ESSAYS

IN

MEDICAL SCIENCE.

I.
ON THE NATURE OF INFLAMMATION.

II.
ON THE ENCEPHALIC CIRCULATION, AND ITS RELATION TO THE PHYSIOLOGY OF THE BRAIN.

BY JAMES CAPPIE, M.D.,
EDINBURGH.

EDINBURGH:
SUTHERLAND AND KNOX, SOUTH BRIDGE.
SIMPKIN, MARSHALL, AND CO., LONDON.
1859.

MURRAY AND GIBB, PRINTERS, EDINBURGH

PREFACE.

In writing the following Paper on the Nature of Inflammation, I was under the impression that I had been original in conceiving, and was singular in holding, the views I have ventured to express in regard to certain parts of the process. I have opposed the opinion that is generally held in regard to the origin of those fibrinous products, that are often so abundantly presented in an inflamed part. They are usually supposed to have been directly exuded from the blood-vessels; but I have advanced reasons for considering this view of their origin erroneous, and for believing that they are immediately elaborated at the seat of inflammatory action. I find, however (from the *British and Foreign Medico-Chirurgical Review* for October 1859), that Professor Virchow of Wurzburg holds the very same view. He "denies that the fibrine found in any part of the body out of the blood-vessels has transuded from the blood." I have never had an opportunity to consult any of Virchow's own writings, and am therefore ignorant of the precise extent to which our views of the nature of inflammation may harmonise, but I need hardly say, that to find so

eminent a pathologist giving decided expression to an opinion that I had supposed would be everywhere considered unorthodox, gives me greater confidence in presenting my own Essay to the professional public. I am not aware which of us (if either of us) has a right to claim priority in giving expression to the view above alluded to. I may, therefore, be allowed to state here that I first published on the subject in the *Edinburgh Medical and Surgical Journal* for January 1854; and that in the Thesis I presented to the Senatus Academicus of the University of Edinburgh on my graduation in 1850, in speaking of the nature of inflammation, I took occasion distinctly "to question how far the plasma found in the intervascular spaces, or on serous, mucous, or granulating surfaces, is to be considered an *exudation* at all." Whether or not I may prove to be less original in my views than I at one time supposed, the Essay may be judged of as an independent contribution to a subject which is confessedly difficult, and in which there is still abundant room for inquiry and speculation.

In the Essay on the Encephalic Circulation, I have had less occasion to come into collision with other writers. I feel certain that, in advancing our knowledge of the physiology of the brain, a consideration of the peculiarities in its circulation will prove a most valuable instrument. To what extent I have been successful in the present attempt, it is for others to determine.

J. C.

18, Frederick Street, Edinburgh,
December 1859.

ESSAYS IN MEDICAL SCIENCE.

PART I.

ON THE NATURE OF INFLAMMATION.

Of the importance of the question we are about to consider, there can be but one opinion. The nature of inflammation is not a subject for merely curious speculation; it is an inquiry of the greatest practical interest. The process is one which the medical practitioner is every day called on to combat—to check or modify its progress—to remove or alleviate its effects. It is a form of disease which directly produces considerable suffering—which tends to impair or destroy structure—which imperils life itself. To determine exactly in what it consists, is admitted to be one of the most important problems that can engage the attention of the scientific pathologist. Many have been the attempts to solve its difficulties; and many also, and opposed, have been the views entertained respecting its nature. On this point great difference of opinion continues to exist among

pathologists; but this circumstance is only an urgent reason for the process being still closely investigated. There is no point in the science of medicine it is more necessary to have settled; for, if an approach to a correct theory be not arrived at, we may be sure that less philosophical, and therefore more dangerous views, will be entertained and advocated.

It is no part of our plan to describe inflammation systematically. With its symptoms, and varieties, and usual progress or tendencies, we presume our reader to be already acquainted. Our attention will be strictly confined to its essential nature, especially at the commencement of the process.

In using the terms "essential nature," we wish not to be misunderstood. We do not mean some *essence* of the disease distinct from the ultimate structures, intruding on, and, for the time being, disturbing these. The disturbance is itself the disease; and the nature of that, simply,—the methodical exposition of its elements,—is the object of our study. Strictly speaking, the pathologist has not so much to do with the abstract terms, *health* and *disease*, as with the epithet from which they are derived. He studies individuals, organs, structures, secretions, etc., as *healthy* or *diseased;* and he considers it as absurd to speak of the essence of disease, apart from structure, as it would be to speculate on the nature of virtue or vice, independently of the motives and actions of individuals. While, therefore, we have no sympathy with those who would banish the term inflammation from the medical vocabulary, believing,

indeed, that it will be almost impossible to substitute a better word in its place, we will rather study tissues as *inflamed*, than inflammation as a disease invading the tissues. We thus get rid of one difficulty, which has very unnecessarily puzzled many pathologists, that, namely, of giving a definition of inflammation. Whatever be its essential nature, the practitioner, to detect its presence, will always fall back on those symptoms which experience has proved to be most trustworthy; while the aim of the pathologist will be to explain those symptoms, by tracing the more intimate processes in which they have their origin.

It appears to be now generally admitted, that inflammation is essentially a form of abnormal nutrition. It is not simply an affection of the capillary vessels—nor a change in the blood—nor an altered action of the nerves. The whole series of changes by which the tissue is renovated is deranged. When we look at the history of opinion on this point, even such a very general view must be considered an important step in advance of previous notions. It classifies the process as a pathological condition. It gives no explanation of the phenomena presented; but it affords a satisfactory basis or starting-point for more particular inquiries. It remains to be determined in what particular respect nutrition is modified when inflammation has commenced. What the pathologist must now endeavour to give, is a *theory* of the process. He must attempt to discover what are the intimate changes which occasion those outward phenomena by which its presence is recognised. Nor, for this

purpose, is it sufficient so to explain the phenomena individually, that the several explanations have no apparent connection with one another. It is not sufficient, for example, to explain the redness, by saying there is a greater quantity of blood in the capillaries; nor to say of the swelling, that it is occasioned by the effusion of fluids from the vessels. Before the theory of inflammation can be considered complete, it must explain why the blood is increased in the capillaries, and why the effusion from the vessels is greater than natural. There must be some central truth, round which all the others radiate—some fundamental change, from which the others are derived naturally and inevitably. To arrive at some knowledge of this change, must be the aim of the pathologist.

A theory of inflammation, it is at once obvious, must be based on, or rather must be perfectly consistent with, what is certainly known of the phenomena and laws of healthy nutrition. Indeed, if our knowledge of the latter were complete and certain, it would be a comparatively easy task to determine the nature of its abnormal forms. Physiology and pathology are to be regarded as subdivisions of the more comprehensive science of biology. This takes cognizance of all the facts relating to organised structures, and its principles apply equally to the phenomena of health and disease. To arrive at a knowledge of these principles, both healthy and diseased action must be put under contribution. As a completed science, physiology might be studied by itself; but as a progressive science, this is impossible. The

phenomena of disease are so many problems that test our knowledge of physiology; and they are also so many natural experiments, giving us additional data from which to draw our inferences. They furnish facts with which the theories of healthy action must be in harmony; and, if these facts often prove views to be erroneous that were considered well established, they at the same time may suggest new ideas, which in their turn may be successfully applied in interpreting the phenomena of health. It is not necessary, therefore, to wait until the physiologist has completed his system, before investigating the nature of pathological conditions. The study of the abnormal forms of nutrition may assist in confirming or refuting particular views on those points of the healthy process on which there is still difference of opinion.

Nutrition has for its object the attainment and preservation of such a constitution to a part as fits it for efficiently discharging the duties it is destined to perform in the animal economy,—it is the process by which these objects are immediately secured. It is not a simple action. It is constituted by a comprehensive combination and succession of phenomena, and must therefore be carefully analysed before any satisfactory progress can be made in unfolding the nature of its abnormal forms. Its phenomena must be minutely studied individually,—we must, so far as is possible, become acquainted with their conditions and healthy modifications, and know the qualities and particular offices of the various structures and agents concerned in their produc-

tion. The more extended and precise our knowledge is in these respects, the better qualified will we be to judge of the nature of deviations from the healthy standard; but, if our knowledge be limited and obscure, and on many points, unfortunately, it is both, then, to a corresponding extent, our theories of morbid action must continue imperfect.

To describe nutrition, it is not sufficient to unravel the tissue,—we must describe its elements in action. So numerous are these, and so little do we know of many of them, so fleeting are their conditions of activity, and so intermixed are their effects, that it becomes most difficult to limit precisely the influence of any one element in the production of any particular result. The physiologist here finds himself in a difficulty somewhat similar to that so complained of by the historian. "It is not in acted as in written history. Actual events are nowise so simply related to each other as parent and offspring are: every single event is the offspring not of one, but of all other events, prior or contemporaneous, and will in its turn combine with all others to give birth to new—it is an ever-living, ever-working chaos of Being, wherein shape after shape bodies itself forth from innumerable elements. And this chaos, boundless as the duration and habitation of man, unfathomable as the soul and destiny of man, is what the historian will depict and scientifically gauge, we may say, by threading it with lines of a few ells in length! For, as all action is by its nature to be figured as extended in breadth and in depth as well as in length, that is to say, is based in Passion and Mystery, if we

investigate its origin, as well as advances towards completion,—so all narrative by its nature, is only of one dimension, only travels towards one or towards successive points: Narrative is linear. Action is solid."[1]

In considering nutrition, then, the first step is to make an analysis of the process. Keeping in view that our ultimate object is to ascertain or illustrate the changes that take place in inflammation, the analysis must be so general as to apply to all tissues that are liable to be affected by this disease. Nutrition, therefore, may be conveniently regarded as constituted by three phenomena, or series of phenomena. There is, in the first place, the changes in the ultimate structures of the tissue; secondly, the movement of blood in the adjoining capillaries; and, lastly, the interchange of fluids between these vessels and the extra-vascular spaces.

Something definite is known of the nature, conditions, and healthy modifications of each of these sets of phenomena. Such knowledge as we may possess must be kept steadily in view while speculating on the nature of inflammation. For our object must be to discover in what manner the various changes are affected individually, or in what respect their combination or succession differs in this state, from what occurs in the healthy process of nutrition.

The changes presented in the ultimate structure of the texture are all more or less immediately connected with the growth, transformation, decay, and reproduction of cells. At any particular moment these are to be found in all

[1] Carlyle.

stages of development. For the evolution of that progressive series of changes which constitutes their life as individuals, the principal condition is the presence of a fluid capable of furnishing them with the requisite materials of growth, and this is fulfilled by the blastema in which they are bathed, and which has been derived from the capillary vessels. On this fluid important changes are effected by any progress in the development of the cells. Some of its elements are removed by those in a state of growth; while other cells, having arrived at the term of their existence, break up, and restore to it in a different form of combination the elements they had previously separated. Circumstances are thus occasioned unfavourable to the growth of new cells. These, with a constitution similar to that which belonged to the parent cells, will be unable to separate the requisite materials of their growth, unless they are to grow differently, and have a different destination.

