2.) All the colourless-cells were more or less entirely filled with the most minute molecules, and there were several little masses and congregated groups of isolated molecules attached to each other by long and delicate filaments. Some of the cells were actually discharging molecules, and others had filaments so attached to them as to appear as if clothed with cilia. There were also several fibrillated networks, composed of filaments, molecules, and corpuscles; and here and there perfect but small epithelial-cells. I now snipped off the point of the vesicle with a pair of scissars, and yet it did not discharge the whole of its fluid. This was explained, when on examining the portion removed by the microscope, it was found to consist of a most intricate network of fibrinous filaments, which ramified through the whole interior of the vesicle, and retained the fluid in its meshes.

EXPERIMENT V.

LYMPH. *(Lymph-cells.)*

A child, 10 months old, with a *nævus on the forehead.* Stimulating applications had been used (solution of muriate of ammonia in vinegar); the surface was very red, shining, and tense, and in two or three places a perfectly transparent fluid or lymph was oozing out. I collected a drop on the point of a penknife; it was placed on a slip of glass, and an equal quantity of milk-warm water mingled with it. On examining it by the microscope, (with a linear power of 900 diameters,) I found numerous large cells, exactly resembling the mucous-cells in saliva, and the majority of them were filled with molecules in the utmost state of energetic motion. I saw several of these cells open, and multitudes of active molecules were emitted, after which the cells assumed the irregular outline and coarse appearance of pus-cells. (Figs. 2 and 3.)

In several places I saw cells aggregated and fused into each other, forming a larger mass, filled with active living molecules. There were a great many red blood-cells mingled with these colourless and molecular cells, and also a great many isolated active molecules.

EXPERIMENT VI.

HERPES LABIALIS. *(Lymph and Pus-cells.)*

The same young woman mentioned before, with erythema and the large bulla or vesicle on the leg

(case 2), became, about a month after, affected with herpes labialis, accompanied by similar general symptoms to those present on her former illness. There were now eight or ten little vesicles, about the size of a small split pea, congregated together, and surrounded by several smaller bright red elevations at the edge of the lower lip and towards the corner of the mouth. I punctured one of the vesicles, and a perfectly clear transparent fluid was discharged. In this fluid I found several colourless-cells, in various conditions; they were for the most part very pale, and filled with minute molecules. Several of them were ruptured, and at the ruptured parts there was a number of minute molecules, which had evidently escaped from them. At various places in the fluid there was a delicate fibrinous or fibrillated network, inclosing molecules and altered corpuscles, and at other parts there were several masses of pale cells connected together, and forming a *cellular network*, very distinct, and very different from the fibrinous network. It is necessary, perhaps, particularly to remark that the colourless-cells in this transparent lymph were much more delicate, their outline fainter, the molecules in their interior more minute, the fibrinous filaments and the number of aggregated *masses* of minute molecules more copious, than in the fluid termed *pus*. (*Vide* fig. 2.)

On the following day the vesicles of herpes, on the lip, were turning milky or yellowish. I again punctured one; the fluid discharged was clouded and more opaque, and I now found by the microscope that it was filled by what are termed *pus-cells*,

and it was necessary to add a drop of water to examine them.

By careful inspection I saw numerous cells, not differing in anything from the mucous-cells in saliva, with myriads of molecules actively moving in their interior. I observed several of these burst open and discharge myriads of these same actively moving molecules; after which the cells became somewhat smaller, but without losing their circular figure. These cells with moving molecules were mingled with numerous others, more varied in their aspect, with larger dark objects and bright granules, more coarse looking, and devoid of any movement whatever in their interior. In many places in the field of the microscope I saw congregated masses of cells resembling pus-cells, running into or being fused into each other, in the midst of which I could here and there detect actively moving molecules; in other places I saw similar congregated or aggregated masses of fused cells, having much more of the form and appearance of incipient epithelial-cells; and in some of these masses I could discover that all the cells were filled with exceedingly minute and very actively moving molecules. The minute molecules discharged from the living cells continue in visible active motion for a considerable time. (Fig. 3.)

EXPERIMENT VII.

Porrigo Scutulata. *(Pus-cells.)*

A child, aged 5 years, under treatment; the head had been shaved the day before. Dispersed over

various parts of the scalp were numerous large and variously-shaped red patches; and upon these red patches innumerable minute white heads and red elevated points. I punctured one of the *white heads*, and squeezed out a little matter; this was mingled with a drop of water, and submitted to the microscope. The fluid was filled with cells and innumerable minute free molecules in active motion. These cells were most of them more or less oval. Some of the cells were discharging molecules and losing their figure. I placed the slip of glass, the fluid being covered with a thinner piece of glass, on the warm mantel-piece for five minutes, and then, on examining it, I found a great many more of the cells ruptured and altered in character thereby; mingled with these, however, there were a great many that still retained their sharp outline, now perfectly circular, and very much larger than before; and in *them* I could readily detect myriads of molecules in very active motion. I saw some of them burst, and emit a part of their contained molecules; and these emitted molecules performed very active motions, which I could attribute only to their being alive. I now punctured one of the *red points*, and a minute drop of blood flowed out; on examining this, without any addition, by the microscope, I found at least one-fourth of the cells colourless, and filled with molecules; and there was an abundance of loose or isolated molecules. The red-cells evinced a very powerful adhesive quality, which I was able to estimate in some degree by the elongation to which they submitted before they would separate from each other; I saw many of them drawn out almost

into a filament before its adhesion to a fellow cell was overcome, and when the separation was effected their elasticity restored them to their normal form. (Figs. 1 and 3.)

EXPERIMENT VIII.

Ulcerated Leg. *(Blood and Pus-cells.)*

A young woman, aged 20, housemaid, asked my advice for a large ill-conditioned ulcer on the leg, with large inflamed varicose veins. The limb was very hot and painful, and the veins were in many places extremely hard and tender. She was ordered to poultice the sore, and keep the leg constantly wetted with cloths dipped in cold water; directions were at the same time given her as regards her diet, the recumbent position of the limb, and strict attention to the bowels. At the end of a week I saw her again, the ulcer was improved in appearance, the veins were less prominent, but the leg was now covered with purulent heads, and small ulcers at the base of each of the hairs. I hailed this as a good omen, for I have always found the old wound to improve and begin to heal when these appearances, which illustrate my theory of nutrition, show themselves. The matter discharged from the sore, and that contained in the smaller purulent heads, contained the ordinary forms of cells; some living and discharging live molecules, others dead and disintegrating; they were mingled with myriads of active molecules. The leg was now strapped and bandaged. At the end of a fortnight the original

ulcer was very nearly healed, the granulations being upon a level with the healthy integument; the minor ulcerations were all healed, and the limb was now covered with white scales and flakes of exfoliating cuticle. The situation where each of these minor ulcerations had been was now marked by a very dark, dusky, red spot, nearly as large as half a pepper-corn, and from the centre of each sprang a hair. I touched one of the granulations of the old sore with a slip of glass, and received upon it a perfectly colourless drop of lymph (?) On examining it by the microscope I found multitudes of *red*-cells mingled with colourless ones. These red-cells were not exactly like those freshly taken from a blood vessel; they appeared more shrivelled, and had somewhat altered their form, probably from exposure to the air at the surface of the granulation.

I now punctured one of the dark dusky spots, in the centre of which was a hair follicle, and I found multitudes of colourless-cells, isolated molecules, and very soon copious fibrinous fibres made their appearance, mingled with the cohering red-cells.

EXPERIMENT IX.

Muco-purulent Discharge. *(Muco-purulent-cells.)*

A little girl, aged 3 years, was brought to me with a white muco-purulent discharge from the vagina. A little of the matter was removed on the blade of a scalpel, it was mingled with a drop of water, and examined by the microscope, with a linear power of 900 diameters. I found a multitude

of cells, of the appearances of which the figures are correct representations. In the interior of all these cells the molecules were in the most active motion. I saw some of them burst or open, and discharge the molecules; and the fluid altogether swarmed with isolated and very actively moving molecules. Some of these motions, particularly as seen in the myriads of isolated molecules, certainly may be nothing more than those seen by microscopical observers in inorganic particles; but there are others to be seen by care and attention which must be something more. (Fig. 3.)

EXPERIMENT X.

Purulent Eruption from Tartar Emetic Ointment.

(Pus-cells.)

Objects, &c., in the white matter, precisely the same in every respect as before. (Fig. 3.)

(Mucous-cells.)

I have never failed finding, particularly after a few hours' fasting, an abundance of cells, with active molecules within them, in the saliva. These cells are mingled not only with the usual broad flat epithelial scales, but also with an abundance of minute and frequently very active isolated molecules. These cells are not distinguishable from those pus-cells which have active molecules within them, and have been enlarged by a drop of water. I have sometimes seen them burst and discharge their contents. (Fig. 4.)

The mucous-cells of the nose are exceedingly various in shape, form, and magnitude; I have several times seen cells with very long and active vibratile cilia in the clear transparent limpid fluid discharged in the beginning of a cold, and I have on one occasion (related in the first series of my Researches) seen the molecules within some of the cells moving very actively. When attempting to observe the effect of water, or of any other re-agent upon these cells, it is necessary to stir the water briskly with the mucus, otherwise this tenacious material entirely protects the cells from its influence. (Fig. 5.)

If these experiments do not establish the identity of the cells of mucus, pus, and lymph, with the colourless-cells circulating in the blood, I am at a loss to understand what amount of evidence upon this point will be considered satisfactory; they are, at least as regards the moving molecules being common to them all, conclusive.

CHAPTER II.

ON THE TRANSFORMATION OF PUS-CELLS INTO A MUCOUS OR FIBROUS TISSUE AND TUBERCLE; ON THE FIBROUS TISSUE OF SALIVA; AND ON THE COAGULATION OF BLOOD.

Pus, Mucus, and Fibrous Tissue.

EXPERIMENT XI.

A large chronic abscess was opened, and a great quantity of pus discharged, Some of the pus was received into a wine-glass; it had the white opaque appearance and the consistence of cream. Twelve drops of the pus were dropped into a watch-glass, and ten drops of Brandish's liquor potassæ were added to them; they were well stirred together with the point of a penknife, and in less than two minutes the mixture became nearly transparent, and so plastic that I was able to suspend the whole mass (twelve drops of pus and ten drops of liquor potassæ) on the point of a needle. Twenty-five drops of pus were then similarly treated with ten drops of the alkali, and the whole of this was suspended on the bare point of the needle. Fifty drops of pus, and fifteen of liquor potassæ, were then tried, with the same result; and, lastly, I found that *seventy-five large drops of pus, and twenty drops*

of liquor potassæ (taking a little longer time to mix them) *could all be suspended on the point of the needle,* for as long a time as I chose, leaving the watch-glass in which they had been mixed nearly as dry and as clean as before they were placed in it. If a few more drops of liquor potassæ be added than the proportions here mentioned, the mixture becomes quite transparent, and it may then be gently drawn out into strings or filaments two or three feet long.

EXPERIMENT XII.

Twenty drops of pus were mingled with *seven drams* of water (about three parts of a wine-glass-ful); they were well stirred together; the mixture was homogeneous, and exactly resembled a very poor milk and water; there was no appearance of flaky matter whatever. Ten drops of liquor potassæ were then stirred in it, and in a few minutes copious flakes appeared; these flakes were found by the microscope to consist of aggregated cells, more or less altered, and connected together by the fibres or plastic material which had resulted from the bursting of some of the cells. Ten drops more of the liquor potassæ were added, and the whole well stirred together; the mixed materials now became quite transparent, and they had all the glairy physical characters of white-of-egg. On examining a small portion of this white-of-egg matter, I found in it numerous disintegrated cells; their diameter was much enlarged, and they were distinguished more by little circular masses of molecules than by any-

thing like entire cells. Water was now placed in a shallow glass capsule; the plastic-matter was emptied from the wine-glass into it, and heat applied. The plastic-matter did not mix with the water, but remained distinct, just as white-of-egg would have done The mixture was boiled for a few minutes, and stirred, so that the animal matter should not burn. There was no visible alteration, except the production of a little froth; there was no coagulation from the heat. While still warm, the transparent white-of-egg-like matter was thrown into dilute acetic acid, and the formation (or rather the appearance) of a distinct and coherent fibrous membrane on the outside of the mass, protecting the interior from the access of the acid, was as interesting as it was novel and remarkable.

The fibrous tissue here formed by my manipulations could not by any visible or microscopical character be distinguished from that formed by the fibrillation of the buffy layer of the blood, or by the process of nutrition in the living body.

EXPERIMENT XIII.

Equal parts of pus and liquor potassæ were well mingled together in a wine-glass; they formed, as before, a transparent and exceedingly plastic compound—mucus or tissue. A large glass capsule was provided, holding a quantity of dilute acetic acid; also two large needles with handles, and a pair of scissars. Various portions of the plastic matter, taken up on the point of one of the needles

from the wine-glass, were cut off with the scissars; they were then placed in the dilute acid, and with the needles I could draw them into a variety of shapes and forms, which soon became *set*, by the formation of an opaque white fibrous membrane, from the action of the acid; and they resembled in external appearance various structures and membranes hitherto, I believe, not known to be formable by such methods.

Now what are the events accompanying or preceding this singular transformation, and what are the results? I have shewn in the first series of my researches that liquor potassæ causes pus-cells to burst open and discharge their contents; and it is evident that, in this experiment, the plasticity of the resulting material arises from the rupture of the cells. The fluid element of pus, before this event, is limpid; that is, it has no plastic quality or tenacity whatever; it drops from one vessel into another like water; but when a majority of the cells have been ruptured, and their contents mingled with the previously existing fluid, then the whole becomes exceedingly plastic and coherent; it will no longer drop from one vessel into another, and it exhibits all the microscopical appearances of fibrous tissue or of mucus. The event, therefore, accompanying or preceding this transformation, is the rupture of the pus-cells, and the result is a mucous or fibrous tissue. I do not understand by the word *transformation*, as applied to cells, any transcendental conversion of one object into another, but that they are altered in appearance by growth, or by death; in character by peculiarity of situation;

and that when they burst or become ruptured, and their contents mingled with the fluid in which they float, they form either a fibrous tissue, a plastic mucus, or a secretion.

EXPERIMENT XIV.

Provide a tall glass jar, a tumbler glass will do, filled with clear water, and two long needles fitted with convenient handles. Mix a few drops of pus with an equal number of drops of liquor potassæ, stirring them well together; if several air bubbles are included in the plastic matter which results, so much the better. Let the mixed materials be now transferred to the water, and if air bubbles are entangled in it, it will float at the surface.

Now take the needles, push the plastic mass under the surface of the water, and on separating the needles with a little manipulation it may be spread out into a most delicate, thin, transparent, and highly elastic fibrous membrane, exactly resembling some of the thin transparent membranes of the embryo, except in the presence of blood-vessels, or the *structureless basement membrane* of Mr. Bowman. In this experiment the number of entire cells or pus globules incorporated with the free molecules and the fibres may be varied at pleasure by varying the quantity of liquor potassæ.

Here, then, we find that we may form not only a glairy mucus, or a fibrous tissue, but a highly elastic and transparent membrane from pus-cells, from dead and dying, or degenerated cells; what the active and the living can do is seen in the sponta-

neous formation of a fibrous tissue in buffy blood. But it may be objected that the liquor potassæ does more, in these experiments, than rupture the cells; I therefore allowed these tissues and membranes to macerate in water for several hours, and I found them not at all altered in character or appearance thereby. I then removed them from the water, and placed them on turmeric paper, and there was not the least indication of the presence of any alkali; moreover, the fibrous structure was rendered still more evident, and not destroyed by immersion in weak acetic acid. Again, it may be said that what I here call an elastic membrane is nothing more than a film of plastic mucus; to which I reply, if so, then that is *a new fact;* and that mucus is a form of fibrous tissue.

EXPERIMENT XV.

Half a tumbler glassful of pus was kept for five days; at the end of this period it was perfectly fresh; there was no smell arising from it, nor was there any visible or perceptible change. A thin stratum of clear, amber-coloured, and saline liquid floated above the cells, which had subsided to the bottom of the glass. When the pus was first withdrawn, it formed with liquor potassæ and acetic acid the fibrous and mucous tissues before mentioned; but I found that it gradually lost this property, and at the end of five days, although liquor potassæ rendered the pus transparent, yet it had none of the plastic properties it displayed at first.

This result shewed that the pus-cells had under-

gone some alterations, not detectable except by the reaction of the alkali; they were incapable, at the expiration of five or six days, of forming the mucous or fibrous tissues which they did at first: hence the necessity of using freshly-secreted or *newly-excreted* pus for the purposes of the foregoing experiments.

EXPERIMENT XVI.

A large indurated gland in the breast of a young woman, who had shortly before been suckling, suppurated. At the end of several days the abscess was opened, and a quantity of pus discharged. This pus had not the dead-white or cream-like aspect of the former; it was more muco-purulent, it had a more plastic quality, and could be drawn out into short strings. On examining it by the microscope, there were many amorphous granular masses, myriads of isolated molecules, fibrinous filaments, and oil globules found in it. After standing a few hours the pus became gruel-like, and many more cells were found ruptured and disintegrated; those that were entire were seen to have from three or four to five or six very minute oil globules in their interior. On adding liquor potassæ to this pus, although it somewhat increased its plastic qualities, it did not produce the elastic fibrous tissue to the extent before described; and I concluded that the pus and pus-cells in this case were a nearer approach to the secreting cells of the tissue, and therefore some stages further removed from the character of colourless blood-cells than in the

former case, where the pus was daily thrown out in large quantities.

The following are the conclusions to be drawn from the preceding experiments:—Pus consists of a fluid element and colourless-cells. The cells may be ruptured or unruptured; the appearance and qualities of the pus will vary according to the proportion of ruptured to unruptured cells. The ruptured cells discharge molecules and a plastic-element; the constituents of the plastic-element are fibrin and albumen. Hence the following synopsis of the composition and changes in pus.