Looking at the texture as a whole, an important change would soon be effected on its constitution by the simple evolution of these changes. As the former constitution, however, was the source of its functional power, some means must be provided by which every change may be remedied, and the integrity of the texture preserved. The worn out particles must be replaced by others possessing the same properties, capable of being affected by the same influences, and, if necessary, of producing similar results. What is immediately required for this end is the removal of the

products which result from decay, and the supply of fresh nutritive material.

The removal of effete matters, and the introduction of the necessary plastic elements, are made mutually subservient to one another. The attainment of these two objects is accomplished by one process. The fluids containing the respective elements being only separated from one another by the thin wall of the capillaries, endosmosis, and exosmosis, must immediately take place. The albuminous fluid within the capillaries will thus pass outwards into the intervascular spaces, while the fluid in the latter, loaded with the products of decay, passes into the vessels.

This interchange having been effected, the inherent tendencies of the growing cells are permitted to develop themselves. The new supply of plastic material is at once the stimulus and the condition of growth. The least progress in this again involves further changes in the blastema. Hence a necessity arises for the fluid in the capillaries being also constantly renewed, and this is accomplished by the unceasing current of the circulation.

The physiology of the capillary circulation is a subject most difficult to treat, on account of the great variety of agencies—physical, chemical, and vital—that are in simultaneous operation to produce or modify one effect. The action of the heart, the calibre of the vessels, and the force of capillary attraction, the occurrence of vital changes, the influence of nervous force, and the conditions of osmosis, are all to be taken into account. Difficulties also arise from

the minuteness of the structures, and from the extreme rapidity with which the various and delicate changes are effected. Never had historian of exciting incident more reason to complain of the tardiness of expression, and the disproportion of time required to narrate the event, to what transpired in its actual accomplishment, than the physiologist has in explaining the apparently simple passage of the blood through the capillaries. To sustain a steady current, in addition to the impulse given by the action of the heart, growth and decay, attraction and repulsion, change and interchange, go on with inconceivable rapidity, and at innumerable points at once.

At present we restrict ourselves to a consideration of the mode in which the movement of blood may be influenced by the forces acting immediately at the capillaries. As is well known, the amount of blood transmitted through the vessels of any part, does not altogether depend upon the rate or vigour of the heart's action. The occurrence of certain changes in the parenchyma, and of a mutual action between the fluids within and external to the capillaries, is a most necessary condition to the free transmission of blood through these vessels. When nutrition is depressed, or its operations cease to be evolved, the current of the circulation is also interrupted, or it becomes completely stagnant. It is also well known that when the nutritive changes are being actively carried on, a force is exerted at the capillaries, by which the movement of blood is occasioned independently of any force acting on it from behind.

The final cause of this circumstance is sufficiently obvious. As the object of the circulation is to act as a stimulus in various vital processes, to afford materials for the formation and regeneration of the textures, and to serve as a medium for the removal of effete substances, there must be some means of so regulating the supply, that while this shall be sufficient for the wants of the texture, it will not be so great as, by its bulk or otherwise, to interfere with the proper exercise of its function. While the general current of the circulation, therefore, is sustained by the action of the heart, the local distribution of blood must be regulated by other influences. Those changes which are the occasion of the demand in particular organs, must involve the means of modifying the supply. The tissue itself, therefore, is made to exert an important controlling power over the movement of the blood. The occurrence of certain changes in the parenchyma is at once a most necessary condition and an active cause of its free transmission through the capillaries, and thus nutrition and the circulation so act and react on one another, that the activity of the former affects most remarkably the current of the latter.

The immediate agency or mechanism by which this is accomplished is very complex, and our knowledge of its operation obscure; but as altered balance of the circulation is one of the most prominent of the changes that occur in inflammation, it would be important to have even a general notion of the mode in which the operations of nutrition may at all affect the movement of blood in the capillaries.

In physical science, the phenomena of capillary attraction and those of combustion, afford instances of a current of fluid being produced, independently of the influence of gravitation, or any obvious mechanical arrangement. The conditions in which nutrition is carried on, may be regarded as involving a combination of the causes that operate in these two instances.

In combustion, the physical changes occasioned by chemical union serve, in ordinary circumstances, to bring a fresh supply of oxygen within the sphere of action. An agitation is kept up in the surrounding air, and the atoms of the burning body attract the oxygen with greater force than the heat repels it. A regular current is created and sustained, by which the combustion is fed and its products carried away. So in nutrition, an agitation is also kept up in the medium by which the organic particles are surrounded; and it extends itself, so to speak, into the adjoining capillary. An exchange of fluids takes place between the latter and the space beyond it. No sooner has this been accomplished to the slightest extent, than between the same fluids, the tendency to its continuance is weakened. We have already seen how the constitution of the blastema is soon altered by the action of the organic particles. If the supply within the vessels were limited, the vital changes would soon be suspended, just as combustion will be extinguished, if the supply of oxygen be exhausted. Within the capillaries, however, a fluid may be obtained from one direction, with which an interchange may be

readily effected. If, now, we suppose (as we are perfectly warranted in doing) that this tendency to interchange is equivalent to the simple force of attraction in rigid capillary tubes, we have the conditions for the operation of the law, that one fluid, having a strong attraction for the walls of a capillary tube, will drive before it another fluid having a weaker attraction. The wall of the capillary vessel may be regarded as neutral, so far as attraction to itself is concerned; but as a point at which exchange of fluids takes place, its influence in affecting the movement of blood within the vessel, becomes very important. If the fluids on either side were identical in composition, an attraction of cohesion would be the result, and opposition would thus be given to any *vis a tergo* that might be brought to bear on that within the capillary. But the vital operations constitute a constantly operating cause of change in the intervascular space; and the arterial blood presents a fluid capable of affording ready interchange, and of sustaining the vital processes. A constantly operating force is thus brought to bear upon the movement of the blood; and we have only to remember how numerous are the points at which it is in operation, to perceive, that in actively assisting or impeding the action of the heart, these capillary influences cannot be unimportant.

We may therefore, conveniently regard the *occurrence of interchange* as an immediate cause of the movement of blood in the capillaries. Whatever favours this phenomenon, will facilitate the transmission of blood, or increase the

force of its current. If nutrition is languid, and the blastema is in consequence slowly affected, the mutual action between the latter and the blood will be less active, and the circulation will be retarded. But if nutrition be excited, interchange will take place with greater energy, as the conditions of its occurrence are more rapidly presented. The influence exerted on the circulation will be correspondingly increased—the blood will be transmitted more rapidly through the vessels.

Such, then, is an outline of the phenomena of nutrition. It is constituted by a complete circle of changes. In the healthy process, these are all carried on, in individual textures, in a certain order of succession and combination. Each phenomenon has a certain relation to all the others. Each may be said to be the condition of all the others. Whatever interferes to modify the process at any one point, may through it affect the whole series of changes.

What nutrition is in its results we see in every texture. It confers a healthy constitution, involving a capacity for regular exercise of function. In inflammation the changes of nutrition are evolved in an abnormal manner, and the result is a wide departure from healthy appearance and structure. What are known as the symptoms of inflammation make their appearance, and the part ceases to discharge its functions efficiently. It now becomes our object to determine in what respect the constituent phenomena of nutrition are modified when inflammatory action begins.

To arrive at a knowledge of the nature of inflammation,

we must of course, in the first instance, take simple facts, so far as these go. The symptoms which are obvious to the organs of sense, and the changes determined by experiment, must be carefully observed; and, for further progress, we must trust to cautious inference. In the present Essay, nothing new need be expected as the result of observation. We will attempt a new interpretation of certain generally admitted facts, and some "false facts" we will controvert. The mode we intend to adopt is very simple. As it is our object to discover a common cause to all the symptoms, effects, or characteristics of the process of inflammation, we will take some of the more important of these, and, reasoning them individually, attempt to assign an efficient cause to each. The various inferences thus independently arrived at, can then be compared; and if we find that they perfectly harmonize—if we find, especially, that all the phenomena may be more or less directly referred to one and the same form of modified nutritive action, we may at least be allowed to claim for our views an unprejudiced consideration.

Proceeding analytically, then, the first phenomenon to which we direct attention, is the redness of the part inflamed—this redness, of course, evidently depending on an increased amount of blood in the capillary vessels. However vascular a tissue may be naturally, let inflammation commence in its substance, and immediately its vascularity becomes considerably greater. And those tissues which, in their healthy state, appear to be permeated by scarcely a

single blood-vessel, become, when similarly affected, the seat of intense engorgement. Moreover, " in parts which have no blood-vessels of their own, and yet which manifest certain of the signs or effects of inflammation, these generally, if not always, involve (as Mr Paget remarks) enlargement of the adjacent vessels, and especially of those from which the diseased structure derives its natural supply of nutritive material. Thus, in inflammation of the cornea, the vessels of the sclerotica and conjunctiva are enlarged; and, in ulceration of the articular cartilages, the same enlargement is seen in the vessels of the surrounding synovial membrane, or subjacent bone."[1]

Nor are the vessels simply distended with blood; the movement of that fluid is more rapid than usual. It may be, that if the inflammation has continued for some time, at certain points the circulation may be slow, or the blood may be completely stagnant. This phenomenon we will afterwards have to consider; but at first the circulation is much excited in all the inflamed texture. The important fact that is to be borne in mind, and of which theory must take cognizance, is, that in a given time the amount of blood transmitted through the vessels of the inflamed part, is considerably greater than in health—invariably so, if the inflammation be at all active. " The whole quantity of blood," says Dr Alison, " returned by the veins from an inflamed part (as in the case of the hand), is found to be greater, and when the inflammation is severe, to be three or

[1] Brit. and For. Medico-Chirurgical Review, Jan. 1851.

four times greater, than that returned within the same time by the veins of the opposite sound organ."

Here, then, is a phenomenon, obvious and constant, and standing in the relation of effect to the morbid action whose nature we would discover. When inflammation is at all acute in any texture, the blood is attracted more powerfully towards it, and is transmitted through the vessels more rapidly than in health. Excitement in the capillary circulation is one of the earliest obvious results occasioned by the process; and when we remember the very intimate relation that exists between the activity of the circulation and the occurrence of vital changes in the ultimate structures of a part, it seems probable, that to account for its occurrence, would at once determine the earliest step of the process,—the first deviation from the healthy order of succession in the phenomena of nutrition.

In referring to the phenomena of health for illustrations of altered balance of the circulation, we find two principal forms in which it occurs. In the one it results from an altered nervous influence affecting the calibre of the arterial vessels, as in blushing; in the other, the occurrence of more active vital changes in the tissue is the first incident in the chain of phenomena, as in the increased vascularity of the mucous membrane of the stomach, when a stimulus has been applied to its surface. In the former instance, the "determination of blood" is more or less sudden, and it is temporary or intermittent. It therefore presents no proper analogy to that of inflammation. In the other case, it is directly related

to the continuance of the vital activity, and may be indefinitely prolonged. We have already discussed the physiology of this phenomenon; and the question comes to be, is the vascular disturbance that characterises inflammation to be referred to a similar cause? Is the more rapid movement of blood in the capillaries, in this instance also, occasioned by more active nutritive changes in the parenchyma? To test this point, we require to examine how far it will harmonise with the other facts of the process, but in the meantime, we may admit its correctness. In doing so, we only assume what has been strongly insisted on by other writers. That there is, "increased action," appears to be the instinctive judgment of any one who studies its phenomena, although, recently, as we shall afterwards see, the correctness of this general view has been called in question. Dr Alison has also distinctly referred the immediate seat of excitement to the parenchyma of the parts involved, and his statements on this point may here be reproduced.