- Pus
  - Limpid Saline fluid
  - Colourless Cells
    - Unruptured
    - Ruptured
      - Molecules
      - Plastic-element
        - Fibrin.
        - Albumen.

If the fibrinous and albuminous constituents remain united after the rupture of the cells, they form a transparent mucous or fibrous tissue, which may have few or many unruptured cells incorporated in it. If the fibrin visibly fibrillates, so as to constitute a network, it forms *flocculi*, flakes, clots, and false membranes, which entangle molecules and unruptured cells; while the albuminous fluid constituent, being added to the original fluid, remains as a serum or sero-purulent fluid.

Pus, Mucus, and Tubercle.

EXPERIMENT XVII.

Half a wine-glassful of pus was well mingled with an equal quantity of Brandish's liquor potassæ.

The plastic-matter resulting could be drawn out into strings a yard long. A delicate thermometer was immersed in the mixture, but no rise of temperature could be detected. Sulphuric acid, previously diluted with six or eight times its bulk of water, was now added to the plastic matter, and gradually it became quite white, resembling coagulated white-of-egg. At the end of two hours there was a very considerable smell of sulphuretted hydrogen issuing from the materials, which had formed themselves into a solid fibro-albuminous mass. This solid mass was now thrown into clear pump water, and on tearing it to pieces with two needles, I found it resembled, in all its visible characters, many of the morbid products found in the living structure; thus portions of it were like the interior of *a vomica*, especially several cavities which had been formed in its interior by the expansion of the gaseous bubbles; and many other portions resembled the pseudo-membranous layers often found lining purulent cavities. Several small shreds were examined by the microscope, and they exhibited a very copious fibrous structure; myriads of minute molecules were squeezed out from the interstices of the fibres, by pressure between the slips of glass, and these exhibited a singularly active molecular action. In some of the pieces or shreds thus examined, it was evident that the alkali had failed to rupture all the cells, so that numerous entire and more or less perfect pus-cells were found incorporated among the fibres.

EXPERIMENT XVIII.

One-third of a cupful of muco-purulent expec-

toration from a patient in consumption, thick, white, opaque, and very stringy or elastic, was mingled with half its bulk of liquor potassæ; the two were well stirred and beaten together; they formed a transparent, greenish-looking, plastic material, the whole of which was suspended on the blade of a penknife. This plastic material, mucus, or fibrous tissue, had the same visible character and mechanical properties as that resulting from the mixture of potass with pus from an abscess in the thigh; and the experiments before related were repeated with it. There were, however, some slight differences: for example, the plastic material in this case having been allowed to remain in the cup for three days, was found at the end of that period to have undergone a separation into an opaque, jelly-like, trembling and fibrous clot, and a yellowish limpid fluid, having experienced a change analogous to that by which the serum separates from a coagulum of blood.* The clot was of a yellowish-brown colour, and although more easily torn than the plastic mucus from which it came, yet it still presented evident marks of a fibrous structure. The clot was now broken up, and the fragments were thrown into a jar of clear pump water; in four or five hours all colour had departed from them; they had swelled a little and become of a pure and beautiful ivory white, semi-translucent at the edges. A portion of this white matter, resembling blanc-mange, was taken from the water and placed in a strong acetic acid; it soon became whiter, harder, and more friable (No. 1). Another portion, im-

* Vide *Medical Gazette*, Vol. I., 1840-41, p. 471.

mersed in liquor potassæ, soon became more transparent, more elastic, and mucus-like (No. 2). On adding a little water to No. 1, and applying heat, the fragments of white matter shrivelled up, became hard, tubercle-like, and very friable: they were not dissolved (No. 3). On adding a little water to No. 2, and applying heat, the fragments of white matter were redissolved into a transparent, elastic, white-of-egg-like matter (No. 4). On adding acetic acid to the white-of-egg-like matter, No. 4, it became fibrous, white, and opaque, forming at first a delicate membranous expansion, which, on briskly stirring the fluid, was broken up into white flakes or clots. These results appear to me to shew that the mucus or plastic matter expectorated from the mucous passages connected with the mouth is identical with that resulting from the rupture of pus-cells taken from an abscess in the thigh, excepting only those differences before noticed, and which might be anticipated, between a mucus formed in the living body, and one formed by artificially rupturing pus-cells; and they corroborate the conclusion, that colourless blood-cells, mucous-cells, and pus-cells, are different forms of the same elementary particles of nutrition.

EXPERIMENT XIX.

Opaque and cream-like pus was taken from a chronic abscess; some portions were mingled with a few drops of liquor potassæ, and other portions were mingled with equal, double, or treble quantities of water, and then mixed with variable amounts

of liquor potassæ. The plastic material, or mucus, resulting, was in some instances perfectly transparent; in others, opaque in variable degrees, according to the varying proportions of pus, water, and liquor potassæ. The plastic matter could, with a little care, be spread out into transparent films of any degree of thinness, but it was so extraordinarily elastic that when left to itself it contracted again into a lump.

A piece of glass, four inches square, was procured, and the plastic material spread upon it with the edge of a card; the glass was afterwards laid in a dilute acetic acid; the plastic matter then became white and opaque, and its elasticity was in a great degree destroyed. After this operation, it was scraped off the glass into water. In this manner, membranes, some of the utmost degree of thinness and transparency, others of a thick, leathery consistence, were formed. The plastic matter, on being submitted to the acid in lumps of various sizes, was changed into an opaque, white, friable substance, resembling tubercle—as, indeed, were the membranes, after a few hours' immersion either in the weak acid or in water.

EXPERIMENT XX.

Ten drops of pus, weighing 8 grains, and ten drops of water, weighing 6 grains, were well mingled together, and then three drops of liquor potassæ, weighing $2\frac{1}{2}$ grains, added. The plastic mucus resulting weighed $16\frac{1}{2}$ grains; it was readily suspended on the point of a needle. On immersing

it in strong acetic acid, it became opaque, white, and tubercle-like ; in a few minutes it was taken from the acid, washed in water, and rolled upon blotting-paper until it ceased to wet the paper. It now weighed 8 grains, the weight of the pus used. But moisture still continued slowly oozing from it, like serum from a clot of blood, and at the end of half an hour it weighed only 6 grains, at the end of an hour 5 grains, and at the expiration of four hours it weighed 4 grains, and could be handled without sticking to the fingers. It had all the microscopical characters of a tubercle.

EXPERIMENT XXI.

Opaque and cream-like pus, a very short time after withdrawal, was mingled with equal and double quantities of blood-serum, and then treated with small proportions of liquor potassæ. The same kind of plastic material, or transparent mucus, resulted as when water was used, and the same kinds of membrane and opaque tubercle-like matter were produced by the action of the acid.

EXPERIMENT XXII.

Ten drops of pus, weighing 8 grains, were mingled with ten drops of blood-serum, weighing $8\frac{1}{2}$ grains, and then the mixture was treated with three drops of liquor potassæ, weighing two grains. The transparent plastic material resulting was suspended on the point of a needle. It was placed in strong acetic acid, and after a few minutes, when it had

become quite white and opaque, it was taken out, washed well in water, and rolled on blotting paper to remove all moisture; its weight was then $14\frac{1}{2}$ grains; moisture continued exuding, and at the end of three hours it weighed 10 grains. A small portion examined by the microscope (linear power 300) exhibited numerous pus-cells still entire, amorphous granular matter, and myriads of molecules; it had the physical properties, visible appearance, and microscopical character, of pulmonary tubercles.

It is remarkable that the whole of the water and serum used in these experiments became worked up with the liquor potassæ into transparent mucus; not a particle of uncombined fluid remained in the watch-glass.

It is also worthy of remark, that when water was used the weight of the moist tubercle-like mass was the weight of the pus used (8 grains, Exp. 20), but when serum was employed the weight of the white and brittle mass was the weight of the pus + the weight of the albuminous element of the serum (viz., $14\frac{1}{2}$ grains.)

These experiments appear to me to substantiate, by a different line of investigation, the conclusions drawn from the results of the first series of my researches, and to shew that tubercles have a relation to abnormal, inactive, or dead colourless blood or pus-cells, identical with that which mucus, fibrous tissue, and the secretions, have to the normal, active, and living cells. Blood-cells form spontaneously a very strong elastic tissue in the buffy coat—they form a very plastic mucus when treated with a little alkali, which is converted into tubercular matter by

a weak acid. Pus-cells have not the power of spontaneous transformation, but they form a characteristic mucous or fibrous tissue when treated with an alkali, which becomes changed into tubercle on the addition of a weak acid. We cannot re-transform tubercles into mucus nor mucus into pus. But beginning with the living cells of blood or pus, we may produce artificially some of the products of their transformation, viz., a fibrous tissue, mucus, and tubercle.

All the various forms of cells found in the healthy and morbid tissues and secretions appear to me to be colourless blood-cells in some or other of their stages of transformation, and beyond the colourless-cell of the blood, which has active molecules within it, I believe no cell to be formed otherwise than perhaps by two cells uniting into one, or the division of one cell into two, events which may occur during their structural transformations. I certainly have never seen the slightest disposition to the formation of cells in any blood-plasma, lymph, blastema, exudation, organizable fluid, effusion, or liquor sanguinis, that I have examined. On the other hand, I have repeatedly seen blood-cells, pus-cells, mucous-cells, and cells in lymph, rupture, discharge myriads of active molecules, and thus form a mucous or fibrous tissue, leaving their integument in the form of an altered cell upon the field of the microscope.*

* Vide *Provincial Medical and Surgical Journal*, June 5, 1844, and Second Series of Researches.

On the Fibrous Tissue of the Saliva.

EXPERIMENT XXIII.

A watch-glass was half filled with *dilute acetic acid,* and two, three, or four drops of clear saliva, free from any air-bubbles, were allowed to fall gently into it. On carefully looking at these drops of saliva, they were found not to have mingled with the acid fluid, but each drop preserved its own figure, somewhat like oil on water, and as small portions of the plastic matter from the pus-cells would have done; there was also a faint opacity observable about each drop. A needle was inserted into this saliva; and on stirring it slightly a small quantity of white matter adhered to the point, which I immediately recognized from its behaviour to be fibrous, and on subjecting it to an examination by the microscope (linear power 300) it was found to be an exceedingly perfect and complete specimen of fibrous structure; the fibres were each of them distinct and well-defined, forming an intricate tissue, and distributed upon the fibres and in the structure were numerous minute molecules, such as are seen in the fibrillated network of the liquor sanguinis. Moreover, in some of the specimens I examined, I saw several of the mucous cells of the saliva, and a great many epithelial scales attached to (the former altered in form) and incorporated with or among the fibres. The fibrous structure or tissue seen in this experiment (which may be varied in many ways) is the most beautiful and perfect of any I have yet seen.

EXPERIMENT XXIV.

A watch-glass was half-filled with spirits of wine, and a quantity of frothy saliva collected in the mouth was allowed to fall into it; it was well stirred with the point of a needle, and in a short time the air bubbles had burst and disappeared. A mass of white fibrous matter collected on the point of the needle, which when pressed quite flat and closely between two slips of glass, exhibited so coarse and tendinous a looking fibrous tissue, that neither microscope nor lens were required to see it, and when rolled up a little between the fingers it was found exceedingly strong and elastic.

Now the saliva is by all agreed to be a secretion, formed by cells—it varies considerably in plasticity; and this experiment indicates that every drop of saliva contains a form of fibrous structure, which may be made visible by dilute acetic acid.

But it may be said that it was well known that acids coagulated the saliva. Yes, but a great distinction has ever been insisted on between *fibrin* and *albumen*. This distinction is very important, and I have endeavoured to observe it, by saying that *fibrin fibrillates* in assuming the visible form—*albumen coagulates*. Now, my experiments shew that mucus, saliva, and the plastic-element of pus-cells, *fibrillate* in the same way that the plastic-element of blood-cells does in the formation of the fibrous structures of the living body, or of the buffy coat of inflammatory blood.

If two, three, or four drops of liquor potassæ be

added to half an ounce of pure water, and then two, three, or four drops of pus be added, and well stirred, the compound has somewhat of the same degree of plasticity as saliva, and the same degree of transparency. If this be dropped into dilute acetic acid, the phenomena are similar to those observable when saliva is treated with the acid.

ON THE COAGULATION OF THE BLOOD.

Blood, immediately on its discharge from the human body, drops like water; it cannot be drawn out into strings, nor does it evince those plastic qualities which it afterwards gradually exhibits, and which go on increasing up to the coagulating point.* Blood, therefore, circulating in the living vessels, consists of a limpid fluid and the cells. The cells are of two kinds, the red and the colourless. The colourless-cells are highly-organized living forms, raised probably to an uniform point of vitality, containing, in theiri nterior, molecules and a plastic-element, the latter having two constituents, fibrin and albumen: wherefore the following exhibits the composition of the circulating blood:—

- Blood
  - Blood fluid
  - Red-cells
  - Colourless-cells
    - Molecules
    - Plastic-element
      - Fibrin
      - Albumen.

* "Liquid when blood is drawn, coagulable lymph gradually becomes, first *viscid*, and afterwards solid. In the viscid state, as I have frequently observed, when it is still transparent, it has the *tenacity of mucus*, and admits of being drawn out in fibres and bands. This viscidity which coagulable lymph acquires in passing from a liquid to a solid form has not, that I am aware, been noticed by authors."—*Researches Anatomical and Physiological*, vol. 2, p. 239.

Fibrin and albumen are the two constituent forms of the plastic-element; the plastic-element and the molecules are the constituents of the colourless-cells.

But the great change of temperature, the sudden exposure to air, and rude shocks, to which blood is subjected on its withdrawal from the living vessels, ruptures many of the colourless-cells, and the plastic-element and molecules from their interior mingling with the blood-fluid, produce the *liquor sanguinis*. When the colourless-cells are relatively numerous, the liquor sanguinis floats as a colourless stratum at the surface of the blood.

In a short time after the formation of the liquor sanguinis, the fibrin fibrillates or coagulates, forming a network or tissue, which entangles in its meshes the molecules and unruptured cells, forming the *clot;* while the albumen or albuminous fluid, added to the original fluid, constitutes the *serum.*

Hence, there are two distinct events upon which the coagulation of the blood depends: the first is the rupture of the colourless-cells, and the formation of the liquor sanguinis; the second is the fibrillation of the fibrin, producing the clot and serum (*vide* Synoptical Table, No. 1.) Any circumstance interfering with or preventing either of these events, will interfere with or prevent the coagulation of the blood.

Now the withdrawal of colourless-cells from the current of the blood, the incorporation of their contents with the tissues, and the fibrillation of fibrin, are essential stages in the process of nutrition. The coagulation of the blood is an actual transformation

from blood to tissue; the events or changes, and their results, are so many stages of nutrition going on before our eyes, and the experiment I have related,* is "a glaring instance" or a "demonstration" of the progress of these stages.

EXPERIMENT XXV.

A man, aged 52, ill in bed with pleuritis, was bled to 16 ounces. In five minutes the whole surface of the blood presented an opaque, shreddy, or flocculent appearance. The following morning the clot was covered by a tough and very thick layer of fibrillated fibrine, and in the cupped centre there was a jelly or *mucus-like* matter of looser consistence.†

EXPERIMENT XXVI.

Several drops of the liquor sanguinis from buffy blood were placed, before the fibrillation of the fibrine, on a slip of glass. The fluid was of a straw-colour, and nearly opaque, from the multitude of colourless-cells. It was well mingled with a drop of liquor potassæ, and gradually it became quite clear, transparent, and colourless, in consequence of the rupture of the cells by the alkali. The mixed materials were now almost semi-solid, and resembled a glairy mucus.‡

* Second Series of Experimental Researches, p. 4.

† *Medical Gazette*, Dec. 1840.

‡ Second Series of Researches, p. 11.

EXPERIMENT XXVII.

A woman, aged 35, ill with acute rheumatism, was bled to 12 ounces. In ten minutes a layer of yellowish liquor sanguinis floated at the surface of the blood. A thin pellicle of fibrine was removed with the point of the lancet, and a teaspoonful of the fluid beneath, free from red-cells, was carefully skimmed off and put into a phial containing an ounce of pump water; the mixture became of a pale white colour, nearly opaque. At the end of a quarter of an hour it was examined with the microscope; numerous colourless-cells were found, of various appearances; molecules and granules were seen in all of them; in some near the circumference, in others towards the centre. There were also great numbers of irregular masses, composed of fibres, mingled with altered cells, molecules, and granules. At the end of an hour, large white flocculi were floating in the fluid, which after some further time settled at the bottom. The fibrinous fibres had now so completely entangled, enveloped, and drawn up together the unruptured cells, molecules, and granules, that upon violently shaking the phial, the supernatant clear fluid was not rendered in the least degree turbid. In this experiment the unruptured cells were enlarged, much altered by the water, and resembled in all points the characteristics frequently assumed by pus-cells; while the white matter constituting the flocculi resembled the matter of tubercle.*

* First Series of Researches, p. 14.

EXPERIMENT XXVIII.

A man, aged 80, with irritable eruption, troublesome cough, copious expectoration of purulent mucus, and erysipelas of the face, was bled to 10 ounces; in five minutes there was nearly a quarter of an inch of colourless liquor sanguinis swimming at the top of the blood; in two minutes more no red portion could be seen. I removed several teaspoonfuls of the colourless liquid, and mixed it in a phial with an ounce of water, shaking them well; in a quarter of an hour numerous shreddy flocculi floated in the mixture, which resembled the curdled pus of an unhealthy abscess more than anything else. In the course of an hour a long loose coagulum (fibrous tissue) had formed in the bottle, leaving a semi-opaque or somewhat milky or straw-coloured fluid; the coagulum swam at the surface. On the following day I found that this milky fluid had separated into two parts; in fact, a second coagulation had taken place, a large loose coagulum resembling mucus had separated, leaving now a perfectly clear but somewhat pinkish liquid. The bottle now contained the first coagulum, firm and straw-coloured; the second coagulum large and semi-fluid, resembling a thick mucus; and a perfectly limpid or clear pinkish fluid.