"Inflammation and its effects," says Dr Alison, "necessarily imply an alteration of vital properties, by which the constitution of the blood, its relation to the surrounding textures, and its movement through them, are determined. . . . . In fact, inflammation is only one of a number of cases of constant occurrence in the animal economy, where some particular cause (commonly, but vaguely called, a stimulus) is applied to the capillary vessels of one part of the body, and determines an increased flow of blood towards, and an increased transmission through, that part. . . . . Whether

we apply to such cases the adage, 'ubi stimulus, ibi fluxus,' or use the term 'adfluxion,' or 'movement of turgescence,' or 'solicitation of fluids,' or speak of a vital erection of vessels, they all present a phenomenon which must be studied and understood before an acurate notion can be formed of many leading facts in the history of the living body in health and disease. When air is admitted into the cells of the lungs, when food is received into the stomach, when a strong impression is made or sensation excited in any organ of sense, when an embryo begins to grow in the uterus, the increased flow into those capillary vessels where these causes act, is immediately perceived, and is essential to the important changes which follow; one result of which changes, in several of these cases, is an alteration in the constitution of the blood itself.[1]

"Inflammation," he then remarks, "consists essentially in a local increase of a vital property of attraction existing among the particles of blood and between them and the surrounding textures, and with which other vital properties are connected and simultaneously excited." The proximate cause of inflammation, he affirms, "although affecting the constitution of the blood, does not reside in the blood only, but primarily in the agency of the blood on the solids through which it passes in the capillary vessels."[2]

"The increased flow to the inflamed part, and probably the gradual relaxation of the vessels leading to it, are the consequence of these attractions, just as the acceleration of

[1] Pathology and Practice of Medicine, pp. 120, 121. [2] Op. Cit., p. 127.

the flow of blood through the lungs, on the admission of air there, is the consequence of the changes, partly chemical and partly vital, thereby brought on the blood; or, as the increased flow to the uterus during gestation, to the stomach during the digestion, or to any secreting organ to which a stimulus is applied, is the consequence, not the cause, of the vital changes to which the blood in these organs is subjected on such occasions." Dr Alison then proceeds, "When the vital properties of the blood and its relations to the living solids shall have been more carefully scrutinised, this proposition will require more precision."

If we turn to the writings of more recent authors on the subject, in the hope of finding this expectation realised, we will be very much disappointed. We are inclined to think that so far as a *theory* of inflammation is concerned, not a single step has been made in advance of the views of Dr Alison. Many facts have been added to our knowledge of its history, but the explanations have not become more satisfactory. Indeed, we may go the length of saying, that in various influential quarters, serious retrogression has been made. The remarks of Williams, Bennett, Carpenter, Paget, and Wharton Jones, have rather tended to make the theory more obscure than ever. With most of these writers vascular excitement is a phenomenon to be explained away, rather than a result which inflammation essentially tends to produce, and which, as such, must be explained. We will afterwards have an opportunity of controverting their views.

To give precision to the general notion that in inflammation there is an excitement in some part of the nutritive process, we require to take up some other effect or characteristic, and again attempt, on physiological data, to determine its probable cause.

The phenomenon, therefore, to which we now direct attention, is the increased production of fibrine. The facts on this point are sufficiently well known. In blood of a healthy constitution, fibrine is present in the proportion of, at the most, 2 or 3 parts in the 1000; but when an acute inflammation is well established in any part of the system, the proportion rises to 6 or 8 parts in the 1000 of blood, or even higher. It also accumulates, sometimes to a considerable extent, at the seat of inflammatory action. The intervascular spaces become filled, or the inflamed surface becomes furred over with it. There is, therefore, an absolute increase in the amount of fibrine in the system, and the question naturally presents itself, How is this increase to be accounted for?

Before this question can be considered, the nature of fibrine itself must be ascertained. We must know, especially, from what source it is immediately derived in the economy, and what are its uses or destination. On these points very opposing opinions are entertained by different physiologists. While some affirm that it is the most highly vitalised constituent of the blood, and one, at the expense of which the solid textures are principally nourished, others as confidently assert, that it results from the disintegration of the tissue,

that it is destined to be resolved into less complex forms of combination, and removed from the system by the organs of excretion.

As this is a most important point,—one, indeed, that must be settled before another step can be made in the theory of inflammation, the reasons may be given why we adopt the latter of these views: that, namely, which regards fibrine to be one of the products into which the tissues are resolved in their natural decay.

This opinion, first suggested by Zimmerman, has, in this country, been advocated by Professor Bennett and Mr Simon. The latter remarks in its support, "I find that fibrine is undiminished by bleeding, however frequently repeated: nay, that it often or even usually increases under this debilitating treatment: its highest figure, given in Andral's book (10·2), was at a fourth bleeding; and Scherer found it as high as 12·7 at the third venesection in a case of pneumonia. I find that under many other circumstances of exhaustion and weakness and inanition, during the progress of starvation, during diseases essentially anœmic, during violent fatigue and the like, its proportion has been found at least as high, perhaps higher, than in the inflammatory process. And, in these respects, I find its proceedings to be in direct contrast with that of the red globules (which we know to be potential elements in the blood, and which are at once reduced by bleeding or starvation), so also do I find a similar contrast in another striking particular. Messrs Andral and Gavarret, in the course of their extensive researches in the compara-

tive physiology of the blood, ascertained that an improvement in the breed of an animal tended always (*ceteris paribus*) to increase the proportion of its coloured blood-corpuscles; they found that the same improvement tended likewise to diminish the proportion of its fibrine. And, I find further indications of the same inverse ratio between the fibrinousness and the perfection of the blood in the facts,—that there is little or no fibrine in the blood of the fœtus, none in the egg, none in the chyme, and less in the blood of carnivora (who feed on it) than in that of the herbivora."[1]

The property which fibrine possesses of becoming solid when the blood is removed from the body has usually been regarded as a tendency to become organised, and this circumstance has no doubt produced a strong impression in favour of the opinion that it is endowed with higher vital powers than albumen. There can be little doubt that the peculiar constitution to which fibrine owes its coagulating property, cannot be unimportant in the economy, but the act of coagulation itself appears to be a physical, rather than a vital, process. The particles are simply precipitated, their attraction is mechanical, and the resulting structure is extremely homogeneous. The process, therefore, resembles as much the formation of a crystal as the growth of a tissue.

Dr Carpenter, though vehemently opposed to what he calls the "extraordinary hypothesis" that fibrine may result from the disintegration of the tissues, has so far modified his views of its nature as to "limit its *histogenetic* value to a

[1] Lectures on General Pathology, pp. 50, 51.

certain class of tissues, namely the gelatinous." To this opinion it may be objected that, in the first place, we would hardly expect a constituent of the blood to become more highly vitalised, in order to afford nutriment to those tissues which are least characteristic of animal structures: and, in the second place, it would prove that in these tissues the assimilating power is to a great extent taken away from the cells, that the tissue is not elaborated by the latter, but that its nutrition is mainly dependent on the physical aggregation of particles, how attracted through the walls of the vessels not being very apparent.

Again, in regard to the same "extraordinary hypothesis," Dr Carpenter remarks, that "it appears to be directly negatived by a comparison of the condition of fibrine with that of the known products of the disintegration of the tissues, such as urea and creatine, in which we see a marked tendency to the reproduction of purely physical modes of molecular aggregation, to the exclusion of those of vitality."[1] Now, Dr Carpenter himself regards fibrine as a "transition" product, and we submit it may be held an open question whether its natural progress is towards the development of a tissue or the formation of excrementitious products. We have stated above some objections to his opinion, that "fibrine is in a state of transition towards the fibro-gelatinous textures,"[2] and we would now add a single argument in favour of the other view.

While it is true that the form in which the products of decay are immediately removed from the system is that of

[1] Principles of Human Physiology, 5th edit., p. 193. [2] Op. cit. p. 192.

substances possessing the physical properties of inorganic matter, and when the tissue is dead, any change that takes place in it is of a purely physical or chemical character, it by no means follows that in the living tissue disintegration involves such complete disorganisation as is implied in the immediate formation of urea and carbonic acid. It is as easy to suppose (and it appears to us far more probable) that in many instances the ultimate structures are simply dissolved and received into the circulation in a fluid state, as that there is only one step between the condition of living organised structure and that of substances exhibiting "purely physical modes of molecular aggregation." The immediate result, we believe, will greatly depend upon the extent to which the disintegrating particles are exposed to the action of oxygen. In the muscular and nervous tissues, whose functional power is dependent on the union of that agent with the elements of their structure, reduction of the latter may at once be most complete, and substances may be formed and introduced into the circulation which are not simply innocuous, as fibrine is, but which require immediate elimination from the system. But when disintegration of a tissue, cellular or fibrous, takes place independently of such direct or powerful action of oxygen, we would suppose fibrine to be one of the substances into which it is resolved. Being introduced into the circulation, it is there brought under the influence of the red corpuscles, and if we may so speak, its further reduction is accomplished at leisure.

This view is confirmed by the proportion which, as a rule,

the amount of fibrine in the blood holds to that of the red corpuscles. Both comparative physiology and the facts of pathology appear to prove that they bear an inverse ratio to each other. We generally find that, when one of these constituents is present in greater quantity than usual, the proportion of the other is diminished. In individuals in very robust health, and in carnivorous animals, the proportion of red corpuscles is higher than the average in the human subject, and that of the fibrine is diminished; while in weak, scrofulous, or chlorotic individuals, in leucocythemia, and in herbivorous animals, the proportion of the corpuscles is diminished and that of the fibrine is increased. Now, while it appears difficult to explain these facts, if we regard fibrine as the most highly organised ingredient in the blood, the explanation becomes comparatively simple if it be regarded as a product of decay. The one is directly related to the other, as effect to cause. Before the fibrine can be removed from the system it must become oxidised, and reduced to several principles of less complex composition than itself. Then, as the red corpuscles are the "oxygen carriers," the facility with which it may be decomposed will entirely depend upon the proportion in which these exist in the blood. Let them be increased in number, and the other will be more readily oxidised; but let them become diminished, and an important condition of the fibrine being converted into urea and carbonic acid will be seriously interfered with, and its increase in the blood must be the natural consequence.

Assuming, then, that the principal source of fibrine is the disintegration of the tissues, we are in a position to discuss how its increase, as the result of inflammation, is occasioned.

Obviously we must look for the cause of its increase to one of two sources. Either the process by which it is primarily formed is so excited that a larger quantity is produced, or that by which it is removed from the blood is interfered with, while its formation goes on as usual.