On examining with the microscope a thin film of the loose coagulum, it appeared like an organized membrane, thickly studded with pale globules or cells, having the aspect of pus-cells. The water in this experiment continued its operation of rupturing cells, so that, after the first, a second coagulum formed.

These experiments not only support my conclusion that pus and mucous-cells are altered forms of colourless blood-cells, but they likewise substantiate the conclusion, that the fibrous tissue forming the buffy coat on the clot of blood originates from the rupture of the colourless-cells.

It appears to me, then, to be demonstrable from my experiments, that the colourless elements or cells of the blood spontaneously transform themselves into an elastic fibrous tissue after their separation from the living structure; into a plastic transparent mucus (another form of fibrous tissue) when treated with liquor potassæ; and into flocculi, flakes, and tubercle-like matter, when acted on by water or acetic acid.

It appears to me also to be demonstrable from my experiments, that a similar fibrous tissue and tubercular matter may be formed by the disintegration of pus-cells, and by treating the saliva with acetic acid or alcohol.

The fibrous tissues from these sources appear to have mechanical properties, a physical character and texture, a microscopical or visible appearance, and a chemical composition, so closely allied to the fibrous tissues and membranes formed by the process of nutrition in the living structure, as to leave no reasonable ground for doubting that the latter result from the transformation or disintegration of cells.

If so, then it appears to me to follow as an inevitable conclusion, that there is no such thing in the living organism as a membrane secreting mucus (taking the ordinary meaning attached to the word secreting); no such thing as an expanse of fibrous,

or of any other tissue, so changing the nature or character of fluids, as they filter or transude through its fabric, that the fluid of the blood on one side, becomes mucus by merely passing through it to the other; on the contrary, it appears to me that we can no longer hesitate to admit that mucus, whether conformable to the type of a normal nutrition, or departing from it so as to constiute an abnormal or diseased element, can exist only in virtue of the life of cells.

Are these cells generated in the tissue, or are they ulterior forms of blood-cells?

All the facts which I have witnessed support the conclusion that the cells from which mucus originates are (or have been) blood-cells; the following being their normal sequence, or order of progression:—

1.—*Isolated or free.*—Swimming in a limpid fluid; in motion through the vessels and capillary channels of the structure. *(Blood or blood-cells.)*

2.—*Stationary.*—United by a plastic-element, or fibrous tissue, which they themselves produce. *(Capillary walls and parenchyma secreting mucus.)*

3.—*Disintegrating.*—Separating and giving place to a fresh succession. *(Mucus and epithelial scales.)*

If these conclusions be true with respect to mucus, then I believe them true also of all other secretions; and the sequential order above stated is therefore only another mode of stating my theory of nutri-

tion, another way of viewing the subject. "In normal nutrition, the colourless blood-corpuscles adhere to the tissue forming the boundary of the blood channels; they pass into, and contribute to form the tissue (the parietes of the capillaries), and are afterwards evolved or thrown off from the nearest free surface—a follicle, crypt, or duct; the epithelial scales and the mucus, or the secretions flowing from the follicles or ducts, being the result of the dissolution of the cells and tissues."*

Now, if the sequential order, if the theory of nutrition here stated, be true, then it follows necessarily, upon reversing the series of events, that mucus and the other secretions, before their final transformation, must have been capillary walls, and the capillary walls must have been blood-cells.

What are the facts supporting this conclusion? 1. An increased amount of the colourless blood-cells in all red or inflamed tissues, where an increased nutrition or secretion is going on. 2. The identity of these blood-cells with the mucus and pus-cells, which are common to all parts of the structure. 3. The phenomena displayed in the capillary blood channels of the frog's foot. 4. The experiments related in the preceding parts of this investigation, particularly those proving the existence of a fibrous element in mucus and in other secretions—and whether we interpret the phenomena of nutrition from the blood to the secretions, or from the secretions to the blood, we arrive at the same result —that the secretions, the organs of secretion, and the blood, are three marked and recognised stages

* Experimental Researches, Second Series.

cell-transformation. Why cells in one portion of the organism should become bile, in another saliva, and in a third milk, can only be answered by answering the questions, why cells in one portion of a flower are green, in another red, and in a third blue; or why cells in one portion of a fruit—a peach, for example—form the kernel and prussic acid, in another the stone and gallic acid, and in a third the fleshy pulp and sugar.

From the active motions visible in the interior of the cells of the blood, of mucus, and of pus, it appears that every molecule essential to a living function has a vital power superadded to its material form; that it is alive, and capable of independent movements; every molecule being alive, it follows that every cell containing them is a living object, and every cell being alive, every organ is alive; and if every organ, then the whole organism: wherefore the conclusion, that the vital power of the body (the organic life) is an aggregate life, susceptible of increase and diminution, and entirely distinct from THE PERSON from whom issueth THE WILL.*

The question what are the stages or the forms of matter between the food and the blood-cells is not now the subject of discussion. If we take the colourless-cell circulating in the blood as the point of departure, then two distinct lines of investigation lie open before us: the one leading from this cell back to the food; the other conducting us from it to the secretions. The former must include the law of nutrition from the food to the blood-cells;

* Second Series of Researches, Sec. III.

the latter the law of nutrition from the blood-cells to the secretions.

It is to the last of these laws, or rather to the latter portion of the general law of nutrition, that my researches have been chiefly directed, and this portion it appears to me may be thus shortly expressed:—*Colourless-cells, isolated, free, and in motion in a fluid, become stationary and linked together by a plastic-element and fibres; they grow, reach a free surface, discharge their contents, and are eliminated.*

In the Synoptical Table (No. 2) I have attempted to embody this theory of nutrition, and to exhibit the relation between the transformable blood-cells and healthy tissue and mucus; and between the untransformable or degraded pus-cells, unhealthy tissue, and tubercles.

CHAPTER III.

ON THE STRUCTURE AND FUNCTIONS OF THE KIDNEY, WITH REFERENCE TO THE NATURE OF THE FLUID ELEMENT OF BLOOD.

Mr. Bowman's paper in the *Philosophical Transactions,* on the structure of the kidney, is one of the last and most successful applications of the microscope to anatomical research.* In selecting the details of this important paper to shew the application of the new doctrine of nutrition to special physiology, the three divisions of the Synoptical Table of the physiological and pathological transformations of cells (No. 2) will be adhered to, and the subject treated under the three several heads of BLOOD, STRUCTURE, and SECRETION; or in more special terms, the blood, the kidney, and the urine.

Under the first head I give a brief account of the course of the blood and the peculiarities of the vessels; secondly, a short description of the special textures of the gland, the uriniferous tubes,

* *On the Structure and Use of the Malpighian Bodies of the Kidney, with Observations on the Circulation through that Gland.* By W. Bowman, F.R.S., Assistant Surgeon to the King's College Hospital, and Demonstrator of Anatomy in King's College, London.—*Philosophical Transactions,* 1842. Part I.

and their epithelium; and thirdly, entering more fully into the details of the prevailing doctrine of secretion generally, and of the urine in particular.

I.—OF THE BLOOD.

The several vessels and channels by which the blood enters, ramifies throughout, and leaves the kidney, may be stated in the following order:—

1.—The renal, or emulgent artery.
2.—The afferent artery to the Malpighian body.
3.—The capillaries composing the Malpighian tuft or body.
4.—The efferent vessel from the Malpighian body.
5.—The capillary plexus on the deep surface of the uriniferous tubes.
6.—The renal, or emulgent vein.

The *renal artery*, sending a few inconsiderable branches to the capsule of the kidney, surrounding fat, and the coats of the larger vessels, subdivides and spreads between the medullary and cortical portions; and after numerous subdivisions, sends off on all sides terminal twigs, each one of which goes to form a Malpighian tuft, and may be termed its *afferent artery*.

The afferent artery of each Malpighian tuft, having perforated the capsule of the uriniferous tube, suddenly breaks up into two, three, four, or even eight branches, which diverge in all directions, subdividing again once or twice as they advance over the surface of the ball, or capillary tuft, they are about to form. The vessels resulting from these

subdivisions are *capillaries, with a simple homogeneous and transparent membrane,* held together and forming a ball (the Malpighian body) solely by their mutual interlacements.

The capillary vessels composing the Malpighian tuft unite into a single vessel the *efferent vessel* which emerges from the capsule of the Malpighian body, close to the afferent artery, and then immediately enters the close *capillary plexus,* or continuous vascular network, which surrounds and envelopes the deep surface of the uriniferous tubes. Springing from this capillary network are the several *radicles* of the renal vein, which, uniting in an irregularly arborescent figure, anastomose and form the *branches* of the renal vein.

II.—OF THE KIDNEY. (Structure.)

The division of the kidney into *cortical* and *medullary* portions is familiar to all. The cortical portion is the seat of the secreting function, and composed of the blood-vessels already described, and of the convoluted uriniferous tubes, with their epithelium; the whole bound together, and imbedded in a peculiar fibro-cellular tissue. The medullary portion indicates the commencement of the *excretory* apparatus, in which the tubes, converging to their orifices, terminate.

The uriniferous tubes of the kidney have two ends or extremities: the one buried deep in the cortical portion of the gland is a closed extremity, and forms the capsule which embraces the Malpighian tuft; the other is an open extremity,

communicating with other tubes, and terminating on the point of a medullary cone. The basement membrane of the uriniferous tubes, forming the capsule of the Malpighian body, is a simple homogeneous and perfectly transparent membrane, in which no structure can be discovered; and is, throughout the entire length of the tube, exceedingly feeble, very delicate, and easily torn. The tubes, after leaving the Malpighian bodies, are exceedingly tortuous; they unite again and again in twos, finally become straight, and converge towards the pelvis of the kidney, forming the medullary cones, or pyramids of Malpighi.

The *epithelium* is spread over the interior of the uriniferous tubes, and forms from two-thirds to nine-tenths of the thickness of every tube; the basement membrane being at all points so thin that it may be left out in any estimate of the thickness of the wall of the tube. The epithelium consists of several layers of cells, having a finely granular aspect; and where the tube expands to embrace the capillary tuft forming the Malpighian body, they are clothed with long vibratile cilia. Fairly within the capsule the cilia cease, and the epithelium beyond is of excessive delicacy and translucence, so that the Malpighian tufts are left completely bare, bathed in the fluid distilling from them, which is lashed into the tortuous tubes by the ciliated epithelium. The epithelium is constantly disintegrating, and its particles, mingling with the fluid flowing from the Malpighian capillaries, pass into the pelvis of the kidney; so that the fluid discharged by the open end of an uriniferous tube

is a very different thing from the fluid entering it at the other.

III.—OF THE URINE. (Secretion.)

From the foregoing description of the anatomical structure of the kidney, it appears there are in this organ *two perfectly distinct systems of capillary vessels,* through both of which the blood passes in its course from the arteries into the veins.

1st. That inserted into the dilated extremities of the uriniferous tubes, which may be called *the Malpighian capillary system,* and is made up of as many parts as there are Malpighian bodies.

2nd. That enveloping the tortuous uriniferous tubes, and lying on the deep surface of the membrane that furnishes the epithelium.

The former is a tuft of capillaries, with exceedingly thin walls, extruded through the wall of the tube, lodged in a dilatation of its cavity, and uncovered by any other structure.

The latter corresponds in every important respect with *the capillary system that invests the secreting canals of other glands.*

"Reflecting on the remarkable structure of the Malpighian bodies, and on their singular connexion with the tubes, it occurred to me," says Mr. Bowman, "that as the tubes, and their plexus of capillaries, were probably the parts concerned in the secretion of that portion of the urine to which its characteristic properties are due, the Malpighian bodies might be an apparatus destined to separate from the blood the watery portion. When the Malpighian

bodies were considered merely as convoluted vessels, without any connexion with the uriniferous tubes, no other office could be assigned them than that of delaying the blood in its course to the capillaries of the tubes. Now, however, that it is proved that each one is situated at the remotest extremity of a tube, and that the whole circumference of every vessel composing the tuft is free, lying loose in the cavity of the capsule, unconnected with any other structure, it would be difficult to conceive a disposition of parts more calculated to favour the escape of water from the blood than that of the Malpighian body." "These views of the function of the Malpighian bodies," Mr. Bowman remarks, "rest principally upon anatomical grounds;" and it may be added are now generally received and adopted by all recent physiological writers.*

"The secretion from the kidneys has been long divided by physiologists into the *urina sanguinis*—the urine voided from the blood only; and the *urina potûs*—the urine voided after drinking and moderate eating. 'Perhaps,' says Dr. Prout, 'a more correct division and nomenclature would be the *urine of the blood,* or the urine resulting from the secondary assimilating processes only; and the *urine of assimilation,* including the urine resulting from both the primary and secondary assimilating processes.'"† Without questioning the propriety of the distinctions pointed out by Dr. Prout, it will be more accordant with the anatomical structure of the kidney, with the views entertained by Mr.

* Pages 59, 60, 74, 75, 77, &c., *loc. cit.*

† Prout "*On Stomach and Renal Diseases.*" 1843, p. 11.

Bowman, and with the important part which it is now known the epithelium of all secreting surfaces performs, in giving special characters to the secreted product, to consider the fluid distilling from the Malpighian capillaries, as the *urine of the blood* —urina sanguinis; and the urine voided or discharged, as *the urine of the kidney and bladder*— urina renalis. The former being the fluid discharged from the blood, the latter the fluid discharged from the blood—*plus* the animal matters derived from the disintegrated epithelium.

The general, if not the universal, doctrine of physiologists with respect to the nature and properties of that portion of the blood upon which the continued nutrition of the body depends, may be expressed in the words of Dr. Carpenter and Dr. J. H. Bennett. "The *liquor sanguinis* of the circulating blood, containing the fibrin as well as the albumen in solution, is the portion of the fluid essentially connected with the formative processes. Its fibrin is continually being withdrawn from it in the healthy state of the body." "The various solid tissues derive the materials of their reconstruction from the blood, especially from its fibrin, which they have the power, by their vital endowments, of causing to assume their own respective forms of organization."*

"The blood consists of a solid and of a fluid portion. The solid particles are subservient to the production of animal heat; whilst the fluid portion is subservient to the function of nutrition, holding

* *British and Foreign Medical Review*, Art. vi., p. 102. July, 1844.

in solution all the principles essential to the constitution of the textures and secretions."*

According to this doctrine both sets of capillaries, that composing the Malpighian bodies, and that investing the uriniferous tubes, notwithstanding the differences in their anatomical structure and relations, must perform *the same kind of operation upon the blood;* for whether the watery portion be abstracted from the nutritive elements, or the nutrititive elements be taken from the watery portion, in either case a division or separation of the liquor sanguinis, or blood plasma, into two separate portions, is necessarily involved; and we must suppose that "a simple homogeneous, transparent, and bare membrane," is capable of allowing water, saline and numberless other materials, to pass out from the blood, and at the same time of excluding the nutrient matter, although in solution in the same fluid. This supposition, which endows a simple homogeneous and transparent membrane with powers of selection or choice, although supported by the singular physical properties of dead animal membranes, amounts to nothing more than a hypothesis, when applied to the function of the Malpighian bodies of the kidneys. Physiologists adopting a theory with regard to the nature of the fluid portion of the blood, have framed a hypothesis with respect to the function of the kidney to support it, in which the anatomical and physiological distinctions recently established between the two capillary systems of the gland are confounded.

* *A Treatise on Inflammation as a Process of Abnormal Nutrition.* By J. H. Bennett, M.D., &c. &c., 1844.

The simplicity of the structure of the Malpighian capillaries is *prima facie* evidence of a simplicity of function; and that their function is as simple as their structure it is the object of the following considerations to establish.

The facility with which various unassimilated substances of a very heterogeneous nature pass in solution unchanged from the surface of the alimentary canal to the kidney, and are discoverable in the urine, is well known. But a short route from the one to the other is not known; and it is evident, therefore, that these substances in their transit must mingle with the fluid portion of the blood.

In 1832 numerous cases of epidemic cholera were treated with saline liquids injected into the blood, not only without any detriment to the patient, but in many instances the injected materials evidently conduced to the preservation of life. In the *Provincial Medical Journal* of October 9th, 1844, there are eight remarkable cases of cholera reported by Mr. Tarrance, of Rugby, in which several quarts of a saline solution were successfully injected into the circulating current in the course of a few hours, (case 4, ten quarts in fourteen hours,) followed by the recovery of the patients from an apparently hopeless state of collapse. In some of these cases, two days after the last transfusion, the patient required bleeding, and the blood was found "highly inflamed, buffed, cupped, and puckered at the edges."

Among many others, there is a very remarkable case reported in the *Lancet*, in which *five gallons* of

fluid were thrown into the veins in the course of four days. The first injection was to the amount of *nine pounds and a half*, containing—

Carb. of soda ℈iv.
Chlor. of sodium ʒiv.
Albumen ℥iij.
Water (temp. 105° to 110°) 10lbs.

It was thrown into the circulation in the space of eighteen minutes. A few hours afterwards an additional *ten pounds* of the saline fluid were thrown in, with *four ounces of albumen*. This was at one a.m. on the 29th of May; at half-past seven a.m. the injection was repeated to the amount of ten pounds, *with the addition of ten grains of sulphate of quinine;* at half-past eleven a.m. the injection was repeated to *ten pounds*. June 2nd, half-past four a.m., six pounds and a half of the saline fluid were injected; half-past four p.m., at the patient's own urgent desire, the injection was repeated; *five pounds of* WATER, with six drops of liq. mur. morphiæ, were thrown in. This patient on the 9th of June was removed to the convalescent ward, where she remained for ten days, and then left the hospital.*

Either of Mr. Tarrance's cases might have been selected for the purpose of quotation; but I take Dr. Latta's case reported in the *Lancet*, he being the first to adopt the practice in the living subject. "The first subject of experiment," says Dr. L., "was an aged female, on whom all the usual remedies had been fully tried without producing

* This case was treated at the Drummond Street Hospital, Edinburgh, by G. Meikle, Esq., and Dr. Mackintosh. Vide *Lancet*, 1831–32, vol. ii., p. 748, &c.

one good symptom; the disease, uninterrupted, holding steadily on its course. She had apparently reached the last moments of her earthly existence, and now nothing could injure her: indeed, so entirely was she reduced, that I feared I should be unable to get my apparatus prepared ere she expired. Having inserted a tube into the basilic vein cautiously, anxiously I watched the effects: ounce after ounce was injected, but no visible change was produced. Still persevering, I thought she began to breathe less laboriously: soon the sharpened features, and sunken eye, and fallen jaw, pale and cold, bearing the manifest impress of death's signet, began to glow with returning animation; the pulse, which had long ceased, returned to the wrist; at first small and quick, by degrees it became more and more distinct, fuller, slower, and firmer; and *in the short space of half an hour, when six pints had been injected,* she expressed in a firm voice that she was free from all uneasiness, actually became jocular, and fancied all she needed was a little sleep: her extremities were warm, and every feature bore the aspect of comfort and health. This being my first case, I fancied my patient secure; and from the great need of a little repose, left her in charge of the hospital surgeon. But I had not been gone long ere the vomiting and purging recurring soon reduced her to her former state of debility. I was not apprised of the event, and she sunk in five hours and a half after I left her. As she had previously been of a sound constitution, I have no doubt the case would have issued in complete reaction, had the remedy, which already had

produced such effect, been repeated."* Mr. Tarrance's humane and praiseworthy perseverance in the cases he has related fully support the correctness of Dr. Latta's supposition.

It is not necessary, in order to establish the conclusion hereafter deduced from these and other cases, to go further into the details of the numerous examples distributed through the various medical publications, in which matters of sundry description have been injected into the veins of the human subject and of animals.†

* *Lancet*, 1831-32, vol. ii., p. 275. The ingredients used by Dr. Latta were the same as those used by Mr. Tarrance, and nearly in similar proportions—three drams of common salt, two scruples of carbonate of soda, and six pints of water.

† For an account of quinine found in the blood and in the urine, vide *Medical Gazette*, 1841-42, vol. ii.; see also *Ancell's Lectures on the Blood*. The putrid matters, and also the pus, he mentions on the authority of Lassaigne and Gaspard, probably contained independent living forms or animalcules. I have made the saline solution mentioned by Mr. Tarrance:—common salt, 2 drams; carbonate of soda, 2 scruples; water, 2 quarts; and have frequently tried its effects upon the cells of blood obtained from a puncture; I have also compared its effects with that of urine, and found them remarkably similar. Upon the red-cells, the *peculiar* influence of these two fluids is to render them (as seen by the microscope, magnifying 700 diameters) somewhat paler, more plump, even at the edges, and usually devoid of any appearance of central nucleus; but mingled with these there are generally many others, varying almost without end. But what appears to me to be a remarkable circumstance, which I have always noticed, is, that those red-cells which have undergone the mulberry-like change, are in constant motion of a semirotatory nature; and with a still higher microscopic power (1000) I have fancied that this motion is produced by filaments or cilia projecting from the dark points, which appear to bulge out the tender integument of the cells, and give them their mulberry-like character. The effect of these two liquids upon the colourless-cells, is to cause them to enlarge in a very moderate degree, their outline remaining sharp and perfectly circular; the molecules are readily seen within them; but I have not witnessed them bursting as they do from the application of water or liquor

The facts here stated appear to me to be opposed to the doctrine that the fluid of the blood is a plastic organizable blastema, "holding in solution all the principles essential to the constitution of the textures and secretions." It is very improbable at least that sundry unassimilated matters can be taken up into the blood from the alimentary canal, or that ten or twenty quarts of salt and water could run through the blood (for the fluid in many cases was carried off by the mucous membrane of the stomach and bowels as fast as it was thrown in) not only with impunity, but with a restoration of the suspended process of nutrition, and with it of the powers and functions of life, if the fluid of the blood be of the nature and have the characters assigned to it.*

Again: the manner in which, according to this doctrine, pus-cells are formed, is unsatisfactory, unsupported by any direct evidence, and not warranted by the facts witnessed by the aid of the microscope.† No microscopical observer, as far as I know, has produced any unquestionable evidence to prove that such highly organized and vitalized forms, as pus-cells certainly are, really *form* in the exuded liquor sanguinis. Dr. Bennett says, "the

potassæ. I think it right to remark with regard to the colourless cells, that when discriminated in healthy blood immediately after its withdrawal, and without any foreign addition, they are firmer and paler, but they are not so much larger than the softer red-cells, as some observers appear to think.

* A Treatise on Inflammation, &c., *ante. cit.*

† It is important to determine, if possible, the origin and source of pus-cells; for in explaining the mode of their production we not only explain that of mucous and epithelial-cells, but we also obtain a clue towards determining the nature of the fluid element of blood.

blood-plasma exuded throughout the body, when first poured out, is in all tissues essentially the same ; and yet we see plastic, exudation, and pus-cells forming in it."* But there is nothing in this passage, nor elsewhere in Dr. Bennett's treatise, to lead the reader to conclude that he had ever seated himself before the microscope and really *looked at* pus-cells forming in the plastic exudation.

I have on various occasions examined the drops of clear fluid which will sometimes exude in less than three minutes after the cessation of the slight bleeding from a graze on the skin. I have closely examined similar clear drops effused where there has been no visible appearance of blood ; and also other limpid and transparent drops obtained by gently touching pimples and healthy granulations. Numerous red-cells have invariably been seen in these fluids, and minute molecules, with altered colourless-cells ; but I have in vain sought for anything indicating a disposition to the formation of any kind of cell. These fluids all hold crystallizable matter in solution of a very singular kind. Dr. Bennett, in treating of the essential phenomena of inflammation, says—"It can scarcely be conceived by any one who has carefully examined the blood globules on the one hand, and the structure of the capillaries on the other, that the former can transude through the walls of the latter without rupture. Such an opinion may be considered as pure hypothesis, only supported by negative argument. No one has ever seen such an occurrence."†

* Treatise on Inflammation, &c., p. 72, *supra cit.*

† Treatise on Inflammation, *loc. cit.*, p. 38.—A somewhat remarkable

But the reader will bear in mind that Dr. Bennett is here speaking of extravasation of *blood*, and therefore it is presumed that these remarks apply to the red-cells especially; particularly as from the note appended to another part of his treatise, we may infer that Dr. Bennett has not himself witnessed the extraordinary accumulation of colourless-cells in the irritated vessels of a frog's foot, their adhesion to and incorporation with the capillary walls; although the announcement of this fact was made in January, 1841,* was corroborated by Dr. Williams and Mr. Toynbee in July of the same year;† again referred to in April, 1842,‡ and in the first series of my researches published in January, 1843.

No one could have imagined or have ventured so startling an hypothesis as to affirm, with respect to a current so rapid as is that of blood normally

instance of the *summary method* adopted by some physiologists in dealing with *new facts*, is exhibited in Mr. Wharton Jones's "Report on the Changes in the Blood in Inflammation, and on the Nature of the Healing Process," in the *British and Foreign Medical Review*, July, 1844:—

"The corpuscles which the fibrinous matter very soon after exudation is found to contain, have," he says, "been alleged to be the colourless corpuscles of the blood; *but this is not the case!* The corpuscles in exuded matter *are new formations*, developed in it as in a blastema." Whether this method of arguing and investigating a most important but very difficult question be satisfactory or not to *physiologists*, I do not know; it will not satisfy *medical practitioners*, who are deeply interested in its solution. As I am, I believe, the only person "alleging that the corpuscles which the fibrinous matter very soon after exudation is found to contain, are the colourless corpuscles of the blood," I could not omit this notice of Mr. Wharton Jones's *argument!*

* *Medical Gazette*, 1840-41, vol. i., p. 690.

† *Ibid*, 1840-41, vol. ii., p. 682.

‡ *Ibid*, 1841-42, vol. ii., p. 146.

circulating even in the frog's foot, that one particular class of cells could choose to fix themselves to, or be selected from the current, to the almost, indeed we may say to the entire exclusion of others of a different kind in the same stream ; but the fact has to a certain extent long been familiar to physiologists, and the extraordinary accumulation of fixed cells in the irritated texture (which must have some meaning) cannot now be denied ; and it constitutes a glaring instance of the necessity of discarding all hypothesis, and of appealing to observation, with respect to the laws of nutrition between the elements of blood and the solid textures. The easy method by theory and supposition must give way to the more laborious one of a strictly inductive experimental research.

Many physiological writers, in arguing their doctrines in opposition to those here advanced, are continually using the terms "escape from the vessels," "transude," "rupture of capillaries," "pores in the vessels," "open orifices," &c., as if these were a kind of *sine qua non* in the process of nutrition which I advocate and believe to be true.

This is by no means the case : a little trouble and perseverance will prove that colourless-cells are deposited all over the interior of the vessels ; that they are joined together by a plastic-element, lymph or mucus, which they themselves furnish ; that they form for a brief period the interior wall of the vessels, and at length pass into the tissue, being succeeded by other cells deposited in like manner ; and these facts are all independent of any orifices,

rupture of or pores in the vessels, allowing the escape of cells. The word *escape* (in constant use) implies that the bodies escaping have got out of the influence of some restraint, or of some law previously controlling them; but the cells engaged in nutrition, whether it be normal or abnormal, do not escape; and although selected by or choosing to adhere to the solid walls of the blood channels, they are still amenable to the law of nutrition; and unless the process of nutrition be entirely changed or subverted, or forcibly interrupted by cutting or laceration, they neither *escape* from the law themselves nor do they permit other cells to do so.

The results of my investigation upon the nature of pus-cells may be thus summarily stated. In all persons and at all times numerous colourless-cells may by appropriate means be detected in the smallest quantity of blood; they are very much increased in number wherever there is any redness of an inflammatory nature, and they abound in blood drawn from a vein in numerous and in very different diseases. Select a small irritable pimple in a person with any form of cutaneous eruption, and puncture it; the colourless-cells will be found very numerous, and the red-cells very adhesive. Select another pimple or spot that has no indication of its containing any other fluid than blood, and the colourless-cells will probably be equal in amount to the red ones, and numerous isolated molecules will be mingled with them. In this way you may be led from blood with but few colourless-cells, up to blood having nearly as much the character of pus as of blood, except that the latter will of course always

contain numerous red-cells. In the saliva, and in all kinds of mucus, similar colourless-cells are always seen, and they are abundantly increased on the slightest irritation. These facts I connect with the appearances seen in the vessels of the irritated web of the frog; and from all the facts is drawn the inference that pus-cells were colourless blood-cells—their peculiar distinctive characteristics arising from their not undergoing the normal transformations required, and performed by other cells in the healthy process of nutrition.*

We have no evidence proving that the blood of man is the place of genesis of cells; on the contrary, from the ascertained results (fibres and molecules) of the rupture of its colourless-cells, and in the present state of our physiological knowledge, it is equally at least, if not more probable, that the cells of blood commence their existence in the chyle. In an experiment hereafter related the enlarged and irritated vessels of the frog's foot were

* Autenreith relates, "That if after wiping away the pus from a wound, we collect *some of the moisture*, which exudes from the surface, and place it between two thin transparent plates of talc, *and allow them to remain in the wound*, that globules will be found gradually to form in it, which enlarge and become opaque; but if this exudation be removed from the atmosphere of the living tissue, no such change is observed."—This experiment is unsatisfactory, because two pieces of talc, *with the utmost care*, could scarcely have their surfaces brought so close together that colourless blood or pus-cells could not get in, in great numbers, between them. Brugman also says, that if a suppurating surface has been washed clean *the pus is at first secreted as a clear fluid, which afterwards becomes thick and opaque.* My interpretation of the fact here stated is this:—When a suppurating surface has been washed clean, a clear fluid is first thrown out, which gradually becomes opaque from the untransformed colourless blood-cells thrown off into the bottom of it.

partially cleared of the red-cells by liquor potassæ. The interior of the walls of the vessels were densely studded with colourless-cells adhering to a stationary plastic-element; they were closely watched at intervals for hours, but without seeing either the cells, or the plastic-element in which they were embedded, display the slightest appearance of being concerned or occupied in any process of cell-genesis, notwithstanding the circulation of the red-cells, although much disturbed, was not entirely arrested. Now if the plastic-element and colourless-cells of blood within vessels still engaged in the function of the circulation and of life, be not a blastema, then certainly no portion of the blood-fluid exuded through a structureless membrane can be so.* Let it, however, be granted that blood-cells generate blood-cells by rupture or division, this furnishes ground neither for argument or proof that the lymph, pus, and mucous-cells, found in the exuded fluid outside the vessels, are formed in it as in a blastema.

In my experiment demonstrating the process of fibrillation in the nascent liquor sanguinis from buffy

* Dr. Carpenter, in the article "Nutrition," of the *Cyclopædia of Anatomy and Physiology*, just published, remarks "That recent microscopical observations have established the important fact, that a great accumulation of white corpuscles takes place in the vessels of an inflamed part." (I would add, also in the vessels administering actively to normal nutrition.) "And this seems (he says) to be caused at first by a determination of those already existing in the circulating fluid towards the affected spot, *but partly by an actual increase or generation of these bodies, which appear to have the power of very rapidly multiplying themselves.*" The latter portion of the passage quoted, which I have put in italics, requires *experimental proof*, which must henceforward form the groundwork both of physiology and pathology. I have in vain sought for anything indicating such a process.

blood, where if cells ever form in the blood-plasma we might naturally hope to see them, the whole progress from the fluid to fibrous tissue may be watched, and yet no one has seen the remotest disposition to the formation of globular particles or cells. It has been objected to this experiment that it is made on a dead surface; the objection might have some weight could it be shewn that the process was stopped or in any degree impaired. But this is not the case; the fibrous tissue formed, is as perfect as if the process had been accomplished on a living surface; and if we can see fibres form as well on a dead as on a living surface, then why not see at least some effort at the formation of cells? In fact, there is nothing to prove that the liquor sanguinis undergoes any other change upon a living surface than we can see it undergo on a lifeless one.

In the second series of my researches there is a drawing (plate 1, fig. 5) of a blood-vessel in the transparent membrane of an embryo hare; it was faithfully copied from nature, and I have lately had opportunities of verifying it in the membranes of other embryo structures. I thought it a strong confirmation of my theory of nutrition; others it appears do not, for in a recent review of these researches I find the following passage:—"We must object to this fact (or this drawing) being used to prove anything with regard to adult structure, since it is well known that at the commencement of the formation of the vessels in embryonic structures they are mere intercellular passages, without any definite walls whatever, and that these are

gradually formed during the same time that a process of metamorphosis is taking place in other structures."*

Now some of the best energies of physiologists have been occupied in tracing out and establishing a wonderful analogy in the elementary tissues and mode of growth and nutrition in all living structures—following the law in the lowest vegetable as well as in the highest animal; but here, in order to carry out a doctrine of nutrition and secretion by molecular deposition, or by exudation, or exosmosis through structureless films of membrane, it is presumed that the process of nutrition in the embryo is no indication of the process of nutrition in the adult! And the writer, so far from trying experimentally to elucidate the question at issue, and determine whether the general law announced be applicable or not, assumes differences where most probably, if the analogies in all living structures be true, there are none; and separates by hypothesis the law of nutrition in the adult, from the law of nutrition in the embryo *but perfect structure of the very same being* (for this was the example adduced, and from which the drawing was made). Upon the question thus raised it is only necessary to remark, that the researches of Dr. Barry and others have shewn that the embryo structure begins with and that all its parts are formed of or by cells, and that the essential constituent of blood is cells; the colour of cells, and their being in motion, does not necessarily vary the law of nutrition, and it is contended that the fact seen in the frog's foot shews that this

* *British and Foreign Medical Review*, July, 1844.

law is not altered by their circulating through the textures.

But the argument here requires further examination. There are many eminent microscopical physiologists who contend that Schwann's theory may explain fœtal development and the organization of new textures, but is not applicable in explaining the maintenance of those already formed, which they think to be accomplished by a molecular deposit from the blood plasma.

That a deposit of some kind or other from blood to the textures is an indispensable part of the process of nutrition must be true upon any view of the subject; the function of the blood is undoubtedly to supply the solid materials of the organism. The essential parts of the question, with reference to the fibrous-tissues, mucus, saliva, pus, and epithelium, are—first, whether the solid deposit be derived from the sliding or stationary colourless-cells or from the blood-fluid; and secondly, whether any portion of this deposit be of the nature of a blastema, containing germs growing into mucous or pus-cells. My argument, supported by repeated observation, is, that the process of nutrition is *two-fold:* "some of the colourless-cells of the blood being expended in forming the tissues; others growing into epithelium." *

With regard to the first proposition, that "*some of the colourless-cells of blood are expended in forming tissue,*" this is supported, first, by the known properties of their interior contents; secondly, by their adhesion to and by their sliding along the

* Second Series of Researches, p. 27.

walls of the vessels; thirdly, by the dragging tail, depicted and described by Dr. Williams, and constantly observed in my experiments; fourthly, by the variable size of the colourless-cells seen within the vessels, also depicted by Dr. Williams, and noticed in the first and second series of my researches.*

With regard to the second proposition, that "*others* (of the colourless blood-cells) *are elaborated and grow into epithelial-cells,*" this I have endeavoured to support and establish by the facts and observations related in the present volume.