We have no sufficient reason to suppose the latter view to be correct. The proportion of the red corpuscles is indeed diminished, but not so uniformly nor to such an extent as to account for the quantity of fibrine increasing so largely and so rapidly. Moreover, this view would in no way explain the great local increase at the seat of inflammation.

We are led, then, to suppose that some excitement must exist in the process by which fibrine is usually produced, and a more particular inference at once forces itself on our judgment. As inflammation is essentially a local disease—as it is constituted by changes occurring in a circumscribed portion of the system, and the increased production of fibrine, therefore, must depend on local causes—the fibrine itself must be elaborated in greater quantity at the seat of inflammatory action. It is naturally derived from the intervascular spaces, these, where inflammation exists, must furnish more than their usual amount. Its increase in the circulation will be the natural and necessary result of its increased local production.

And how can the tissues produce a greater amount of

fibrine? Let us suppose that it is a secretion which it is the natural function of the tissue to produce, and which, instead of being carried away by a channel of its own, must be received into the circulation. If we were wishing a circumscribed portion of any tissue to produce it in greater quantity than usual, we would simply require to adopt such means as would cause the changes of growth and decay to go on faster than usual. The ultimate elements of the texture must be produced more abundantly, or pass more rapidly through the series of changes that ends in their dissolution.

Unless our reasoning be proved to be inconsequent, we must hold that this is actually what takes place in inflammation. In one important point, however, such an inference is directly opposed to opinions almost universally held. For, it has always been assumed that the local increase of fibrine has been owing to its direct exudation from the blood. All writers on the subject, however much they may differ in interpreting the other phenomena of the process, seem to agree in regarding this as a matter of fact.[1] Dr Bennett affirms it is a "demonstrative fact," and he speaks of it as one of the phenomena actually observable by the microscope. If it be a fact so capable of demonstration, of course, it will, with the usual stubbornness of its genus, remain unaffected by any argument of ours to prove the contrary. It is to be remembered, however, that medicine is

[1] So I believed when the above was written. I understand, however, that Professor R. Virchow is also opposed to the opinion that fibrinous exudations can take place. See preface to this volume.

proverbial for its number of "false facts," and we cannot help thinking that the explanation usually given of the local increase of fibrine in inflammation is erroneous. We reserve the objections that may be urged against it till we come to consider the views of Professor Bennett. At present we only point out how entirely consistent our own explanation is with the deduction we had previously made in regard to the greater vascularity. To account for the increased production of fibrine, we have arrived at exactly the same modification of the nutritive process that we assumed to be the cause of the vascular excitement. Both are to be referred to more rapid or more numerous vital changes occurring in the ultimate structures of the tissue inflamed.

We need not do more than allude to the satisfactory manner in which the increased heat and tenderness of the part may also be explained by the same views. If the vital operations are carried on with greater activity, chemical changes must also be taking place with increased rapidity, and a greater amount of heat will be thereby evolved. The vascular excitement, and the increased tension of the parts in which they lie, will exalt the functions of the nervous structures, and render them more susceptible of impressions.

As we are not writing an Essay on the whole process of inflammation, we need not dwell in detail on its further stages, nor on the manner in which it is modified by the nature of the texture involved. The germs of all the varieties of cell and corpuscle detected in the so-called exudations, have been derived more or less directly from the tissue

itself; but, on a consideration of their development or degeneration, we do not at present enter. It is sufficient, in the mean time, if our views are not opposed by any of the facts established in regard to the subsequent changes. We think, however, that further explanations will rather be facilitated.

The preternatural excitement cannot long continue without involving very important consequences. The most remarkable fact to be noticed in connection with normal nutrition is, that notwithstanding the innumerable changes carried on in the ultimate structures, essentially the same constitution is preserved. In inflammation the conservative power is destroyed. The production and development of the cellular elements take place too rapidly to allow that gradual and regular transformation necessary for the formation of the more complex tissues. The general rule, that the greater the rapidity with which a tissue is formed, it is the more liable to degenerate, soon becomes well illustrated. The resulting tissue is of a low type of development. The evidences of vitality soon become less marked; and, at length, if the inflammation be severe, nutrition becomes entirely suspended. The current of the circulation first becomes languid, then it oscillates, and at last becomes completely stagnant. These evidences of decay are the natural and inevitable result of the excitement that characterized the first stage.

In healthy nutrition, the removal of the products of disintegration, and the introduction of the materials of reproduction, are, on the whole, directly related to one another.

In inflammation, the fibrine is elaborated more rapidly than it is being introduced into the circulation. Its amount increases in the intervascular spaces; and it thus soon interferes with the nutritive process—the vital operations are depressed. The conditions for the occurrence of interchange become less favourable, and, in consequence, the circulation will begin to flag. The globular constituents of the blood will accumulate in the capillaries, because the mutual action between these and the tissues is less energetic, and the fluid portion of the blood will be more readily affected by the action of the heart. In proportion as the vital changes become more languid, the circulation will be slower; if the former be suspended, the latter will become completely stagnant. An attraction of simple cohesion, rather than a tendency to interchange, will exist between the fluids on either side of the capillary wall.

Of the phenomenon of stagnation, we think far too much has been made. A prominence has been given to it in discussions on the nature of inflammation, that it does not deserve. It has been generally assumed, that no action can strictly be called inflammatory, until the blood has become stagnant in the capillary vessels. Now, we are not prepared to admit that it occurs in the active stage of the process at all. We cannot believe that the blood is stationary in the vessels we see so intensely engorged in acute conjunctivitis, or that the fiery appearance and feeling of the skin in erysipelas is due to impaction of red corpuscles in distended capillaries. It will require more than the demonstrations

of the microscope, on a comparatively structureless membrane, to convince us that such is the case. We believe that stagnation and acute inflammatory action are incompatible. The former is a result of the latter, and not a preliminary stage nor essential constituent. Some confusion has arisen on this point from too exclusive a regard to the revelations of the microscope. The attention of pathologists has been too much concentrated on these, while broad general truths have been too much overlooked. We are very sceptical as to the power of the microscope to detect, or even to throw much light on, the nature of the process. The phenomena observed are by no means uninteresting, and, indeed, are necessary to complete our knowledge of the natural history of the disease. But they appear rather to furnish materials for further minute, but comparatively unimportant speculation, than to afford any explanation of more obvious phenomena.

To account for the stagnation of the blood various theories have been entertained, and much discussion occasioned. No efficient physical obstruction can be detected in the vessels, and yet the cause must be a local one. We must here again consider the influence of the structures external to the capillaries. As the increased vascularity of the early stage of inflammation was referred to an excitement in the operations of nutrition, so stagnation of the circulation, when present during the latter stage, will depend on these being in the first instance suspended. The current will thus be interrupted, not so much from the operation of any

new physical impediment, as from the mere absence of the force which assisted the movement of the blood during the healthy state of nutrition.[1]

Before proceeding to discuss the opinions of other writers respecting the intimate nature of inflammation, we may look at those we have expressed, in their bearing on the rational treatment of the disease. A theory of any morbid process is important, according as it affords an explanation of the mode in which remedial agents operate in checking its progress and removing its effects. We are inclined to think that the views we have expressed respecting the nature of inflammation, will, to say the least, admit of as wide an application in this respect as any of the more prevalent theories on the subject.

A review of the sequence in which its phenomena occur, will serve to show how every means which prevents the free determination of blood to the seat of inflammation, will tend to lessen its intensity and favour resolution. The local

[1] I expressed myself as in the above paragraph in Jan. 1850 *(Edin. Med. and Surg. Journal).* Towards the latter part of the same year, the *Manual of Pathological Anatomy*, by Dr H. Jones and Dr Sieveking appeared, and a similar account of the *stasis* of inflammation is given in that work. "Our limits forbid discussion," writes Dr Jones, "and we, therefore, simply pass on to state our own opinion, so far as we may venture to offer one on this *questio vexata.* We saw reason to believe that the tissues, in virtue of their nutritive power, exercised an influence on the movement of the blood; that in active hyperœmia their attractive force was increased; and we would now add, that it is through the failure of this nutrition power that we believe stagnation takes place," p. 109. The same explanation has since been adopted by Dr Carpenter and other writers.

vascular excitement is at once the consequence and the condition of the process. The supply of blood is simply in proportion to the demand for it. A diminution in the amount of the former, therefore, must inevitably interfere with the operations that occasion the latter. The evolution of the various changes by which it is constituted, cannot be carried on with the same degree of vigour if the nutritive materials be less readily supplied, and thus an opportunity is afforded for the balance of nutrition being restored. The vital operations are retarded, and the natural termination of the process more speedily effected, either in consequence of an essential stimulus being withdrawn, or, the condition of free and immediate interchange not being present, by the fibrinous products of decay accumulating more readily in the interstices of the tissue.

Assuming that our object is to arrest the progress of inflammation by modifying the supply of blood to the part affected, the question arises, How is this to be accomplished most effectually, and with least expense to the vital resources of the system? Shall we diminish the entire volume of blood, or lower the action of the heart, or derive the blood to other parts? To assist us in resolving this question, an important point in the general pathology of inflammation requires to be borne in mind.

"There are none," says Dr Alison, "who resist the exciting causes of inflammation so well as those in whom the blood is abundant and the vascular system vigorous. But the tendency to inflammation is remarkably given by all

permanent causes of debility, by imperfect nourishment, impure air, long continued heat or cold, excessive evacuations, and intemperance."

At first sight it might be supposed that these statements bear directly against our own theory of inflammation. We have regarded the process, in its acute stage, as essentially one of excitement; and how is it, therefore, that it is not most readily produced when "the blood is abundant and the vascular system vigorous?" A closer consideration of the subject will prove that our views are in entire harmony with the conditions that regulate the local distribution of blood. The "permanent causes of debility" diminish the power of nutrition to preserve the equilibrium of the circulation, and, therefore, favour the more free determination of blood to the seat of inflammatory action.

A constant antagonism is exerted between all parts of the body in relation to the circulation. If A and B are supplied with blood from one vessel, the amount which A will receive will not altogether depend upon the amount of stimulus applied to it, but also on the intensity of the attractive force operating at B, and on the facility, therefore, with which the latter will permit itself to be deprived of a portion of its supply. And so, in the general system, it is not only the amount of stimulus applied to an organ or texture which determines the amount of blood it shall receive, and, consequently, the effect that will be produced on nutrition. The result will greatly depend on the degree of force required to derive that fluid from other parts of the body. The

readiness with which the latter may be deprived of their natural proportion of blood, will have an important influence in aggravating or repressing the tendency to local excitement,—in favouring or counteracting the influence of the stimulus. If the operations of nutrition in the system generally be vigorous, the textures will with difficulty be deprived of their natural supply of nutritive fluid; but if nutrition be languid, and the attraction for blood be in consequence feeble, the latter fluid will, with comparative facility, be determined in greater quantity towards any point at which operations causing a stronger attraction for it have been excited. This must be at least one of the reasons why, in enfeebled constitutions, inflammation takes place with greater certainty on exposure to its exciting causes.