It is contended, therefore, that the deposit from blood to the textures is derived from sliding or stationary colourless-cells, and not from the reappearance, in a visible and solid form, of nutritive matter in solution in the circulating fluid of the blood; moreover, whether the deposit accrues from sliding or stationary cells, no facts have been produced to shew that the molecules of such deposit have any share in generating either the colourless-cells within the vessels, or the pus and mucous-cells outside them.†

* Vide Experimental Researches, and "*The Principles of Medicine,*" by Professor Williams.

† Upon the still debated question of the identity of the colourless-cells of blood, pus, and mucus, it may be asked, with reference to the argument adduced against it, how it is we judge of the identity of ordinary objects, but by seeing, handling, and trying them with other things? How do we judge of the identity of a chemical result, derived from two different sources, but by a similarity of aspect and sensible quality—by a similarity of behaviour under the operation of tests, and a similarity of result after the application of the test? Now the colourless-cells of blood, pus, and mucus, have the same remarkable active molecules within them—reagents, as water and liquor potassæ, have a similar effect upon them—and the result of

From the foregoing facts and considerations, I conclude that the physiological doctrine, *that the fluid of the blood is an organizable blastema, holding in solution all the principles essential to the constitution of the textures and secretions,* must be abandoned. It seems to have grown up solely from the necessities of the case, previous to the renewed application of the microscope to physiological researches; to be a mistaken inference formed at a time when our ignorance prevented us from drawing a right conclusion; to be supported only by an imperfect interpretation of a few facts which can now receive a more satisfactory explanation; and destined to fall under the weight of evidence daily accumulating against it. It is at variance with the simple anatomical structure of the Malpighian bodies of the kidney; with the well-known fact that sundry and very different kinds of unassimilated matter may be very largely mingled with the blood-fluid; and with the phenomena witnessed during the fibrillation of the liquor sanguinis. It leaves unexplained the novel and remarkable fact of the accumulation of

their touching them is also the same. Until, therefore, those other characters, which have been so much insisted on as constituting the distinction, are pointed out, I must believe that we possess ground sufficient to warrant the inference of their identity; ground which I am unwilling to surrender in favour of an opposite doctrine which cannot be maintained, except by a series of hypotheses; and especially when such surrender would leave unexplained the remarkable facts seen in the irritated web of the frog. Germ-cells may have all the known characters of blood, mucous, and pus-cells; but they have an additional one in their previous history, warranting their separation from the category; and any argument founded on their distinctions are inapplicable in determining the question at issue, which has no relation to them but to the cells of blood, pus, mucus, and epithelium.

the colourless blood-cells on the altered walls of the capillary vessels of irritated or inflamed textures; it has never been of the slightest use in the practical details of the treatment of disease; and lastly, it requires, when applied to physiological and pathological facts, two hypotheses to support it. First, that simple homogeneous, structureless, and transparent membranes, such as that composing the coats or walls of the capillaries of the Malpighian bodies, are active agents, having a power of selection or choice. Secondly, that highly-organized living cells, differing in no respect from the colourless blood-cells, except in having lost their normal power of transformation, generate and *grow* in a degraded blood-plasma or liquor sanguinis effused upon surfaces modified by an abnormal process of nutrition. These hypotheses merit Bacon's apothegm:—"Indefinite contemplations have swallowed up the true *passages* and *processes* of nature, therefore they are to be set aside, being but *notional* and *ill-limited;* and definite axioms are to be drawn out of *measured instances,* and so assent to be made to the more general axioms *by scale.*"

It may be difficult to determine by any direct method the nature and characteristics of the fluid element of the circulation, because it is always more or less mingled with secreted animal products, derived from the rupture of cells; abundant evidence, however, has been adduced to shew that it must greatly vary in its qualities and constitution.

Blood cannot be withdrawn from the body without being largely charged with cells, and it imme-

diately commences a series of internal changes, evinced by its gradually increasing plasticity and ultimate coagulation. The microscope shews that these changes occur in consequence—first, of the rupture or disintegration of the colourless-cells; and secondly, of the spontaneous fibrillation of the fibrine; and there is no sufficient ground to conclude, that the serum remaining after these important changes is the fluid element of the circulating blood. As many reasons might be advanced for supposing that the limpid and transparent fluid of a blister, or that the limpid fluid from which the cells subside in pus, is the blood-fluid, as for concluding that the serum remaining after venæsection is so.

A person evacuates his urine, and immediately after drinks wine, cider, or beer; probably in less than half-an-hour he has the desire to discharge it again. It has now but little colour, and few of the peculiar characteristics or odour of urine. This fluid or urine must come from the blood, draining through the simple transparent membrane of the Malpighian capillaries. Now the rapidity with which urine thus sometimes accumulates, the physiological effects of saline injections, and the simple structure of the Malpighian capillaries, all correspond with the evidence afforded by microscopical observation in favour of the conclusions advocated in these researches.

EXPERIMENT XXIX.

A. B., with an irritable eruption on the legs, which were swollen, hard, and red, had leeches applied;

the next day a clear fluid was oozing plentifully from the leech bites; in five minutes a drop as large as a small pea collected on each of them. The fluid was colourless, limpid, and saline to the taste. On examining it by the microscope a few red-cells were found in it, and also a few altered colourless ones. On allowing the fluid to evaporate, by warming the glass on which it was received over a lighted candle, a white crust remained, which, when examined by the microscope (linear power 300), displayed copious singular and beautiful crystalline arborescent forms. When the fluid was quickly dried they were small; if more slowly, they were much larger and more arborescent. There are several important considerations connected with these crystalline forms; but the fact to which I now ask attention is, that the action of heat or warmth upon the colourless-fluid effused in this and in other similar examples, is quite different from that of heat upon serum remaining after a venæsection. On removing the upper colourless portions of the fluid, and examining that deeper seated at the bottom of the little wounds made by the leeches, it was found abounding with colourless-cells, which, on the addition of a drop of lukewarm water, displayed all the characteristics so frequently insisted on in these researches as common to blood, pus, and mucous-cells; yet in this case there was no appearance, to the unassisted eye, denoting a discharge of pus.

It is evident, as regards these and other saline and limpid fluids discharged from the living body, the bulk of the fluid in urine, the watery part of the pulmonary exhalation, and the sweat, that a distinc-

tion (not a definition) must be recognized between the secreted animal products and the saline crystallizable blood-fluid—between elements furnished from the interior of organized cells, and those which have never risen so high; between the albuminous element, for example, found in the serum of blood after the fibrillation of the fibrine, and the unassimilated watery, saline, and crystallizable elements of the blood-fluid. These products or materials are mingled together in animal fluids and secretions, in all possible proportions; $a+b$ in the serum of the blood; $a^{x}+b$ in the urine and in the limpid fluids rapidly discharged from abrasions on the skin; but $a+b^{x}$ in the bile, saliva, and milk, where a represents the saline blood-fluid, and b the elaborated or cell products.

"The peculiarity of secretions does not depend," says Müller, "on the internal conformation of the glands; for, as I have sufficiently demonstrated, each secretion is in different animals the product of the most various glandular structures, and very different fluids are secreted by glands of similar conformation. The nature of the secretion depends, therefore, solely upon the peculiar vital properties of the *organic substance which forms the secreting canals,* and which may remain the same however different the conformation of the secreting cavities may be; while it may vary extremely, although the form of the canals and ducts remain unchanged. The variety of secretions is due to the same cause as the variety of the formation and vital properties of organs generally; the only difference being, *that in nutrition the part of the blood which has undergone the peculiar change is*

incorporated with the organ itself, while in secretion it is eliminated from it."*

Now the recent investigations of physiologists have established the fact, that the *organic substance which forms the secreting canals* consists of cells, and that from their vital actions and metamorphoses true secretions are produced. My researches, as I interpret them, tend to shew that the *part of the blood* "which," as Müller says, "in nutrition is incorporated with the organ itself, and in secretion is eliminated from it," is a part visible by the aid of the microscope—a highly organized part—a structure—and a centre of peculiar vital activity; that it is the part which, seen in the living vessels or in recently drawn blood, has been called a white corpuscle, or colourless-cell; which, seen incorporated with the organ itself, has been termed an organic-cell; but which, when met with loose or isolated on the secreting surfaces, has been variously denominated a lymph-globule, a mucous-globule, a pus-corpuscle, or an epithelial-cell.

It has been objected to these views of the nature of the blood and the blood-fluid, that "on watching the circulation in the living animal, the number of colourless-cells which traverses the field of the microscope is by no means sufficient to hold the quantity of fibrine and albumen which are known to exist in the amount of blood that has flowed through the vessels during our observation."† But here the argument is founded on an assumption; we *do not know* the quantity of fibrine nor of albumen flowing

* "*Physiology*," by Baly, vol. i.

† *British and Foreign Review*, July, 1844.

through living vessels, as distinguished from that contained within the colourless-cells, and I should much like to be made acquainted with any experiment by which it could be determined.

Observation and experiment both concur in proving that blood drawn in health, immediately on its withdrawal, drops like water; and that blood drawn in inflammatory diseases, or in pregnancy, contains an unusual amount of colourless-cells. Observation and experiment also concur in proving that these cells contain a fibrinous constituent in their interior; and that many of them are rupturing and falling to pieces from the moment they escape from the body to the period of complete coagulation. Now as the number of unruptured cells which are seen, bears a ratio to the ruptured ones which are not seen, so therefore when the amount of unruptured cells is large, the amount of fibrous tissue or buffy coat is large also in proportion; and the nature and characteristics of the serum obtained at the end of all these changes ought not to be taken in illustration of the nature of the blood-fluid circulating in the living vessels.

There is another objection which has been brought forward, and which I may notice in this place, viz., "that the albumen of the serum of blood needs *no elaboration*, but is derived immediately from the food;" and Liebig has even gone the extent of saying, "*that boiled and roasted flesh is converted at once into blood.*" Upon this latter point I have no intention of arguing, for one very good reason, I do not comprehend it; but in the former the argument turns upon the meaning of

the word "*elaboration,*" one of those convenient physiological terms in constant use, with a vague meaning. Many horses live for months, and work hard, upon oats, hay, and water; am I to believe that the albumen of the serum of their blood is the identical albumen of these vegetable substances? On the contrary, it has appeared to me that every recent physiological fact has tended the more firmly to establish the conclusion, that no material whatever can take any essential share in the nutrition of the textures, or in the secretions of the living organism, without passing through the structures of at least one species of living cells peculiar or appropriate to the organism; and this I take to be the meaning of what is called *elaboration or assimilation.* If I am correct in this view, the albuminous element found in serum must have passed through the structure of one or more series of organic cells; and if so, then has it been elaborated in the sense in which I have used the word in my researches; and I should not consider it as the *identical* albumen of the food.

The following is a summary of the functions of the kidney, deduced from the facts discussed in these researches.

The blood conveyed to the kidney by the renal artery, on reaching the bare capillaries of the Malpighian bodies, has a large proportion of its fluid element drained off by a simple process of exudation. The blood thus, as it were, concentrated, with its nutrient particles brought more closely together, then enters the capillaries of the uri-

niferous tubes, where the process of nutrition proceeds, as in other glandular structures.

If by any means we could determine the amount and nature of the animal matter discharged in the fluid, distilling through the coats of the capillaries of the Malpighian tufts, and thus eliminate it from the animal matter added from the epithelium of the uriniferous tubes, ureters, and bladder, we might reason with some confidence upon the contents of the urine discharged, with reference to the condition of the blood; but until this be done, there must be many sources of fallacy.

In all cases of normal secretion, the secreted matter is composed of the contents of stationary cells, performing vital functions peculiar to the sphere in which they are placed, and affording materials differing from anything found in the blood itself.

Such secreted matter is added to the Malpighian fluid before it can reach the bladder; therefore no reasoning from the contents of the urine discharged, to blood can be otherwise than unsatisfactory.

There is another, and as it appears to me, most important source of uncertainty and error into which the rage for chemistry seems to be leading physiologists, and of which the doctrines regarding urea may be given as an example. Urine, as soon as it is discharged from the body, like all other animal matter, undergoes a series of immediate changes; and in two or three days, in a warm atmosphere, according to my experience, swarms with exceedingly minute living forms. When, therefore, urine is submitted to a high temperature during

evaporation, it is probable that other very different changes are induced; and when, in addition, it is submitted to the action of one of the most corrosive and most nitrogenised liquids in our possession, surely we are justified in looking with much doubt upon the nitrogenised product when placed before us as a constituent of urine. The quantity of urea may be a valid criterion whereby to judge of the amount of certain animal matters in urine; but we are not justified, in my opinion, in supposing that the result obtained by the application of nitric acid to heated urine, exists in the same form in the natural excretion. Similar remarks apply to many of the products of chemical manipulation upon other secretions.

The physical changes and transformations which blood-cells undergo have a much greater degree of *practical* interest than chemical changes; in other words, the physical forms assumed in the process of nutrition by cell transformations interest the pathologist more than the variations of the chemical elements. Surely it must be of more use to the medical practitioner to know whether pus-cells are or are not untransformed blood-cells, and whether they do or do not cause an abnormal deposit of fibres, tubercle, or granular matter, in the normal textures, than it is to know that the formula for *protein* is C 48, H 36, N 6, O 14, or that choleic acid is a compound of choloidic acid with allantoine and water. The chemist informs us that his formula for fibrine and albumen is the same; but whether the fibrine is deposited in the form of fibres, the albumen remaining in solution; or whether they

are both deposited in the textures, and form together a tubercle, makes all the difference to the medical practitioner and to the patient; and this whether the chemical formula remains the same or not.

The analysis of a healthy lung, and of one full of tubercles, would probably, for equal weights, afford the same result; while the physical condition produced by a crowded, misplaced, and abnormal cell-metamorphosis, would settle the question of health or illness, life or death. Hence, therefore, the microscopically visible changes and transformations of blood-cells, the locality of their transformation, and the physical forms or mechanical properties resulting from them, are of infinitely more *practical* value than the more recondite distinctions determined by a purely chemical research. It is not *so much* by bringing about or by preventing chemical changes that patients are cured of their diseases, as by preventing an accumulation of untransformable cells, or a crowded and abnormal transformation in the textures.

Our efforts, therefore, in grave inflammatory diseases, must be to distribute the untransformable cells over as wide a space as possible, or to draw them away from the essential textures which compose the internal organs, to those surfaces where they can be readily eliminated or discharged. This is the great principle involved in bleeding, purging, and counter-irritation.

The general conclusions drawn with respect to Blood, are—

1.—That the normal blood-fluid holds in suspension, and not in solution, the matter essential to the constitution of the textures and secretions.

2.—That this fluid is not a blastema, or cell generating fluid, but a limpid saline liquid, which becomes sticky, lymph or mucus-like, in inflamed textures.

With respect to the KIDNEYS—

1.—That the capillaries of the Malpighian bodies allow the blood-fluid to filter through their simple and transparent coats, forming the *urina sanguinis*.

2.—That the capillaries of the tubes are the true secreting vessels; the colourless blood-cells detached from the circulating current, and incorporated in their structure, compose the epithelium, which, disintegrating and mingling with the urina sanguinis, forms the *urina renalis*.

With respect to the URINE—

1.—That it consists of two very distinct portions, the *urina sanguinis* and the *urina renalis;* and that it varies with every change in the nature of the food and with every alteration in the process of nutrition, wherever situated or from whatever source arising.

2.—That when finally discharged it undergoes a series of spontaneous and progressive changes, which are altered by the application of heat or of corrosive chemical liquids.

CHAPTER IV.

A DEMONSTRATION OF THE PHENOMENA AND RESULTS OF INFLAMMATION.

There are exceptions to every general rule, and sometimes the clearest and most demonstrative proofs of the truth of the rule may be drawn from the exceptions. When, therefore, it is argued from the grounds before stated, that the blood-fluid is normally a limpid fluid, it is not intended to affirm that it never becomes sticky or mucus-like—that a plastic or mucous element, consisting of a fibrinous and an albuminous constituent, derived from colourless blood-cells, never mingles with it; on the contrary, no one can have *closely* watched the changes within the capillaries of the irritated web of a young frog, without observing that the colourless-cells accumulated upon, and sliding along their walls, are frequently linked together by an adhesive bond; without seeing cells *dragging* as well as pushing others from the texture into the current of the circulation. But this mucus-like element does not appear fairly to mix with the more limpid fluid in which the red-cells so freely move—it seems rather to belong to, and to be of the same nature with the matter stationary between the central

current and the fibrous wall of the vessels; and it has evidently some share in impeding the easy and equable motion of the red-cells.

EXPERIMENT XXX.

Select a small, young, and light-coloured frog, with as few pigment spots as possible; irritate the web with tepid water, and afterwards very *gently* scratch it with the point of a needle, taking care not to wound any of the vessels; at the end of an hour or two all the principal veins, as well as the capillaries, will probably be thickly studded with colourless-cells. Then very very cautiously apply, from the point of a fine needle, the *minutest possible* quantity of liquor potassæ; there can scarcely be too little, and if too much then all circulation is stopped; or what is perhaps better, a weak solution of liquor potassæ, one part to three of water, may be lightly brushed over the web, immersing it in cold water immediately afterwards. The application of the potash, if carefully and successfully accomplished, so as not to stop the circulation, produces a new disturbance, and several of the venous radicles especially become gradually larger or more dilated, at the same time fewer red-cells pass through them, so that the sliding or adherent colourless ones may be clearly seen and closely watched or examined.

In vessels in this condition I have observed phenomena indicating that in them the blood-fluid becomes plastic or mucus-like. Masses composed of many red-cells glued together, and lumps of

plastic-matter, formed by several colourless ones fused together, may be seen passing away into the widening channels of the small veins; or becoming stationary, they have been the means of dividing the current of the blood into two streams within the calibre of the vessel.