In the treatment of inflammation, then, the object must be to restore at the same time the balance of the circulation and that of nutrition. And we can readily suppose that in favourable cases, blood-letting, by moderating the supply of plastic materials, may often have a very powerful influence in "disposing to a favourable termination," or even in "cutting short" the morbid action. It is also obvious, however, that it cannot generally be trusted to for restoring the balance of nutrition. The loss of blood will tend to exert a depressing influence on this process throughout the system generally, as well as at the seat of the disease. It may also happen, that at the latter part the operations are still *relatively* more active than at other points, and thus inflammation may go on unchecked, or it may even be aggravated.

In the majority of instances, then, our object will be more efficiently accomplished by stimulating nutrition in other parts of the system, and so causing an increased amount of blood to be determined towards them. Not the least important means of doing so is to act on the various organs of excretion. A beneficial effect is thus produced in two ways; 1st, by directly affecting the balance of the circulation, and deriving the blood from the seat of increased action towards other parts, for example, the mucous surface of the intestines; and, 2d, by eliminating impurities from the blood, and so removing one source of depressed nutritive force in the system generally.

In some cases tonics may be employed to modify the distribution of blood. Their action, in this respect, is remarkably illustrated by the action of quinine in the cure of intermittent fever. In the latter disease the diagnostic phenomena are associated with, if not occasioned by, general disturbance in the balance of the circulation at regular intervals; and this, again, is connected with a weakened state of nutrition in the system. At the commencement of a fit of ague, a less amount of blood than usual is determined to the surface and extremities of the body, while congestion takes place in the internal viscera. Now, as there is no obvious physical or biological cause for the occurrence of this phenomenon, and we are consequently ignorant of any action to subdue or counteract, the rational mode of treatment must be to adopt such means as will tend to preserve the equilibrium of the circulation. If, by the introduction into the blood of

any substances having an irritating or stimulating effect on nutrition, we can cause that process to be carried on more vigorously, then, on the one hand, the attraction for nutritive fluid is rendered stronger, and the textures are deprived of their supply of blood with less facility ; and, on the other, the tendency to passive congestion is counteracted. If, in this way, the simple equilibrium of the circulation be preserved, the characteristic phenomena of the fit of ague will be prevented from manifesting themselves. And such we believe to be the *modus operandi* of quinine and arsenic in its cure. They act on nutrition generally, and cause its operations to take place with increased vigour. Their influence is exerted, in the first instance, on the ultimate structures of the texture, rather than directly on the blood vessels. In most cases of acute inflammation, however, the system is not in the condition most favourable for the administration of tonics, and the medicines, therefore, that have a derivant or eliminant effect will be most likely to prove beneficial.

As the theory of inflammation we have ventured to advance, differs widely from that of any other writer on the subject, we may now employ the less pleasant, but not less legitimate, means of showing the correctness of our own position, by pointing out the weakness of those to whom we may be opposed. It unfortunately happens that we are thus brought into collision with writers whom we hold in the highest respect and admiration. Indeed, we will have occasion to mention none to whom we are not in many re-

spects indebted. It would unduly extend our Essay to examine in detail all the varied and opposed opinions that have been entertained respecting the nature of inflammation; but there are some authors of the present day, whom, from the deservedly high position of their writings, it would be uncourteous, if not pusillanimous, not to notice. If we expose ourselves to the charge of presumption in entering the lists against such authors as Carpenter, and Paget, and Bennett, and Williams, we can only say that such a feeling has often pressed strongly on ourselves. We must adventure the risk, however, deeming it hardly necessary to premise that nothing is further from our intention than to question the talents, or to aim at the reputation of any one. We attack particular opinions only; but in regard to these, if our blows are puny and ineffectual, they are given, we may confess, with hearty intent to do as much damage as possible.

We proceed first to examine the theories advanced by Dr Carpenter and Mr Paget. These authors resemble one another very closely in their views of the essential nature of inflammation, and both take up a position on this point, almost diametrically opposed to that of Dr Alison. They insist strongly that the evidence by which the notion of increased action has been supported, is fallacious; and, going with a bound to the opposite extreme, they proclaim diminished or suspended nutrition—diminished formation force —to be characteristic of the process. Their statements and arguments we will require to examine a little in detail.

"An examination of the very nature of inflammation,"

says Mr Paget, "may best be made in the form of a comparison of its effects with those of the normal process of nutrition. And this comparison may be drawn with two principal views; namely, to determine, 1st, how the effects of inflammation differ in respect of *quantity* from those of the normal process; and, 2d, how they differ from the same in respect of *quality* or *method*." [1]

We are not convinced that this is a very fair or scientific mode of putting the question. "Quantity" and "quality or method" of what? The effects of inflammation? Then the whole effects, local and general, must be observed and compared with those of health. But Mr Paget restricts his attention, in the first place, to the "quantity of the organic formation effected during the inflammatory process *in the proper substance* of the inflamed part." This he finds "is evidently less than in health;" and "the impairment or suspension of the nutrition of the proper substance of the inflamed part," is the first characteristic of the inflammatory method of nutrition. In the second place there is "the production of a material which may be peculiarly organized," and the second characteristic of inflammation is "the exudation from the blood of a material more than sufficient in quantity for the nutrition of the part, but less than sufficient in its capacity of development." The general conclusion he arrives at, "as well from the productive, as the destructive effects of the inflammatory process," is, that "it is accompanied with a small expenditure of vital force."

[1] Lectures on Surgical Pathology, p. 430.

We are inclined to think that Mr Paget entirely mistakes the sense in which the expression, "increased action," is used. We are not aware that any one has supposed there is any "increased formation in the proper substance" of the inflamed part. In pneumonia, for example, there is certainly no increased formation of pulmonary tissue, but its obliteration. No one doubts that inflammation is a depraved form of nutrition, that it is of a lower type than the healthy process, and that its tendency is to lower the vitality of the tissue or organ affected. "The tissues become soft or quite disorganized; they are relaxed and weakened; they degenerate and remain lower at once in structure, chemical composition, and functional power; or else, after degeneration, they are absorbed, or are disintegrated or dissolved and cast out; they die in particles or in the mass."[1] But it by no means follows that the inflammatory process itself is "accomplished with a small expenditure of vital force." That force may be so mis-directed that the more intense the action is, the more rapidly and completely will its destructive effects be produced. Both Dr Carpenter and Mr Paget in considering this question, have overlooked the broad distinction that should be drawn between the vitality of an organ or tissue *as a whole*, and the exercise of vital action in certain of its compound particles. Increased vitality should be synonymous with increased healthfulness, and every sort of abnormal action may be regarded as an indication of decreased vitality, either in the individual or in the

[1] Paget's Lectures on Surgical Pathology, p 431.

organ; but increased vital action may be partial, and tend essentially to the degeneration and death of the part affected. On this point, however, we have already enlarged in a previous part of our Essay.

We are rather surprised to observe that these authors are inclined to associate only increased formation of the proper tissue of the part with the expression, "increased action." We would ask whether the very highest form of vital action that is presented in the animal system, is accompanied with "increased formative force?" Or do Dr Carpenter and Mr Paget suppose, that when the muscular and nervous systems are in active exercise there is then no "increased action" as compared with the previous condition of rest? In speaking of the muscular and nervous textures, Dr Carpenter says, "their existence as living structures appears terminable at any time by the exercise of their functional powers; for the development of muscular contractility or of nervous force seems to involve, as its necessary condition, a metamorphosis (so to speak) of the vital power which was previously exercising itself in the nutritive operations; and the materials of these tissues, now reduced to the condition of dead matter, undergo those retrograde changes which speedily convert them into excrementitious products."[1] Now, what would be the result if this mode of nutritive action were allowed to go on unchecked? We may allow Dr Carpenter to state what it is in the case of the brain, when the functions of the latter are kept too long in con-

[1] Principles of Human Physiology, fifth edition, p. 318.

tinuous exercise. "In all these cases (of entire absence of sleep) the preponderance of the destructive processes over the constructive, manifests itself in the exhaustion of the mental and bodily powers."[1] And what does this "exhaustion of mental and bodily power" indicate? Evidently what Dr Carpenter avers respecting the part affected with inflammation,—that "its vital power is depressed rather than exalted." We may also safely assert, that in the production of this condition there has been "a diminution of the formative activity of the tissue." Are we then to go a step further, and say that the form of nutritive action in the brain which constitutes the exercise of function, "is accompanied with a small expenditure of vital force?" We believe neither of these authors would admit the correctness of any such inference, and yet, in the case of inflammation, they make a similar inference on precisely analogous data.

Inflammation may be regarded as bearing the same relation to nutrition as acute mania holds to the normal exercise of mind. The ravings of the maniac are not supposed to indicate an increased development of the mind itself, but they certainly express, in a certain sense, increased mental action. Certain mental states are more rapid, more intense, or more prolonged than can occur in healthy mental exercise; and yet the mind, in its highest sense, has ceased to exercise its functions. So in inflammation, the function of the part is suspended, nutrition of the tissue, as a whole, is also suspended, but certain steps or stages of the act of

[1] Op. cit, p. 641.

nutrition take place more rapidly than usual, and are out of the normal proportion to the others. The expression of this activity is shown, not in the greater development of the proper tissue of the part, but in what are usually spoken of as the symptoms or signs of inflammation.

Of these symptoms Dr Carpenter and Mr Paget make very short work. "It may be said," says the latter, "that the signs of inflammation are signs of increased action. But these are fallacious, if again by increased action be meant any increased exercise of vital force." "The redness and swelling of the inflamed part indicate the presence of more blood; but this blood moves slowly; and it is a quick renewal of blood, rather than a large quantity at any time in a part, that is significant of active life.'[1] Here, as may be expected, we are not prepared to admit Mr Paget's facts. We insist that the active stage of inflammation is characterised by "a quick renewal of blood." This is an inference that must force itself almost irresistibly on any one who observes the phenomena of the early stage of inflammation, and it is one which experiment abundantly confirms.

In Mr Paget's work there is a wood-cut representing "the two ears of a rabbit, of which one was inflamed by thawing it after it had been frozen. The rabbit was killed when the ear was in the height of inflammation, and the head being injected, the two ears were removed and dried. A comparison of the ears, or of the drawings from them, shows all the arteries of the inflamed ear three or four times larger

[1] Lectures, p. 433.

than those of the healthy one, and many arteries, that in the healthy state are not visible, are in the inflamed state brought clearly into view by being filled with blood."[1] To suppose that this enlargement of the vessels could take place from "diminished formative force" in the part, or from "diminished vitality of the arterial walls," is to set at defiance the laws alike of physics and physiology. In a part situated as the ear is, a slow circulation, diminished support to the column of blood, and depressed *vis a fronte*, would inevitably cause the amount of blood in the vessels to be less than natural. The mere influence of gravitation would ensure this result, and the more completely the vessels have lost their tone, the more readily would they be emptied of their contents.