Plate 2 has been engraved from a sketch, made in the autumn, from the web of a young frog, the subject of the preceding experiment; it was drawn about thirty-six hours after the application of the irritants.

(A) is a small artery; the current in the centre is very rapid; nevertheless several colourless-cells come into the field, following one another, slowly sliding along the wall of the vessel, and their interior contents are drawn out into a tail behind.

(V) is a venous radicle, the calibre of which is dilated, and the nature and appearance of the walls are quite altered. The tolerably uniform line of demarcation, which, when the experiment commenced, marked the junction of the blood-current and the fixed texture, has disappeared; it is now replaced by a very broken or irregular outline, formed entirely of round colourless-cells, with molecules distinctly visible within them; and when the circulating current is arrested by light pressure from the finger, it is impossible to tell which are the fixed cells of the texture, and which the moveable ones of the current.

(N N) are fibrous-looking lines, generally strongly marked, and usually accompanying the small arterial twigs. Sometimes they are seen only on one side of the arterial twigs, at others on both sides.

As the twigs break up into capillaries, these fibrous-looking lines leave the blood channels, and forming fan-like loops, incorporate with the tissue. If, in trying the foregoing experiment, the operator has stopped the circulation by applying too much liquor potassæ, he has then a very favourable opportunity of studying the course and arrangement of these lines or filaments, which I have no doubt are nerves.

It sometimes happens, in making the foregoing experiment, that the cuticle of the web becomes thickened and opaque, and the parts beneath consequently obscured. This I have generally been able to remedy, by removing with the point of a needle the outer layers of the epidermis; they readily peel off a short time after the application of the potash.

Now there are several important and interesting points which it appears to me may be demonstrated or cleared up by a careful repetition and study of the preceding experiment; viz., those relating to the changes in the character of the blood-fluid, to the accumulation of the materials of nutrition or colourless-cells in inflamed textures, to the alterations experienced by the walls of the vessels, the accumulation and nature of pus-cells, and lastly, the truth or falsity of the doctrine of a cell-genesis in inflamed textures.*

* The appearances here depicted in living vessels indicate the nature of the alterations which the walls of the capillaries and small veins experience in inflammation (*i. e.* when the process by which the flowing blood-cells become the fixed tissue-cells, is accelerated and abnormal); they also shew how pus or untransformable cells accumulate and replace the healthy textures. But it has been asserted that pus-cells never form in the frog. Those, however, who affirm this, must first tell us what they mean by pus-cells. In my experiments I have

With respect to the changes in the character of the blood-fluid. This, it appears to me, is rendered sticky, lymph or mucus-like, in the site of an abnormal or accelerated process of nutrition; *i. e.*, in inflamed textures.

This conclusion, which is the result of actual observation, is supported by the remarkable adhesive quality displayed by the red blood-cells taken from an inflamed spot in man. (Plate 1, fig. 1.) Such adhesive cells are always largely mingled with colourless-cells, and with numerous isolated molecules; and the fluid in which they float deposits a much more copious crop of filaments of fibrine, than does the fluid-element of blood drawn from situations where no inflammation exists.

The accumulation of the materials of nutrition, or colourless-cells, their stationary character, the alterations in the physical condition of the walls of the vessels in inflammation, and the origin of pus-cells, have all been investigated and discussed in the present and in the former series of my researches.

With respect to the doctrine of a cell-genesis in the textures, or in the fluids exuded in inflammation. If this doctrine, whether true or not true, admits

always seen the irritated vessels more or less thickly lined with round colourless blood-cells, and the fixed textures also either loaded with similar cells or overspread with an opaque tubercle-like or granular matter. Now, it is to be remembered, that the cells seen stationary within the vessels have a considerable thickness of texture to pass through ere they reach the outer surface of the epidermis; as they approach this, the water in which frogs are usually kept begins to operate, and converts the untransformed-cells, which are here analagous to pus-cells, into mucus, granular-matter, or tubercle, rupturing their exterior integument as shewn in the first series of my researches, p. 23, and in the experiments related in this volume.

of demonstration by experiment and observation, then the process of inflammation, as far as all its visible phenomena and results, redness, swelling, pus, and fibrous-membranes, are concerned, admits likewise of demonstration. Or if the process of nutrition, as between the blood and the solid textures, can be demonstrated, then the process of a cell-genesis from the interior of colourless blood-cells, and the process of inflammation, can also be demonstrated.

These three processes are all bound together, and are essentially the same, so that if one can be seen they all can be seen, if they exist.

Now if the experimenter, having first carefully observed the normal circulation and condition of the capillary walls in the frog's foot, will sit down, as I have done, with the microscope near him, and watch every now and then for a few hours irritated vessels approaching the condition represented in plate 2, he will see the process of normal nutrition replaced by a process of abnormal nutrition; the uniform line usually marking the interval between the current of blood and the solid texture, will be gradually replaced by an irregular outline, composed of stationary or sliding cells. He will see some of the cells leave the walls of the vessels and enter the circulating current, others coming in thickly from the neighbouring vessels to supply their place; he will see the texture, or islets of tissue between the blood vessels, more or less loaded with similar cells; and he will see the molecules or granules in the interior both of the fixed and of the moving cells; in fact, he will see that the reciprocal actions between the blood

and the solid texture consists in *colourless-cells, isolated, free, and in motion in a fluid, becoming stationary and incorporated with the solid texture.* But I believe he will not see the slightest evidence of anything approaching to a cell-genesis.

Let the reader now compare plate 2, just referred to, with the wood-cut in Dr. Williams's *Principles of Medicine,* with the plate in Dr. J. H. Bennett's *Treatise on Inflammation,* with the third plate in the first series of my researches, and with the figures in the fourteenth and fifteenth plates of Wagner's *Icones Physiologicæ ;* and surely it will be impossible for him to deny (if any one of the figures here depicted, or any of the drawings from which they were engraved, be copies from nature) that with the microscope we have ample means for determining what are and what are not the reciprocal actions between the *blood-cells* and the *solid textures* ; *i. e.,* whether the colourless-cells of blood do or do not "rapidly propagate their kind, and multiply themselves by subdivision."

Where there is no blood there can be no inflammation. The existence of blood necessarily implies the existence of blood-cells. The primary processes of nutrition, those from the food up to the blood-cells, must have been completed before inflammation can begin. Hence, therefore, the phenomena of inflammation must be comprised in the reciprocal action between blood-cells and the solid textures ; they must be *forms* of nutrition ; but *the reciprocal actions between the blood-cells and the solid textures, in a process of nutrition, may be demonstrated. Every process of inflammation is a process of nutri-*

tion. Therefore *the process of inflammation may be demonstrated;* and if there be a cell-genesis along the interior boundary of capillary vessels, by the growth of the molecules, or the so called "germs," within the colourless-cells, it must, or ought to be seen.

In the numerous experiments and observations I have made, with especial reference to this subject, I have never seen anything to support this doctrine.

The general conclusion drawn from my researches is, that the essential phenomenon of the process of nutrition, as between the blood and the solid textures, is also the primary and essential phenomenon of inflammation; and as the one can be seen or demonstrated, so also can the other. The short summary or definition of nutrition before given (p. 41) is this:—"That colourless-cells, isolated, free, and in motion in a fluid, become stationary and linked together by a plastic-element and fibres; they grow, reach a free surface, discharge their contents, and are eliminated." But short and stringent definitions are inapplicable to the phenomena of physiology or pathology, because the individual particles by which they are governed are invisible to the unaided sight; hence, in contrasting the phenomena of normal nutrition with those of inflammation, it is necessary to take a wider scope. In nutrition the colourless-cells float freely in a limpid saline fluid until the time arrives for them to take their part in the repair and reproduction of the solid textures; they are then linked together by a plastic-element and fibres which they themselves produce; they

grow out into various organised living forms, and their interior contents are elaborated into various products in subjection to the law of the organism of which they constitute the essential elements; these contents build up the textures and form the secretions by which the organism is characterised.

On the other hand, in a part presenting the phenomena termed inflammation, the colourless-cells (and the red ones also) move with difficulty in a sticky fluid; their normal growth and transformation into healthy textures and secretions is impaired or entirely lost; so that great alterations are necessarily produced in the textures bounding the capillary channels through which the cells are flowing, whereby these channels or capillary vessels become either enlarged and very irregular, or, from the number of untransformable and adherent cells, narrowed and blocked up. When these abnormal nutritive actions reach a certain amount, the results are disordered sensations and unhealthy secretions; if going beyond this amount the untransformable cells continue gradually to congregate and replace the healthy textures, the result is an abscess or ulceration.

The visible results of normal nutrition, which have their analogies in inflammation, are—

1.—The fibrous textures.
2.—Epithelial, lymph, and mucous-cells.
3.—Secretions—milk, bile, saliva, fat, &c. &c.

Or *vice versa*:

The visible results of inflammation, which are analogous to normal nutrition, are—

1.—Abnormal fibrous textures, bands of fibres, false membranes, &c. &c.

2.—Pus or untransformed cells.

3.—Abnormal secretions, unhealthy cell-elaborations, muco-purulent and sero-purulent products, granular matter, clots, tubercles, &c.

First—If cells congregate or accumulate in any texture, and undergo, *for the most part*, a normal transformation, but, in consequence of their excessive numbers, render the blood-fluid passing through the part affected mucus-like and sticky, then the fibrinous-constituent of the mucus or fibrous-element (derived from the congregated and stationary cells) being deposited upon the walls of the contiguous and surrounding vessels, causes abnormal adhesions, indurations, and swellings; while the more soluble albuminous-constituent of the plastic-element remaining in solution in the circulating blood-fluid and reaching the kidneys, is eliminated by the Malpighian tufts and discharged in the urine.

Secondly—If cells accumulate in any texture, and, *for the most part*, preserving their individuality and form, do *not* undergo any transformation, they constitute pus.

Thirdly—If cells accumulate in any texture, and, for the most part, experience an imperfect or abnormal transformation, they form granular matter, fibrous-clots, unhealthy muco-purulent products, or tubercles.

If the first of these abnormal processes, characterised by swellings and indurations, but a little way removed from the normal type, be called *adhesive*

or plastic inflammation; and if the second, characterised by pus or untransformed cells, be called *suppurative inflammation;* then I can see no valid reason why the third, characterised by granular matter or tubercles, may not be called *scrofulous or tubercular inflammation.*

A great deal of discussion has at various times taken place with respect to the condition of the blood-vessels in inflammation, but it must be borne in mind, that where the process of nutrition or inflammation is actually going on, *there* the vessels are capillary; and capillary vessels are channels running in a determinate manner around and among little fixed islets of living tissue. It is the figure of the islets that determines the arrangement and figure of the channels; take away the islets and no vessels remain.

But as these islets or masses of tissue are composed of cells, or of the living and active materials from the interior of cells, so they depend for their repair or reproduction upon the continued supply of new transformable cells brought to them through the capillary-blood-channels which intersect them; and when these become blocked up, narrowed, widened, or otherwise altered, the islets of tissue must themselves be altered also.

The primary arrangement of the fixed textures in all classes of living beings appears to be into small communities of cells and molecules, which have intervals between them, and therefore something of an independent or isolated character and appearance. In the frog the intestinal canal is empty during the winter; and if at this period the interior

layers of the epithelium be scraped off and examined by the microscope, they will be seen composed of small but distinct masses of coherent *cells;* the exterior ranks of the cells are clothed with vibratile cilia, in very active motion; but the interior ranks have them not,—at all events they are not seen. When these little masses or communities of living texture are gently pressed out between two slips of glass the arrangement exactly resembles a capillary-network; the intervals between the masses of the cells, in which the cilia are beating to and fro, typifying the capillary-blood-channels which intersect the more bulky masses of what is called vascular texture. The same kind of arrangement, with the vibratile cilia in motion, may also be seen in the interior of the transparent alimentary canal of many aquatic larvæ,—of very young lumbrici, &c. &c.; and also by scraping the peritoneum of a frog just killed. From the cell, therefore, we are led up to minute masses formed by several adherent cells; these masses are placed near each other with small intervals between them, intervals much too small for circulating cells to pass. From these primary masses or communities we are led on to others larger and composed of several of the smaller ones; these larger masses form the islets of vascular tissue, having intervals large enough to admit the floating cells of blood between them. It is impossible, therefore, to attribute any active power to capillary vessels upon these views of their nature.

All active power and every visible change must be referred to the molecules and cells of the organism, and the changes in the capillaries must

be enumerated in the class of effects. The fallacies which have so long ruled on this head appear to have arisen from the elaborate vascularity demonstrated by minute injections But we must bear in mind that in the living body it is the blood and the solid living textures that are engaged in the functions of nutrition and life, the vessels or channels are very subordinate, and apart from them amount to nothing. In injected preparations, one of the essentials of nutrition, the blood, is absent, and the other essential, the textures, are shrivelled and altered; all that remains are blood-channels, filled with size and vermillion, or some other injected matter. The prominence and beauty of well-injected capillaries have obtained for them an importance which has long stood in the way of pathology; they have been supposed to do this, or do that and the other; whereas it is the active molecules, and the cells of the blood, and the textures, that do all.

We must also bear in mind, that the meshes between capillaries must be governed by the size and figure of the islets of tissue; and that the diameter or area of capillaries must be governed by the degree of approach which these islets of tissue make to one another. The size of the islets of tissue, and the degree of approach they make to one another, must be governed by the life and functions of the cells and of the active molecules composing them, by the increased or increasing number of new cells adherent to their boundaries, which form the walls of the capillary channels. The disposition of the cells (moving through the capillary vessels) to adhere to the several boundaries or faces of the fixed islets of

tissue *must* be governed by very complex laws, determined partly perhaps by the living molecules within the cells, and partly by the concentrated vital activity resident in the nervous tissues.

If any analogy were required to illustrate these points, I would take a city where the width or area of the streets is determined by the masses or clumps of houses; the houses are built up or reared in accordance with the general plan of the city and the wants of the community; the aspect of their interior and their furniture is governed or determined by the individuals who construct them.

The *histologists* of the city are the people, who build their houses close to each other, and leave avenues and streets for traffic and for the conveyance of materials to and from them; the *histologists* of the living organism (as far as the known and visible forms of matter are concerned) are the active molecules which construct cells and place them so as to leave open channels or capillary vessels for the supply of new cells, and high roads, follicles, crypts, and ducts, for carrying off the old ones.*

Carrying out this analogy, the colourless-cells of blood are floating houses ready furnished and inhabited, requiring only to take a fixed and normal position to form part of the structure and to contribute to the functions of the organism.

While making these remarks upon the nature and functions of capillary vessels, it would be an

* The term *histology* is a novelty in the medical science and physiology of this country; I presume its meaning to be *the science which treats of the active agents employed in constructing and weaving together the various tissues which compose the living body.*

omission not to draw the attention of the reader to the analogies existing between the structure of the capillaries of the Malpighian tufts in the kidney, and the structure of the capillaries of the membrane of the air-cells in the lungs.

The former are tufts or balls of capillary vessels, the coats of which consist of a simple homogeneous, transparent, and bare membrane; *the latter* form an extended network, running between the two layers of an equally simple homogeneous, transparent, and bare membrane.

Both systems of vessels allow the fluid-element of the blood to transude their walls; and in both the function of nutrition must be different from what it is in the capillaries of the true secreting organs.

The capillaries of the Malpighian tufts have a single function to perform, that of regulating the bulk of the fluid of the circulating current, and of allowing, with the watery element, all the grosser unassimilated materials an outlet from the organism. They are closely packed together, forming a ball.

The capillaries of the lungs have a double function to perform; first, that of allowing the readily vapourisable fluids and materials an outlet from the blood; and secondly, that of bringing each individual blood-cell into the closest possible relation with the air bubbles which distend the hollows of the air cells. They are therefore drawn out upon a series of extended surfaces.

In the lung of the toad or the frog, even when the capillaries are gorged with blood, the homogeneousness and transparency of the membrane, between the laminæ of which the vessels are spread out, is

very remarkable, and when the capillaries are empty, it is as transparent as glass.

On several occasions, when observing the circulation of the blood through these capillaries, I have remarked not seeing any of the lymph or colourless-cells become stationary on their walls, as I have invariably done when observing the circulation in the web of the foot, or the tongue.

Again, the mucous follicles which are seen on the under surface of the tongue of the frog, appear to me not without their analogies in the secreting structure of the kidney. The loops or convolutions of the arterial capillary, varying in number from two to eight or ten, at the bottom of the follicle, are analogous to the arterial convolutions composing the Malpighian tuft; while the broad basin-shaped follicle itself, embracing or surrounding the capillary convolutions, and thickly clothed with mucous or saliva-cells, is analogous to a very short uriniferous tube.

Hence it is probable that the capillaries of the Malpighian bodies of the kidney, the capillaries of the air-cells of the lungs, and the capillaries of the true secreting canals or surfaces, have analogous though varying functions.

The capillaries of the Malpighian body have one simple function, regulating the bulk of the blood-fluid, and the amount of unassimilated saline matter in the circulating current.

The capillaries of the lungs have a double function, allowing exit to vapourisable elements and permitting blood-cells to *breathe* the air.

The capillaries of secreting canals, follicles, and

surfaces, have also a double function, allowing certain minor proportions of the blood-fluid to permeate their walls, and detaining perfect blood-cells for the reproduction of the textures and the secretions.

With these views we readily comprehend some of the most important phenomena of disease; for if an abnormal process of nutrition or cell-transformation be established in the Malpighian capillaries, or in the capillaries of the lungs; if in these vessels the perfect or colourless blood-cells congregate and set up a series of transformations when they ought to pass freely and quietly on to other structures; then, necessarily, the normal functions are impaired, alterations of texture commence, and illness ensues as a matter of course.

We know that various impressions on the organism, mental emotions, fear, anger, &c, powerfully affect the circulating current of the blood, and that torrents of cells, in obedience to some law, rush here or there, suddenly distending the capillaries of the face and neck, and as suddenly leaving them again. We know that these phenomena are accompanied by various disturbed sensations, by accelerations of the pulse, sickness, faintness, &c.

It is, therefore, only a fair inference from these facts to assume, that in cases of crisis or metastasis, similar causes are followed by similar effects. In all local inflammations or disease, colourless blood-cells are thickly congregated in a particular spot; and if not yet incorporated with the fixed texture, some sudden impression on the system or organism may be followed by an effect analogous to that wit-

nessed normally from the emotions, and they may all be suddenly hurried away, as if magically, to find some other more or less inconvenient spot for their transformations. This would be an instance of metastasis.

In all cases of fever or general disorder, abnormal blood-cells are circulating through the organism, whereby the secretions or cell-transformations are, here or there, more or less arrested or impaired; and the phenomena and results of *the crisis* depend upon the particular organ or surface they fix upon to congregate, and gain an outlet from the system.

Every pathological fact or phenomenon has, doubtless, an analogy in some or other of the physiological phenomena occurring every day. The blushing of modesty, and the pallor of fear, exemplify the facts of metastasis. The distress and loss of appetite attendant on mental anxiety, and the cheerfulness and hunger following its removal, exemplify the phenomena and crisis of a fever. The facts both of physiology and pathology are within the course of nature, and are governed by the operation of laws: the one embraces the law consonant with man's health and comfort, the other the law not consonant therewith; physiology is the usual course, pathology a departure from it.

It is these views which enable us to understand and appreciate the forcible and energetic language of the great Lord Bacon:—

"*We denounce unto Men,*" says this noble author, "*that they would give over Trifling; And not imagine, that so great a work, as the stopping, and turning back, the powerfull course of Nature, can be*

brought to passe by some Morning Draught, or the taking of some precious Drug; But they would be assured, that it must needs be, that this is a worke of labour; And consisteth of many Remedies, and a fit connexion of them amongst themselves; For no man can bee so stupid, as to imagine, that what was never yet done, can be done, but by such wayes, as were never yet attempted."

The schools say, find out the disease of the patient, classify, name, treat, and cure it. Experience and Nature say, find out the temperament, constitution, and habits of the patient; how the essentials, food, air, water, temperature, exercise, &c., have been used or abused; and how emotions operate upon him; make the classifying of the disease, subordinate to the study of the individual, and the treatment of the disease, subordinate to the treatment of the man. The disease is the sign—the symbol. It is the powerful course of Nature that is to be stopped or turned back; and be assured that this is a work of labour, and consisteth of many remedies and a fit connexion; and he that knows not the ways of Nature, how can he succour her, or turn her about?

Great difficulties have been thrown in the way of pathology by the many terms which have been used in describing the process of inflammation and in designating its products. These terms are now become a perfect wilderness, in consequence of the many new ones added by various microscopical observers; and it is absolutely imperative that some (though it may be an imperfect) attempt should be made to give them something of a harmonious or

classified meaning. This I have endeavoured to do in the Synoptical Table, No. 4, which has been constructed in accordance with the theory of nutrition and inflammation, which I believe not only to be true, but to be susceptible of demonstration and proof by an experimental investigation.

The following is an explanation of this Table, No. 4:—

The Blood-fluid, distilling from the capillary tufts of the Malpighian bodies, holding in solution the matter of the disintegrated epithelium of the uriniferous tubes, ureters, bladder, and urethra, forms the urine. Infiltrated into the intercellular spaces, tissues, and cavities, and variously modified by the soluble matter derived from cell-transformations, forms dropsical-fluids.

The Red-cells are transformed into colourless ones. (This I believe to be true, but have hitherto been unable to prove it.)

The Colourless-cells present endless appearances, according to the circumstances in which they are placed, and the period of their growth or development. In normal nutrition they form lymph, mucus, and fibrous textures, epithelial-cells, and secretions. In inflammation they form pus-cells and sundry abnormal products.

The Plastic-element, from the interior of cells, may be mucus-like or variously altered by the presence of fibrillated fibrinous filaments, by aggregated masses of molecules, granules, &c., or by being mingled with entire but altered cells.

The Molecules, although in the living cells perfectly distinct and in very active motion, are in the dead ones much altered—and both within or without the cells, they may, when no longer active, form various-sized masses, and lead the judgment of the observer astray.

The Fibrinous-constituent of the plastic-element may form conspicuous bundles of fibres, or it may be variously spread out, *in nutrition*, into layers of mucus or normal fibrous membranes; *in inflammation* into masses of coagulated lymph, layers of purulent mucus, or false membranes.

The Albuminous-constituent of the plastic-element from the interior of cells, usually soluble in the blood-fluid, and characterising serum and serous fluids, may assume a visible, amorphous, granular, or minutely molecular form, and mingling with, may render more complex the other forms.

Upon these views the Table or Synopsis, No. 4, has been constructed.

Finally, whatever may be the terms used to designate an abnormal process of nutrition, or to particularize its visible result, we must ever bear in mind that the floating masses of living tissue, the colourless-cells of blood, are individually invisible to the unaided sight; that many of them may be collected into one place, and yet defy our ordinary means of observation. If the particles themselves are invisible, of course their individual changes and transformations must be invisible likewise. Hence every *definition* in physiology and pathology, whether of health or disease, of normal or abnormal nutrition,

of pus, of serum, of mucus, or of tubercle, whether of one kind of inflammation or disease, or of another, must provide for invisible and imperceptible transitions.

The philosophical physiologist, in recognising all those necessary distinctions which nature places before him, or which improved methods of research enable him to detect, will still hold his definitions lightly, as merely convenient expressions embracing no more than the major result,—the preponderating sensible effect; he will neither attempt, nor wish to exclude or to limit the minor results, nor will he overlook or neglect the less sensible effects.

Whatever, therefore, may be the ultimate result of these investigations, they must tend to disembarrass the mind from the cramped and narrow views produced by scholastic and unnatural definitions; and we may yet hope to see pathology and the practice of medicine, when studied upon the broad basis of universal nature, emerge from the atmosphere of "indefinite contemplations,"—the regions of theory and hypothesis, and take their appointed station among the inductive sciences.

SYNOPTICAL TABLES.

I.—THE COAGULATION OF BLOOD.

Blood circulating in the living vessels.	First event.	Blood withdrawn from the vessels and prior to the second event.	Second event.	Final Result.
Blood-fluid . . Colourless-cells . Red-cells	. . . . . . Rupturing { Molecules / Plastic-element . { Fibrin / Albumen } }	Blood-fluid Molecules Fibrin . Albumen . } Liquor sanguinis . Red-cells (unruptured) Colourless-cells	{ Fibrin, fibrillating + molecules, red and unruptured colourless-cells . . . Albumen, in solution + blood-fluid . }	} Clot. Serum.

II.—THE PHYSIOLOGICAL AND PATHOLOGICAL TRANSFORMATION OF CELLS.

	1st STAGE (BLOOD) Isolated, free, swimming in a fluid, and in motion through the vessels and capillary channels of the structure.	2nd STAGE (STRUCTURE) Stationary, linked together or united by plastic-element and fibres, which they themselves produce.	3rd STAGE (SECRETION) Disintegrating and giving place to a fresh succession.
PHYSIOLOGICAL	Normal and transformable *(blood-cells)*	Growing into lymph, mucus, and epithelial cells, with active molecules } forming { Capillary walls, parenchyma of the secreting organs—fibrous tissue, membranes, &c.	Mucus, saliva, bile, milk *(eliminated)*.
PATHOLOGICAL	Abnormal and untransformable *(pus-cells)*	Pus-cells with inactive molecules, or with active molecules, but not transformable } forming { Abnormal capillary walls, pseudo-membranes, flakes, clots, pus.	Muco-purulent, sero-purulent, serous-fluids, flakes, clots and pus *(eliminated)*. } or { Fibro-albuminous solids. TUBERCLES.—Pseudo-membranes. Flaky-serous-fluids, clots and pus *(not eliminated.)*

III.—THE STRUCTURE AND FUNCTION OF THE KIDNEY.

BLOOD.			STRUCTURE.	SECRETION.
Blood-fluid . . Red-cells . . Colourless-cells .	carried to and from the kidney by	Renal artery . . . Afferent arteries . . . *Malpighian capillaries* . . Efferent vessels . . . *Capillaries of the tubes* . . Renal vein	Malpighian bodies . . . { Discharging the blood-fluid } Uriniferous tubes Capillaries of the tubes Epithelium . . . . { Disintegrating and mingling with the blood-fluid }	URINE.

IV.—SYNOPTICAL TABLE OF EQUIVALENT TERMS.

Blood . . { Blood-fluid / Red-cells / Colourless-cells . . . . { Molecules / Plastic-element . . . . { Fibrine or fibrinous-constituent. / Albumen or albuminous-constituent.

CELLS.	PLASTIC-ELEMENT.	MOLECULES.	FIBRINOUS-CONSTITUENT.	ALBUMINOUS-CONSTITUENT.
Altered forms of blood-cells, chiefly colourless, sometimes red.	Plastic-element and molecules, mingled with variable amounts of the blood-fluid.	Molecules moving in the interior of cells.	The fibrinous-constituent of the plastic-element fibrillated.	Visible particles (excluding fibres) from the interior of cells, including the visible particles of coagulated albumen.
Exudation-cells	Organizable-plasma	Molecules	Primitive fibres of lymph	Exudation-granules
Plastic-corpuscles	Fibrinous-plasma	Dark objects	Primitive filaments	Amorphous-granular-matter
Lymph-globules	Plastic-lymph	Granules	Fibrinous fibres	Molecular-base
Primitive-cells	Coagulable-lymph	Discs	Primitive fibrils	Granular formation
Fibrinous-corpuscles	Organizable-lymph	Nuclei	False membranes	Finely-granular-matter
Nucleated-cells	Lymph	Nucleoli*	Molecular filaments	Germs, &c. &c.
Isolated-cells	Plasma	Germs, &c. &c.	Fibres	
Pus-globules	Blastema of blood		Filaments, &c. &c.	
Mucous-globlules	Blood-plasma			
Pale-corpuscles	Liquor-sanguinis			
White-corpuscles	Protein, &c. &c.			
Incipient-epithelium, &c. &c.				

* An immense degree of confusion has arisen from the *use of these terms*, *nuclei* and nucleoli; the oval or rounded spot seen in the epithelial scales from the cheek I consider as a genuine example of a nucleus, it is attached to the wall of the scale; a similar object attached to the wall of the cell may be seen in almost every saliva-cell, and entirely distinct from the molecules.

EXPLANATION.

TABLE I.—The circulating blood consists of *the blood-fluid, the red and colourless-cells.* When blood is withdrawn from the body, *the first event* is *the rupture* of some of the colourless-cells. *The molecules* and *plastic-element*, from the interior of these cells, consisting of *a fibrinous* and *an albuminous constituent*, mingle with *the blood-fluid*, producing *the liquor sanguinis*. *The second event*, which very shortly succeeds, is *the fibrillation of the fibrin*, which entangles the molecules, the red and unruptured colourless-cells forming *the clot*, leaving the albumen in solution in the blood-fluid, forming *the serum.*

TABLE II.—If the colourless-cells of blood undergo a normal transformation, their contents form the normal textures and secretions. If they undergo no transformation, they constitute pus-cells. If they experience changes and transformations inconsistent with *the law* of the organization, *they* form abnormal products, diseased textures, and unhealthy secretions.

TABLE III.—Blood is conveyed by the ramifications of the renal artery *to* the Malpighian tufts, where large proportions of its fluid element are removed. It is conveyed *from* the Malpighian tufts *to* the capillaries of the uriniferous tubes by the *efferent vessels.* The peculiar distinctive characteristics of urine arise from the disintegration of the organic cells or epithelium of the tubes, ureters, &c.

APPENDIX.

NARRATIVE OF THE EXPERIMENTS REFERRED TO IN THE PRECEDING PAGES.

Experiment I.—*Dec.* 16, 1841.—On examining the circulation in the web of a frog, very few lymph-globules could be distinguished. A crystal of salt was applied. The first effect appeared to be to quicken the circulation in the neighbouring vessels; the part immediately beneath the salt was too opaque to be seen. As the crystal dissolved, the circulation was found entirely arrested where the salt had rested; in the vessels around this the blood was oscillating, just moving to and fro; at some further distance, the circulation was going on slowly and irregularly; beyond this, again, the circulation appeared somewhat quickened.

In half an hour the tissue between the vessels had many rounded globules distributed on it, just like the lymph-globules; though I could not observe any of the globules leaving the vessels.

On examining the part, at the end of an hour and a half, the number of the lymph-globules had very much increased, and the part on which the salt had rested appeared red for some distance, as if from blood effused into the tissue; but this I could not satisfactorily determine. There was a considerable or large vessel (a vein I judged it to be from the rate of the circulation) leading into this red portion, and as it approached it I could easily see in the red current a great number of lymph-globules. The vessel was too large, and the current in the centre too rapid, to distinguish the red-globules; but from the slower, irregular motions, and occasional stoppages, the round lymph-globules were readily discovered.

At this part of the vessel, where the lymph-globules were seen, and which extended some distance from the red spot, the diameter of the vessel appeared to be greater than the red current, and here a great many lymph-globules could be readily seen. In the capillaries around I could observe more of the lymph-globules than were seen before the application of the salt; but a much larger proportion appeared in the vessel before mentioned.

Among the irregularities observed was a period of congestion, in which the red-globules were very much crowded together, and either moved slower, oscillated to and fro, or stopped altogether. This period of congestion is sooner or later terminated; if the circulation has been altogether stopped it begins again by the crowded red-globules or corpuscles moving a little, sometimes one way, sometimes another; they oscillate, and at length rush through the vessels with considerable velocity.

During the period of congestion the calibre of the vessel is somewhat enlarged, and when the circulation is resumed it may be remarked, that the limits or circumference of the vessels is better defined, it is more easily seen. But not only is the limit of the vessel more distinctly marked, but the current of the red-globules appears to keep in the centre of the vessel; they do not appear to pass along the circumference, which is either free from any particles or it is occupied by lymph-globules.

On the following morning (17th) the blood in some of the capillaries moved at its usual rate, but in others it was irregular and slower. In most of the larger red veins a great number of lymph-globules could be readily seen, especially at the circumference and through the red current at the bottom of the vessel, or at the further part of the circumference; three, four, or five together might be seen stationary in the vessel, and then moving on with the irregular, sluggish, interrupted motion of the lymph-globules.

I was very careful that there was no deception; I know that the capillaries crossing a larger red vessel both above and below, and running parallel or beneath, may be readily seen with the microscope, and that, without caution, the globules in some of these may be taken for lymph-globules in the larger red vessel.

The lymph-globules are not nearly so readily detected in the capillaries this morning as they are in the larger red vessels,

where the red-globules are so numerous, and moving so quickly, that *their* figure and outline is quite lost In some of the vessels where the circulation is most languid, the whole interior of the vessel appears to be lined with lymph-globules; but if they are watched for some time, five or ten minutes or more, it will be observed that they are not permanently attached to the tissue of the vessel; they are occasionally detached, and fresh ones take their place, or they sometimes gradually disappear one after another, being carried into the current, and then the vessel may appear without them for a short period, or only a few be left.

Experiment II.—*Dec.* 17.—The webs in both feet of a frog were stretched out. Circulation rapid and equable; corpuscles large, well defined; the tissues between the capillaries granulated minutely; some hot water, a drop or two, poured on one of the webs; it was rendered opaque, and the circulation entirely stopped, but there was none of that congestion of the vessels which followed the application of the salt. The vessels appeared to be empty, and the circulation arrested; whereas when the circulation ceases, after the application of salt, the vessels are red.

In half an hour: the tissue between the vessels has a distinctly reticulated appearance, and there are many apparently well-characterized lymph-globules distributed about; indeed, the whole reticulated aspect appears due to these globules aggregated. The spaces between the capillaries, where this reticulated appearance is most marked, are more transparent, and the channels, or outline, or circumference of the vessels, is well marked, and can be distinctly traced even in those vessels which are quite empty of globules, which some of them are.

In two hours: the lymph-globules in the vessels are much increased, and many are seen in the tissue out of the channels of the circulation. The interior of some of the vessels which have been affected by the hot water appears to be thickly studded with lymph-globules; they adhere, although the red-globules are thrown by them out of their course, and repeatedly knock against them.

The amazing rapidity with which the red-globules fly, as it were, through the vessels, when the circulation is beginning to be restored, after the first effects of the application have sub-

sided, is quite singular; single globules or corpuscles will sometimes follow each other like lightning through a large dilated capillary, the calibre of which appears large enough to admit many at a time. There is no movement of the sides of the vessel; the circumference is much larger than the diameter of the corpuscles, unless it is their longest diameter, but they pass through the vessel with the long diameter in the axis. The vessel furnishing the globules is sometimes seen in a congested condition; every now and then corpuscles are detached from it, which rush with the utmost rapidity through an adjoining capillary in the way just mentioned. The cause of this, and the origin of this sudden rapidity, while the vessels remain motionless, is quite inexplicable.

Dec. 18.—On examining the web this morning I can perceive, by the eye alone, that the spot on which the hot water was applied looks white and opaque, and there is a well defined line between this whitish opaque spot and the surrounding portion of the web. On placing it under the microscope I found the circulation entirely ceased in the whitish spot, but the texture is in a remarkably singular manner reticulated, an appearance evidently produced by the copious distribution of large globules. The tissue had none of this appearance before the application of the water. The circulation around the whitish spot is languid, and a great many distinct and characteristic lymph-globules may be seen in and near the larger vessels, and in the capillaries also; they are in some places so thickly congregated, and remain so stationary, that they appear to form an interior irregular coat to some of the larger dilated vessels. In the other foot the circulation is going on equably, though somewhat slowly, and not more lymph-globules are to be seen here than may be observed under ordinary circumstances.