Again, Mr Paget refers to "Mr Lawrence's well known and instructive experiment. In a patient with an inflamed hand, he made similar openings into veins in both arms. From the veins on the diseased side, three or four times more blood flowed than from the vein in the healthy arm in the same time." This reference, however, is made in connection with the observation, "that the stagnant or retarded blood is not apt to coagulate!"[2] He adds, however, and more to the purpose, "this increased flow represented at once the greater determination of blood about the focus of the inflammation, and the greater tension in which the walls of the blood-vessels, and, indeed, all the tissues of the inflamed and swollen part were held;" but he makes no attempt to

[1] Op. cit., p. 295.

[2] Ibid., p. 310.

explain the greater determination of blood, nor the increased tension of the vessels.

The next symptom examined is "the local increase of heat." This, says Mr Paget, "is too inconstant to afford grounds for judging of the nature of inflammation."[1] When manifest, he thinks it may partly be due to the "quickly moving blood around the inflamed part communicating its heat to that which is moving more slowly." "Some of it is probably due to the oxidation of the degenerating tissues." "Still, in relation to the question, how far the increased heat is a sign of the quantity of formative force that is being exercised, we may argue that as the general supply of heat in our bodies is derived from oxidation, or combustion of wasted tissue or of surplus food, so in these local augmentations of heat, the source is rather from some similar destruction of organised substances, than from increased formation of them." Now we are not inclined to question that there is increased oxidation going on during inflammation, but what we would insist on is, that every change is one of vital action. The oxidation is not so direct as in simple combustion, neither does it resemble eremacausis. The change is essentially vital—as much so as that "destruction of organised substance" involved in the exercise of muscular or nervous tissue; and, therefore, whenever we have increased local heat from increased oxidation, there also we must of necessity have increased vital action.

The pain that accompanies inflammation is a symptom

[1] Op. cit., p. 433.

to which Mr Paget scarcely alludes, and which Dr Carpenter notices as follows:—"And lastly, with regard to the unusual tenderness of inflamed parts, this is obviously due to such a combination of causes, neither of which can be legitimately held to indicate an increase of its proper vital activity, that nothing can be rested on this alone; especially as we see an augmentation in the susceptibility of the sentient nerves, under many circumstances (as in hysterical disorders), in which, far from an *augmented*, there is obviously a *diminished* activity in the parts from which they spring." This is all he says respecting it, and a sentence less clearly expressed, or an inference less logically drawn, we think it will be difficult to find in all the other writings of Dr Carpenter. No one seeks to rest anything "on this alone." It is only one of a multitude of effects all pointing in one direction. The pain of inflammation, unlike that arising from "hysterical disorders," is regulated by certain well-known conditions. Especially it is influenced by the greater or less difficulty with which the tissues yield to accommodate the effusion. When the parts are easily distended the pain may be trifling; when this is effected with difficulty, and greater pressure is in consequence exerted on the nervous filaments, the pain is intense. "Inflammation of bone is more painful than inflammation of skin, and erysipelas is more painful than inflammation of mucous membranes; inflammation of fibrous and serous membranes more painful than either."[2]

[1] Principles of Human Physiology, 5th edit., p. 342.

[2] Miller—"Principles of Surgery."

Now, if in inflammation there be depressed vital action, how is this increased outward pressure produced? What new physical or physiological force is called into existence, that can cause greatly augmented effusion from the vessels, in spite of strong opposing physical conditions? We would have supposed that all the constituent phenomena of nutrition would be more easily checked than usual, when the process itself had become depressed.

Not only in the circumstances, but in the nature of the effusion, we have evidence of vital action more powerful than that of health. The materials effused are all those which, in the healthy state of the parts, are required to repair the organic structure. In healthy nutrition, the amount and nature of these are dependent on, or regulated by, the vigour or mode in which the process is being carried on. According to Dr Carpenter and Mr Paget, however, no such relation exists in diseased nutrition. The quantity of nutritive material determined towards and effused from the vessels, is independent of the demand for it, nor do they give any reason, physical or vital, for such an occurrence.

Among those who have written on inflammation, none have expressed themselves more decidedly in regard to its nature, than the zealous professor of the Institutes of Medicine in the University of Edinburgh. Dr Bennett has embodied his views in a definition, on the correctness of which, as is well known, he insists very strongly. Inflammation, he says, is "exudation of liquor sanguinis." Exudation "is

the essential phenomenon—the *sine qua non* of the process." He contends, indeed, that "the word inflammation ought to be banished from medical language, and exudation substituted for it. This (he believes) is what the progress of pathology is slowly but surely bringing about."[1] To Dr Bennett's views, however, the objections that may be raised are neither few nor trifling. As a definition of inflammation, we regard his proposition as narrow, unscientific, unproductive, and incorrect; and we have further to complain that, of inflammation as a process, he has, strictly speaking, no *theory* at all.

In the first place, we have to consider what the definition of a process like that of inflammation ought to consist of. It must, we think, be made to accomplish one of two objects. First, it may give such a summary of the symptoms as will enable any one to recognise its presence; or second, it may be a statement of the perverted vital action in which these symptoms may be supposed to have their origin. The one definition is descriptive, the other explanatory;—the one is diagnostic, the other scientific. As the latter must necessarily include the former, it would, no doubt, be considered the more important, but if we test Dr Bennett's definition by the mode in which it fulfils either of the indications we have mentioned, it appears completely to fail.

Supposing exudation to be a matter of fact, how is its occurrence to be immediately recognised in practice? Would our acceptance of Dr Bennett's definition assist us

[1] *Edinburgh Monthly Journal of Medical Science*, December, 1850.

in the diagnosis? Would the question, what are the symptoms of exudation, be more easily answered than the other, what are the symptoms of inflammation? We think, not in the least. The ordinary, and by Dr Bennett, too much slighted combination of symptoms,—the *rubor et tumor, cum colore et dolore*,—or, according to the part affected, the physical and rational symptoms which we know from experience to indicate its presence, would still require to be trusted to. The physician or surgeon can lead us to the bed-side, and by a simple appeal to certain readily recognised phenomena, can declare authoritatively, *there* is inflammation. The problem he then puts to the pathologist is not, what is the essential phenomenon (in the limited sense in which these terms are used by Dr Bennett), but what is the essential condition—the first cause—of these effects? There must be some relation of these symptoms to a modified form of vital action in the tissue,—can that relation be traced? He does not require any other definition than that he has been accustomed to, but he wishes to have a theory or explanation.

The latter requirement, however, Dr Bennett's definition does not provide for. It explains scarcely anything. It gives an opinion in regard to the nature of inflammation, in so far as it gives prominence to a presumed step of the process, but it gives no theory of the process itself. By "essential phenomenon," Dr Bennett simply means a certain stage of the process, anything short of which does not constitute inflammation. He makes no attempt to shew

how exudation is related to the phenomena that occur before it; neither does he point out how the symptoms by which we recognise the presence of inflammation are related to exudation. The only symptom it may, to a certain extent, explain, is the swelling ; nothing else. Neither the vascular excitement, the heat, nor the tenderness, nor the general constitutional disturbance, can be referred for their cause to the mere occurrence of exudation.

If Dr Bennett's definition, then, neither assists in the diagnosis, nor explains the symptoms of inflammation, we may suppose that its recognition as a fact in pathology, must be a most important point to be remembered in the treatment. So Dr Bennett believes, but the benefits he speaks of as likely to arise from its acceptance are, we fear, far from encouraging. "In practice," he informs us, "it is often very important to check an exudation, but no means have yet been proved to do so." In contrast with this statement regarding *exudation*, Dr Alison affirms that, "under favourable circumstances *inflammation* is more completely under the control of remedies than any other diseased state." What can be the cause of this discrepancy of statement? The condition to which Dr Alison applies the term inflammation, cannot, surely, be the same as that which Dr Bennett calls "exudation." A consideration of the whole scope of Dr Bennett's writings on inflammation tends to confirm this view. Dr Alison regards inflammation as constituted by "a combination and succession of phenomena," with Dr Bennett there is only one "essential phenomenon;" the

former applies his term to a *process*, the latter to a *result*. Dr Alison supposes the vascular disturbance to be immediately caused by those changes by which inflammation is essentially constituted; according to Dr Bennett, it is a wise and necessary provision of nature *to remove the exudation*![1]

[1] Lest we may be thought to misrepresent Dr Bennett on this point, we give his own expressions:—

"But why should nature in cases of inflammation draw an increased amount of blood towards the part? She does so, it seems to me, in obedience to one of her wisest laws, but one which has been too much ignored by medical practitioners. It must be obvious, however, that an inflammation having occurred, the great work now to be accomplished is an increased growth of cell formation, whereby that exudation is to be broken up, the pressure it exerts on the nerves and blood-vessels removed, and the whole rendered capable of being eliminated from the economy either directly by discharge externally, or indirectly, first, by passage into the blood, and second, by excretion through the emunctories. To perform this work of increased growth an augmented flow and amount of nourishing fluid is necessary, the same as is observed at the period of heat in animals to ripen the Graafian vesicles; in the stag's scalp during the growth of the antlers; in the mamma when the milk is first secreted; in the gums during the process of dentition; in the ascent of the sap during spring in plants, etc., etc. In all these cases, especially the last, the fluid is not sent or determined, but drawn to the part in consequence of an increased growth of cells imperatively requiring a greater amount of blastema. So in inflammation, an exudation having been poured out, which has to be transformed by a process of cell growth, in order that it may be removed or rendered subservient to the wants of the economy, it is absolutely imperative that the part in which these nutritive changes go on should receive more blood to enable it to accomplish them. Hence the increased current. But hitherto, medical practitioners have supposed this phenomenon is injurious and ought to be checked by blood-letting and antiphlogistics. The rapid flow of blood which is so necessary, they have sought to diminish; and the increased amount in the neighbourhood of the part, which is so essential for restoration to health it has been their object to destroy. In doing so we argue they act in opposition to sound theory, and as we shall afterwards attempt to shew, to good practice also."—*Principles and Practice of Medicine*, pp. 277, 278.

"We cannot cut short an exudation once produced," says Dr Bennett. If by "cut short" he means that we cannot at once restore perfectly healthy structure, when inflammation has caused certain changes in the ultimate structure of the tissue, we presume no one will affect to differ from him. But from various expressions used by him, we are led to infer that the exudation ought to be the sole object of treatment. The attention is to be directed, not to the biological cause, but to the pathological effect. The series of changes which precede and are necessary to the occurrence of the so-called essential phenomenon, are not to be interrupted,—cannot be interrupted,—and the sole object of the practitioner must simply be to assist nature by favouring the "increased growth of cell formation, whereby that exudation is to be broken up, the pressure it exerts on the nerves and blood-vessels removed, and the whole rendered capable of being eliminated from the economy."

Thus far, then, we have found Dr Bennett's pathology of inflammation to be entirely negative and unproductive. It is therefore perfectly arbitrary and unscientific. To give expression to one of the results, however characteristic it may be, can never be accepted as the definition of a process. No one attempts to define nutrition by simply singling out some one of its phenomena. Nutrition, as we have seen, is constituted by a complete circle of changes, and to fix on any one of these as the essential phenomenon,—as indeed constituting in itself *the* process, would be absurd. And yet, to define nutrition to be "effusion of albuminous fluid," would

be more scientific than to define inflammation as "exudation of liquor sanguinis," and for this reason, the phenomenon we have mentioned is one of the essential *conditions* of nutrition. But, as we have already seen, "exudation" appears to be the condition of nothing that is characteristic of the active stage of inflammation.