Dec. 20.—Examined the web of Experiment I. Several large red vessels traversing the web; in some of them the blood is quite stationary; they are dilated. In the neighbouring portion the capillaries are still carrying on an irregular circulation, and the vessels into which they empty are dilated and very red. In some of the capillaries are many lymph-globules, one in particular with a great many. The tissue between appears studded with large globules, giving the reticulated appearance already noticed.

Experiment III.—Having watched the circulation in the web of a frog for a quarter of an hour, I could only see six lymph-globules. I then placed the foot in water at 94° for thirty seconds. The frog attempted to kick about, as if suffering pain. I then found the circulation going on at much the same rate, but with a great increase in the number of lymph-globules. I could now see multitudes of them; and in two or three large red veins, where the circulation was going on languidly, the red-globules appeared as if passing over a bed of marbles, so numerous were the lymph-globules in them. I observed, particularly, one capillary almost filled with these round lymph-globules, which were oscillating to and fro, as if uncertain which way to go; and I watched several oval red-globules pass through the same vessel with great ease and rapidity, threading their way between the lymph-globules, but sometimes they stopped in their course, and then moved as rapidly back again.

I now immersed the foot in water at 110° for the same period of time. I then found the circulation entirely arrested in many of the capillaries and veins; yet at the same time, in the same field, there were many minute vessels in which the circulation was going on with its previous or accustomed rapidity; and in the arteries I thought the stream even more rapid. In other vessels the red-globules were either just moving sluggishly, or oscillating at the rate of forty-five oscillations per minute. The lymph-globules were very numerous, and a great number in many of the larger vessels were quite stationary, appearing to form or to line the interior of the vessels.

The capillaries appeared to form very decided channels in the tissue; their outline was much more distinct, as if they had worn a deeper channel, or as if the tissue around them was puffed or swelled. The tissue intervening between the vessels looked as if studded with lymph-globules, giving it a kind of netted appearance.

On examining the vessels in the other foot I could see many lymph-globules, particularly in some of the larger veins, rolling slowly along their sides, and sometimes drawn out into a flask-like form behind. But this slow motion of the lymph-globules did not extend along the whole length of a particular vessel, for at some parts of its course I could see many lymph-globules,

and at other parts I could not detect them, and I could detect only a few in the capillaries. But the circulation in these capillaries was going on with its usual rapidity, and then, even in the smallest capillaries, it is impossible to make out the figure or character of either kind of globules.

I now again examined the web that had been immersed in the water. I observed the circulation re-establish itself in many of the obstructed vessels, which always appeared to contain many lymph-globules; some of which seemed permanently attached to the interior of the vessel, others oscillated to and fro, or moved very slowly through; while the red-globules, singly, and at longer intervals, threaded their way through in the intervals between the lymph-globules, sometimes thrown on this side, sometimes on that, and sometimes urging or pushing the lymph-globules off from the side of the vessel into the current.

I traced a large vein for some distance; at the first part, where it was small, the current was rapid, and only a few lymph-globules could be detected in it; in its course it increased in size, the lymph-globules were more numerous, the red current appeared to be moving slower, and at length the boundary or walls of the vessel seemed to be entirely composed of lymph-globules, and the red current seemed rushing over a bed of marbles.

Experiment IV.—*Jan.* 24, 1842.—A small young frog having been secured, I found the circulation going on in the web of the foot in an irregular manner; in some of the capillaries the blood was almost stationary, in some others it was going on rapidly, in others the blood oscillated to and fro, and in others again it was propelled through the capillaries in regular pulses, at the rate of from fifty-four to fifty-six in a minute. The tissue of the web is marked by dark longitudinal lines. The red-globules appear less numerous, and the blood therefore lighter coloured than in old frogs, but the globules are quite as large.

The handling of the foot, the ligatures on the toes, and the warm temperature of the room, may perhaps account for the irregularity of the circulation. There are many lymph-globules moving slowly in the capillaries, and several may be seen in one or two of the larger vessels.

I immersed the foot, for about thirty seconds, in water at 120°;

the frog suffered some pain. The tissue of the web was now much more transparent; in some places the vessels were filled with red-globules, they were gorged, and all circulation in them had ceased; there were other vessels quite empty, at least of all globules; in others the circulation was going on by pulsatory movements.

In some of the capillaries several lymph-globules were seen moving slowly, and of very different sizes, some twice the size of others. The red-globules in these vessels were subject to all possible kinds of movement; some moved with the greatest rapidity, darting through a vessel, and threading their way between the lymph-globules; others oscillating, sometimes moving one way, and then suddenly, without any apparent reason, retrograding rapidly; in some of the vessels the red-globules were heaped and impacted closely together,—oscillating; then the circulation became restored, and the globules subsequently passing through the vessel, but just before congested and clogged up, were seen darting through it with the rapidity of lightning; then again, in the same vessel, the congestion would come on a second or a third time; and sometimes the current would entirely change its direction, after flowing for some time one way it would become permanently changed, and go in the opposite one.

In the scene of all these various movements the lymph-globules evidently accumulated, a great number of various sizes being seen. In the larger veins they became exceedingly numerous, like marbles, in the vessels; but I could not detect any in an arterial branch going to the inflamed web; whether they existed in the current, but were not arrested at the sides of the vessel, or whether there were really none in the vessel, the current was too rapid for me to determine. In the veins they were particularly numerous.

In an hour afterwards the circulation was going on with great speed and regularity in the same vessels. The tissue of the web had become somewhat swollen, so that many of the vessels appeared as if they had worn for themselves a deeper furrow through it. In most of the capillaries numerous various-sized lymph-globules were very apparent, and in most of the larger veins they were in multitudes. The tissue now presented a much more distinctly net-like or reticulated appearance, and by

altering the focus of the microscope a little, removing the objects a little out of focus, it had all the appearance of being spread over with a covering of the same kind of globules as those seen in the blood, I mean the lymph-globules.

I now dropped a little spirits of wine on the web; the circulation in the entire of it ceased, except in one or two of the larger trunks, in which the red-globules were congested and were oscillating. In an arterial branch, the same as that I just now referred to, the blood was pulsating and moving slowly but gradually forward, and now I could see lymph-globules in it of various sizes.

Two days afterwards I found there was no circulation going on in the web operated on, but a thin skin peeled off, which, under the microscope, had very much the characters of a thin film of coagulated fibrine; it was densely studded with globules somewhat smaller than the lymph-globules seen in the vessels, and having a less circular outline.

Experiment V.—*Feb.* 5.—I secured both legs of a frog to a frog-plate, and found the circulation going on freely and equably in the web of each foot; the pinker blood of the arteries flowing with great rapidity, the darker blood of the veins more slowly; here and there is a small capillary with red-globules passing separately and singly, in others they are somewhat crowded; a few lymph-globules are occasionally seen. I have carefully looked over the webs for half-an-hour, and have seen no other changes. The islets between the vessels have nowhere a net-like or reticulated appearance; on the contrary, they exhibit a confused series of irregular pigment-spots, coarse dark specks, and curved lines. I immersed one foot in water at 100° F. for about three seconds; the frog suffered some pain, and broke the ligatures with which the foot was secured. Having tied them again, I observed, on placing the web under the microscope, that the circulation was quicker than before, though there were many capillaries in which the red-globules were crowded, and some in which they were passing at intervals, darting singly through the vessel.

Ten minutes afterwards: the circulation in the capillaries is much slower, the red-globules mostly crowded. In some of the vessels they move very sluggishly, so that the form and outline

of each globule can be distinctly seen. The lymph-globules are now very numerous, but not equally so in all the vessels, although the whole foot was immersed in the tepid water; none can be seen in many vessels, while in others they have accumulated eight or ten together. They do not, at least I cannot see them, form in the vessels; they come into them and become arrested, while the red-globules pass quite freely through the same vessels. In the other foot the circulation is going on just as fast and as equably as at first.

In twenty minutes: the circulation is still more unequal and much slower, but in some capillaries the blood is moving faster, and in a different manner to what it is in others; in some of the larger veins the lymph-globules have accumulated in an extraordinary degree, appearing just like a surface of round shot, over which the stream of red-globules is gliding. In some of the capillaries also this increase has taken place, and the red-globules rapidly, but singly, one by one, strike against the lymph-globules, and occasionally dislodge one or two, which soon have their place supplied with others. The blood is circulating equably and rapidly in the other foot as at first, nor can I see any more lymph-globules, occasionally one or two as at first.

In ten minutes more: the circulation is becoming more natural—more equable. There are still, however, capillaries which are sometimes empty, without red-globules, and then single globules pass, but not very rapidly; sometimes they stop; then the circulation is natural for a moment, and all at once the current is retrograde, lymph-globules are now and then arrested; these changes are constantly recurring. By immersion in warm water the tissue between the vessels is certainly rendered more transparent, and soon after assumes a distinctly reticulated character; in fact, it looks as if dotted over with lymph-globules

In ten minutes more: the circulation is still going on unequally, in some capillaries the blood is passing very slowly, sometimes single red-globules pass more quickly; the lymph-globules have accumulated in almost all the vessels. A great quantity of lymph-globules are seen in all the larger veins; they are mostly stationary, or moving only at long intervals, and in many places they appear as if actually fixed to the interior of the vessels. It requires a little nice adjustment of the focus to

see the lymph-globules in the interior of the larger veins. The same foot was now immersed in water at 104° for three seconds. The first effect was to render the circulation evidently slower in some of the capillaries, and as evidently accelerated in others. This effect soon passed off, and the circulation went on as before this second and short immersion.

In an hour after: the circulation has nearly returned to its normal condition, and fewer lymph-globules are seen in the vessels; but the appearance of the islets of tissue is as if they were loaded with lymph-globules.

I now immersed the foot in water at 102° for a longer period, twelve seconds. The first effect was an evident retardation in many of the capillaries, but not in all, and in some of the venous radicles the blood moved slowly by pulses at the rate of fifty-eight in a minute; in a few of the capillaries the circulation had quite ceased; this cessation, and the pulsatory movement in the veins, lasted only a short time. In many of the neighbouring vessels the blood was either passing irregularly by starts, or was altogether quicker.

Experiment VI.—*Feb.* 6.—I secured a frog, the circulation going on rapidly and equably, except here and there a capillary in which the motion is a little slower than in the rest. Placed the foot for five seconds in water at 105°. For the first two or three seconds the frog did not appear to feel it; it then violently withdrew the leg, and at the end of the five seconds broke the threads. On tying it again, I found the circulation slower in most of the capillaries, and the red-globules were much crowded in them; the capillaries seemed somewhat enlarged, and they were redder. I now saw all the phenomena of stopping or hesitation in the red-globules; pulsatory movements at the rate of forty-eight pulsations per minute, oscillations, and their hurried, darting, and rapid movements; during all which the lymph-globules accumulated in an extraordinary degree. The whole interior of some of the venous radicles appeared lined with them; and I saw one or two of the capillaries stopped up by them. After some time the circulation became more regular. I then sprinkled a crystal or two of salt upon the web, the effect of which was very different from that of the tepid water. The

circulation within the influence of the salt became gradually more and more languid, and at length entirely ceased; the vessels being gorged with red-globules, and consequently very red. In the surrounding vessels the circulation appeared to be somewhat quicker. After a short time the red-globules in the gorged vessels began to move, making pulsatory efforts which gradually increased in force; and at length the channel became pervious, and they then darted through, followed by a stream of others from the neighbouring vessels. There was now a bustling air of activity and restlessness in the red-globules, as they passed through the channels lately gorged; they entered them, and then stopped and retrograded, and seemed as if they could hurry about here or there. There did not appear to be any additional increase of the lymph-globules in consequence of the application of the salt, though the tissue of the web became very much more distinctly cellular.

Observation.—The circulation of the blood in the lung of a toad or a frog may be readily seen. I have on two occasions watched it for half an hour. The current is so rapid that it is impossible to distinguish the outline of the globules. I watched carefully for half an hour the circulation in the transparent membrane of several cells, but I did not see even a single lymph-globule stop or move more slowly than the rest; in fact, during the whole time of my observation I was unable to define the outline of a single globule of any kind. I thought the globules were elongated in passing through the capillaries; but there was a rapid, equable, and continued stream, passing without any retardation, until the creature was killed by dividing the spinal marrow, *when the circulation suddenly and completely ceased.** A great number of lymph-globules were afterwards seen in the blood. The diameter of the islets of membrane between the capillaries measured from $\frac{1}{700}$ to $\frac{1}{750}$ of an inch; and the diameter of the capillaries from $\frac{1}{1500}$ to $\frac{1}{1590}$ of an inch.

Experiment VII.—*March* 7.—Tied up the foot of a frog, and submitted the web to examination by the microscope; the

* The passage in italics has been erased in my notes by a pencil-line drawn through it; I believe it was so, because this effect did not follow in some of the subsequent experiments which were made.

circulation was going on at a normal rate. In one or two capillaries the motion was slower than in the rest. A few lymph-globules were seen occasionally passing along the sides of the vessels, as usual, more slowly than the red-globules. In one of the larger vessels I observed two lymph-globules together, quite stationary, one much larger than the other; the red-globules pushed by them, losing their figure, and then regaining their figure passed on. After the lapse of half an hour the circulation was in all the vessels uniform and normal. I warmed over the lamp the point of a needle, and plunged it through the web; the frog did not move in the least, and appeared quite unconscious of the wound. There was not any blood poured out. I saw no globules that had escaped or were escaping. The circulation in all the capillaries for some distance around the perforation was stopped. In the vessels beyond these the circulation exhibited all the phenomena noticed when the foot has been immersed in tepid water. In some of the capillaries the red-globules were congested and stationary; in others they were moving very slowly, oscillating to and fro; in others passing through the vessels by a pulsatory motion, the pulsations being at the rate of fifty in the minute. Here and there there were capillaries quite empty of either red or lymph-globules, while in others a few globules far apart were passing; and these would sometimes stop, oscillate once or twice, and then go back again. In some of the congested vessels the densely congregated red-globules would seem to be urged on by the pressure of the current in some of the adjoining vessels in one direction, and then suddenly, without any apparent cause, they would move off freely in exactly the opposite direction.

In a quarter of an hour: in the vessels surrounding the wound every variety of movement and every variety of fulness may be seen: in the movements from stationary to slight pulsatory motions, oscillations, and retrograde motions; and from these to quick, rapid, and darting motions; in the fulness, from complete emptiness of all globules to one or two globules, and perfect congestion.

In an hour: in all the vessels in which the normal rate and uniform motion of the circulation has been disturbed the accumulation of the lymph-globules is quite extraordinary. In

some of the larger vessels their numbers are so great that they appear almost to choke up the passage, adhering to the tissue, and being detached with difficulty by the impetus of the red-globules. In all the capillaries the lymph-globules are very abundant; some of these lymph-globules are quite double the size of others, and I can detect, besides the minute granular matter characterizing them, in some a larger kind of nucleus.

During these phenomena the islets of tissue between the vessels assume a more distinctly cellular character, and appear as if overspread with irregular-shaped lymph-globules. I could detect no alteration either in the size, figure, or character of any of the lymph-globules while observing them under the microscope, though many of them were closely watched continuously for some minutes. I could never detect any *forming* in the vessels; they appeared to come into the field of view in the current, and to adhere to the tissue of the part. The web having been exposed under the microscope upwards of two hours the circulation was still going on irregularly. A great number of lymph-globules were still rolling over or accumulated four or five together, or stationary, apparently incorporated in the fibrous textures. The tissue between the vessels was studded with globules similar to the lymph-globules. This appearance was not, however, presented by all the islets, only by some of them; others had the confused though somewhat cellular appearance of the islets in their normal state, others had the larger cellular meshes of the cuticle.

Observations.—During these and other experiments and observations, I have frequently seen the facility with which the capillaries become either a venous or an arterial channel, as the case may be. If a vein at a certain point be stopped or perforated, a course is immediately opened by the current through some of the capillaries, which speedily enlarge in diameter to accommodate it; the same thing takes place with the arteries.

On applying alcohol to the web, the circulation was affected in a different manner than when salt was applied; it was observed to cease gradually in the capillaries without any previous congestion; the vessels were quite empty of all globules, though the circulation of globules was going on briskly at either end of them. At the end of a quarter of an hour, when the circulation

of globules through the apparently empty vessels was restored, it was so by two or three red-globules, or one or two lymph-globules, passing with hesitation, singly, and far apart, at long intervals; then more in number and more rapidly; and then the vessel was filled with red-globules, which passed very rapidly. The calibre of the capillaries appeared to be diminished, and the red-globules lengthened and compressed.

On various occasions, when liquor potassæ has been used to irritate the web, I have seen both the red and the lymph-globules burst and disappear *within the vessels;* and in some of these cases, when the stimulus has not been over much, the circulation through the vessels in which this phenomenon was seen has been afterwards perfectly restored.

Experiment VIII.—*Dec.* 1, 1844.—A young frog was secured; the circulation was going on rapidly; a great many lymph-globules or colourless-cells were adhering to and sliding along the walls of the vessels. The point of a needle, a little heated, was plunged through the web. I did not see a single blood-globule escape when looking at it immediately afterwards, nor was one seen loose in the field. The hole appeared to have a thin irregular edge, and the blood made no attempt to enter the vessels near the wound, though they were plainly seen without any cells in them; it was circulating beyond these vessels, slowly in some vessels, irregularly in others, and more rapidly and regularly in others. The commencing trunk of a considerable vein had been perforated, and although it was evident, from blood-cells occasionally getting into it, that the channel was open nearly up to the hole in the web, still the column of blood in the vein made no attempt or effort to pass into it. Occasionally when globules were thrown into the empty part they returned again into the current.

In an hour: the circulation is now going on in the vessels which were before empty, and blood is passing in the capillaries quite up to the edge of the hole. The lymph-globules have accumulated in most of the venous-radicles.

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