Even although a relation could be proved to exist between exudation to the perverted vital action on the one hand, and to its symptoms on the other, Dr Bennett's definition is an attempt to introduce into biology an apparent simplicity scarcely attained in physics. The chemist, for example, defines combustion as "chemical combination attended with light and heat."[1] He does not give an essential phenomenon, but the essential condition in combination with certain effects (or symptoms). A successful definition of inflammation must be perfectly analogous.

We have, lastly, to affirm that exudation is not even a fact. No one insists more strongly than Dr Bennett, on the necessity of distinguishing between fact and opinion. "Our facts may be correct although our conclusions derived from them are wrong. This proposition, however generally admitted, is seldom acted on in medical inquiries, in which we find fact and hypothesis so mingled together, that it often requires considerable critical and analytical power to separate one from the other."[2] We do not hesitate to classify exudation

[1] Gregory.

[2] *Monthly Journal of Medical Science*, Feb. 1850. Principles and Practice of Medicine, p. 136.

among the "false facts" of medicine. It is an improbable event, because, in the first place, no sufficient cause can be pointed out for its occurrence; and, in the second place, it is opposed by other uncontradicted facts.

Although Dr Bennett has no proper theory of the process of inflammation, he has a number of theories to explain the individual phenomena observed by the microscope (one of these being exudation of liquor sanguinis). These explanations, however, have no apparent relation to the more easily recognised phenomena presented to the unassisted vision. Of exudation, he says, "the theory of the essential phenomenon consists in the attraction of liquor sanguinis through the vascular walls into the surrounding parenchyma or neighbouring cavities, when it coagulates to form a solid body." Now what can occasion this attraction? It is to be remembered that the same principles are in operation here, as are at work in healthy nutrition, and that fibrine (according to Dr Bennett's own physiology, which we consider correct) is a substance for which the growing cells have no affinity. Vital action, therefore, or an attraction depending on the occurrence of vital changes, cannot be the cause. Neither has it ever been proved that retarded circulation alone could cause fibrinous fluid to pass outwards through the vascular walls. We know, therefore, of no efficient means by which exudation can occur.

Again, we consider that the exudation view of inflammation is directly negatived by a well known fact, to which we have already alluded in a previous part of our Essay.

An increase in the proportion of the fibrine in the blood, is almost simultaneous with the commencement of inflammation. This is surely opposed to what we would expect if the essential part of the process consisted in the transudation of that element from the vessels. If in peritonitis, or in erysipelas, or in pneumonia, we were to have, as an essential phenomenon, a fluid largely charged with fibrine plentifully exuded over a large surface, or into an extensive parenchyma, the proportion of fibrine in the blood ought to become diminished. Instead of this, it is actually increased to at least two or three times its usual amount. Soon after the local signs or general symptoms have presented themselves, the quantity of fibrine in the blood is increased, and gradually becomes greater in proportion to the intensity of the process, and the amount of tissue involved in it.

If we correctly understand Dr Bennett, however, he regards this increase to take place only after the inflammation has subsided. He says "during the *disintegration* of simple, tubercular, and cancerous exudations, the animal matter broken down, is again rendered fluid, repasses into the blood and *then* constitutes that excess of fibrine detected by chemists."[1] Unsupported as it is by even any attempt at proof, this statement appears to us to be rather an extraordinary one. Either it is utterly inconsistent with fact, or other writers have been most unaccountably misled in their inferences on this point. The augmentation of fibrine, says Dr Watson, "begins with the inflammatory process, in-

[1] Op. cit., p. 152.

creases with its increasing intensity, and diminishes as it abates." Such appears to be the view almost universally held, and yet Dr Bennett does not consider it necessary to advance a single argument to prove its erroneousness.

Thus the course which, according to Dr Bennett, the fibrine takes in inflammation is not a little remarkable. It is first of all derived from the tissues by the natural progress of vital change; then, by some unexplained action or attraction, it fixes on a particular locality, and there passes in considerable quantity out of the vessels; and lastly, notwithstanding the great local and constitutional disturbance that accompanies the process, it again re-enters the vessels, without its own composition or properties being in the least affected!

Dr Williams in his work on the Principles of Medicine, has entered largely into a consideration of the phenomena of inflammation, and at one time we intended to have also examined his views with some detail. But this would take up too much space. It would be necessary to examine and refute a large amount of narrow and erroneous physiology, and we therefore content ourselves with a single remark or two.

Like Dr Bennett, Dr Williams has ventured on a definition of inflammation. It is "too much blood in a part, with the motion (of that blood) partly increased, partly diminished." To this definition all the general objections may be applied that we have already urged against that of

Dr Bennett. If repeated to one unacquainted with the facts of pathology, but intimate with the principles of physiology, it would give nothing like a correct idea of the actual phenomena of inflammation. All Dr Williams' explanations are of a remarkably mechanical nature. "So far as is known" he says, "the blood vessels are the essential seat of the whole process of inflammation." He might as well say that the blood vessels are the essential seat of the whole process of nutrition. "The determination of blood is caused by enlargement of the arteries; and this enlargement is the effect of the pressure of the arterial distension from behind, acting on a tube which has lost some of its contractile power." As Dr Williams professes to be unable to understand how, and because he does not understand he will not admit that the vital operations can influence the movement of blood in the capillaries, we need not appeal to what we must consider fundamental principles in the physiology of the circulation, to prove how inefficient such an explanation is to cover all the phenomena observed. We content ourselves, therefore, with a physical illustration. To allow ever so free a draught to a furnace would never increase the heat it produces, unless the first effect be to cause increased combustion in the coal. Without combustion the draught will be neither created nor sustained, and its strength will depend entirely upon the intensity with which the burning body attracts the oxygen of the air. In like manner, no matter to what extent the arterial vessels may have lost their tone, unless the reaction between the blood and the tissue becomes more

powerful or more rapid, the phenomena characteristic of inflammation will not be presented. Even supposing, therefore, that some altered nervous or physical influence affecting the calibre of the vessels, is the first step in the sequence of phenomena,—and in some instances very possibly it is so,—the altered reaction between the blood and the tissue is the cause of those symptoms by which the diseased action is immediately manifested, and to ignore that relation must be considered fatal to any definition that pretends to be founded on the intimate changes in the tissue.

In regard to his explanation of the stasis of inflammation, that it depends in part on "the unusual formation of white corpuscles, which adhere to the walls of the tube and to each other," we need only remark that on this point, Dr Williams is contradicted by other equally competent observers.

PART II.

ON THE ENCEPHALIC CIRCULATION,

AND ITS

RELATION TO THE PHYSIOLOGY OF THE BRAIN.

THE circulation within the cranium, as is well known, contrasts remarkably, in several respects, with that of other regions of the body. In the structure of the venous sinuses, and in the general arrangement and relations of the other blood-vessels; in the almost uniform amount of blood these, as a whole, contain; and in the relation of that blood to the pressure of the atmosphere, it exhibits striking and important peculiarities. There can be little doubt that these peculiarities must exert some influence in regulating or modifying the action of the brain; and in the present Essay it will be our object to show that their consideration deserves greater prominence in the study of the physiology of that organ than they have yet received. We will endeavour to show in what manner they may probably affect the action of the brain, and how they thus may subserve the attainment of important ends. Especially, we will point out some modes in which, through their means, the mind and its material organ may reciprocally affect one another.

In describing the encephalic circulation itself, we will be

very brief. To enter on the discussion of all the questions that have been raised respecting its peculiarities, would lead us far beyond the limits of an Essay like the present. As occasion may present, however, we may perhaps take an opportunity to say a word or two in defence of the views taken on disputed points.

The first peculiarity that attracts our attention is the structure of the venous sinuses. These are a series of angular channels, tunnelled in various directions through the fibrous envelopes of the brain. From the rigid nature of their structure, they must always preserve pretty uniformly the same diameter. They will not yield to any considerable extent, either by dilating from internal pressure, or by becoming compressed by external force. The structure of the other blood-vessels presents nothing peculiar.

Another peculiarity of the encephalic circulation, is the general arrangement of the blood-vessels. The circulation of the brain itself is almost entirely capillary. Its substance is penetrated by scarcely a single blood-vessel of size. Its arteries ramify external to the organ; and "in the dura mater they subdivide to such a degree as to convert that membrane into an extremely fine and close network, from which issue the arteries that lose themselves in the substance of the brain, and which are truly capillary." In like manner, the veins, which are seen disposed everywhere over the surface of the brain, and which are of considerable size, have their origin in vessels of extreme minuteness, which only unite after they have emerged from the nervous substance.

Although this peculiarity is very striking, it does not appear to have received much attention, and, so far as we are aware, no attempt has been made to assign it a purpose.

A third peculiarity is, the nearly uniform amount of blood that at any one time must be contained within the encephalic vessels. Considerable controversy has arisen on this point; but into that we cannot enter fully at present. We are far from asserting that the amount must in all circumstances remain constantly the same; but the general statement, that it must be extremely uniform, may, we think, be easily proved. It is a necessary and evident result of the physical qualities of the cranium, and of the conditions that regulate any change in the other contents. The cranium is a cavity whose capacity cannot be altered, and, obviously, the bulk of its contents must remain constantly the same. These contents are—the brain, with its membranes and blood-vessels; the blood; and the cerebro-spinal fluid. Increase or diminution in the amount of any one of these constituents can only take place with diminution or increase in some other, to exactly the same extent. If the bulk of the nervous substance be increased, that of the fluids must be diminished, and *vice versa;* or, if, while the substance of the brain remains unaffected, the proportion of one of the fluids be increased, that of the other must be diminished to a corresponding extent. Now, it is quite probable that the amount of nervous tissue is subject to variation, and, in certain circumstances, the quantity of serous fluid may be affected. The amount of blood in the vessels may thus also be caused

to vary. But we yet think it sufficiently obvious that the extent to which this can take place, must, in ordinary circumstances, be extremely limited. Time must be an essential element in any change that can take place in the bulk of either of the other contents of the cranium. The amount of nervous substance can only be altered by the progress of ordinary physiological changes, and it is improbable that the extent can be great within limited periods of time. The serous fluid cannot be immediately increased unless a force is employed to raise it from the vertebral canal; and we are not aware that any such force can be exercised. Neither can it be readily effused from the vessels unless the pressure these receive on their external surface tends to be lessened. It may therefore be safely asserted, that, in short periods of time, however much its mode of distribution or rate of movement may alter, the absolute quantity of blood circulating in the vessels within the cranium will not be liable to much variation.

The last peculiarity we have to notice, is the relation of the blood within the cranium to the pressure of the atmosphere. That pressure is exerted not on the external surface of the vessels, as in other parts of the body, but on their internal surface, and its constant tendency must be to retain the blood within the cranial vessels. The weight of the atmosphere, bearing on the general surface of the body, readily communicates its influence through the soft textures, and the principal blood-vessels of the system may be more or less readily affected by it. It requires but a glance at

the construction of the cranium, however, to perceive that all the contents of the latter are completely removed from its direct action. From the rigid nature of its structure, and from the complete manner in which all its foramina are guarded, the atmospheric pressure can only affect the interior of the cranium by means of the blood-vessels that enter or make their exit from its cavity. The blood is the only medium through which any influence can be communicated; and that influence must therefore be exerted, in the first instance, on the internal surface of the vessels.

Such, then, are the peculiarities of the encephalic circulation, the influence of which on the action of the brain we intend to study. Before doing so, however, two particulars require to be noticed. They are self-evident deductions from the facts we have already mentioned, and have long been recognised, but their application we will find to be very important.

In the first place, if the total quantity of blood within the cranium remains tolerably uniform, then no change can take place in the amount distributed to one part of the encephalon without immediately affecting that in other portions of the organ. If one set of vessels be made to receive more blood, others must to an exactly corresponding extent receive less. Dr Abercrombie used to illustrate this point in the following manner. Supposing the whole amount of blood circulating through the brain is as ten, and that in the healthy state of the organ it is distributed between the arteries and veins as five to five, if the arteries are by some sudden impulse

from the general circulation distended by a quantity as six, the veins will be able to contain a quantity only as four.

Again, if any alteration takes place in the distribution of blood within the cranium, pressure must be produced on some part of the brain. If any portion becomes more vascular, if any vein becomes more engorged with blood, its bulk must of course become increased, and it cannot expand in any direction without occasioning some amount of pressure on the surrounding nervous tissue.

Assuming, then, the correctness, or at least the approximate correctness, of the above premises, we proceed to discuss their relation to the physiology of the encephalon.

The cranium has often been studied and admired, as supplying, by its physical qualities, means most beautifully adapted to afford protection to an organ of such delicate texture and important function as the brain. And yet, it may be questioned whether mere protection against external injury is not only one of its secondary purposes. At all events, we will hope to prove that the peculiarities in the circulation which it involves so affect the action of the brain, that they facilitate the exercise of function in the latter, and are absolutely necessary to secure harmony of action among its different parts.

The first point to which we direct attention is one of a general character. We wish to show that, in securing a sufficient supply of blood to the brain, the cranium is a most important auxiliary to the action of the heart.

We have already stated that it is the tendency of the atmospheric pressure to retain the blood within the intra-cranial vessels. This it could effect in opposition to the influence of gravitation. The latter force, by itself, is insufficient to cause a single drop of blood to leave the cranial cavity. No matter how the head may be placed, any fluid can be dislodged from the vessels only by a force from within. It is obvious, then, that to permit the free flow of blood through the vessels of the brain, an equilibrium of pressure must be preserved between the general surface of the body and the interior of the cranium. There must be some force, or forces, constantly operating within the latter, to counteract the tendency of the weight externally to retain the blood in the vessels.

The sources of this force are, we believe, principally two. In the first place, there is the action of the heart affecting the blood in the arterial vessels. It is obvious that for any quantity made to enter the cranial cavity by this means, an equal amount must be simultaneously dislodged from the veins. The second, and perhaps the most important source of internal pressure, is the influence of nutrition on the capillary circulation. The action and reaction that take place between the blood and the tissue so affect the fluid in the capillaries, as to occasion its movement onwards independently of any impulse from the heart. The force thus produced is an essential aid to the circulation in all parts of the body. It does not intermit, like the arterial wave, but its amount is subject to considerable variation. It is usually

directly related to the activity of the nutritive process, and especially to the vigour of functional exercise. The existence of this force has been entirely overlooked by Dr Burrows and other writers on the encephalic circulation; and this oversight has perhaps given rise to more than one argument in support of (what we suppose to be) erroneous views of the encephalic circulation.

In reference to the exercise of these forces, the cranium subserves a most important function. It assists materially in counteracting the influence of gravitation, as this affects the circulation of the brain. It is most important that the supply of blood to the latter be steady and uninterrupted; but when the body is in the erect posture, as it usually is when the brain is most active, and consequently, when there is the greatest demand for nutritive material, the influence of gravitation is directly opposed to the free determination of blood to the head. In some of the lower animals we see, even more strongly than in man, the necessity for some provision being made against this unfavourable influence. In the giraffe and ostrich, for example, the column of blood to be supported and propelled is very considerable, and the change in the position of the head relatively to that of the body is frequently rapid. In such circumstances, serious consequences would result if the blood in the encephalic vessels were exposed to the pressure of the atmosphere from above; or, in other words, if no arrangement existed to counteract the influence of gravitation on the blood. The venous vessels would be rapidly drained, and thus the uni-

form pressure on the nervous substance, which is so necessary to its healthy action, would be disturbed. Arterial blood would also be less easily determined to the brain. The cranium, therefore, has a most important function to subserve in preventing these untoward events. This it does by preventing the mass of blood within its cavity from gravitating too directly or powerfully towards the heart. The arrangement that secures this, will also enable those forces that affect the capillary circulation to operate more powerfully on the arterial blood, and it thus affords positive aid to the heart's action in sustaining the circulation through the brain.

In proceeding to examine more closely the reciprocal actions that take place between the brain and its circulation, it will be necessary to discuss, in certain points of view, the relation of mental to cerebral activity. On this subject, we may perhaps be allowed to premise a few general observations.

In speaking of the mode in which mind and material organization act and react on one another, the physiologist must use largely the phraseology, however thoroughly he may repudiate the idea, of materialism. This is an unavoidable result of the point of view from which he is led to consider the operations of mind. The mere metaphysician starts from the phenomena of consciousness, and he only takes cognisance of those phenomena which his consciousness reveals. Self-consciousness he assumes to be an attribute

of mind; and mind he regards and speaks of as an entity, essentially distinct from, and independent of, the material organ with which its operations are at present associated. The attributes or powers of this entity—the various modes in which mental activity may manifest itself, and the conditions or laws affecting their existence and succession—are the immediate objects of his study. The physiologist, on the other hand, begins with the material organs. He looks at the nervous structures as a portion of the completely organized animal system, and he inquires what part they perform in that series of operations, the sum of which constitutes the life of the individual. A long series of observations has enabled him to recognise the brain as the organ of mind; and he has been forced to admit that a change in its substance is involved in every act of intellect and volition, and is necessary to the very existence of consciousness. He finds, then, that so far as he has to do with mind, it is not simply as an independent entity, but as an agent whose operations are controlled and modified by the conditions of its instrument. That instrument he knows to be one of great delicacy, and, like every other organ in the body, its action is governed by stringent laws. Its structure has certain relations to other structures and functions, and is extremely sensitive of any alterations in these. Its functional capacity is greatly influenced by slight modifications in the nutrition of its substance. The physiologist is therefore led to inquire whether, to some extent, the particular mode, or amount, or facility of mental manifestation, may not often

depend upon the particular qualities or conditions of the instrument through which the manifestation is made.

All vital, like all simply physical phenomena, are dependent on the fulfilment of certain conditions. Some of these we may recognise and regulate, although the action itself be involved in complete mystery. We cannot explain how consciousness is connected with an active state of the brain; but we are able to determine some of the conditions of that activity. One of them, for example, is the presence of oxygen in the blood circulating through its capillaries. Let the blood become loaded with carbonic acid, and the brain is paralysed, and all evidence of the presence of mind is obliterated. In the latter case we recognise a sufficient cause for the symptoms observed, although the union of oxygen with the elements of nervous tissue furnishes no explanation whatever of mental activity. We simply discover, in the absence of an essential condition, a reason why the brain does not respond to its accustomed stimuli.

In like manner, however closely the physiologist may inquire into the reciprocal action that takes place between the mind and its organ, he must study the changes in the latter as the remote, though, in the present state of existence, essential conditions, rather than the immediate explanation of any manifestation of the other. The mystery of the union between mind and matter he readily admits, and does not attempt to fathom. He never hopes to explain the fact of consciousness; but he may perhaps be able to determine some of the circumstances that regulate its intensity and

particular direction. He does not attempt to refer mind to the operation of laws affecting the activity of the nervous system; but he feels certain that every advance in our knowledge of these laws will also increase our knowledge of the reciprocal affections of the mind and body. He knows that for every mental manifestation a particular mode of action in the material structure is essential; and when this is interfered with, the corresponding psychical phenomenon is modified, or it fails to be presented. It therefore becomes a perfectly legitimate, as well as an interesting subject of inquiry, to trace any relation between particular conditions or modes of action in the nervous structure, and particular mental states or modes of manifestation.

As already hinted, we intend to study the action of the brain in its relation to the circulation. We have nothing new to advance respecting the intimate changes that take place in the nervous tissue itself; but we will study the functional activity of the brain, as a whole, in relation to one of its most important conditions. No effort will be made to explain the union that exists between the mind and its organ; but we will direct attention to certain modes in which they reciprocally affect one another. We will endeavour to show how changes in the relation of the nervous structure to its circulation affect the mode in which its functions are discharged, and how in this way an influence is exerted on psychical phenomena.

As the simplest mode of proceeding, we will now take for

consideration one of the special subjects which we believe to be intimately related to the peculiarities of the encephalic circulation. The first to which we direct attention is the cause of sleep. It will be our object to determine the physiological conditions on which this state immediately depends.

We are aware that this is a subject considered by many as one beyond the scope of physiological inquiry, and some readers may be prejudiced even at the attempt to solve the difficulties that surround it. It may be necessary, then, in the first instance, to define more exactly what will be our object. "It is plain," says Sir Benjamin Brodie, "that, in some respects, the condition of the nervous system must be different during sleep from what it is when we are awake; but it seems impossible that we should know in what that difference consists, when we consider that neither our unassisted vision, nor the microscope, nor chemical analysis, nor any analogy, nor any other means at our disposal, enable us to form any kind of notion as to the actual changes in the brain or spinal cord, on which it or any other nervous phenomena depend."[1] Now it will be no part of our object to determine the "actual changes" that take place in the brain. In attempting to determine its immediate cause, we will regard sleep as a negative condition. It is a state characterized by the absence of mental manifestation, rather than by the presence of any positive phenomenon. It is not constituted by the relaxed condition of the muscles, nor

[1] Psychological Inquiries.

by the closing of the eyelids, but by the consciousness being suspended. Viewed in this aspect, it is not necessary that we should first be able to explain how consciousness is associated with an active state of the nervous tissue,—we assume the fact. We require simply to discover how the action of the brain, as an organ, is interfered with; and some definite conclusion on this point may be arrived at, although the "actual changes" that take place in the nervous substance may be far from being understood. The link may be remote, and not the less certain. As the presence of an extravasation of blood is deemed a sufficient explanation of the existence of coma, so the mild temporary coma that characterizes sleep, may perhaps be found to depend on some condition of the brain of which we are able to become cognisant.

We need hardly say that we have no intention to dwell on the phenomena of sleep descriptively; neither have we anything to do with its psychical aspects. We have no hypothesis to advance in regard to the state of the mind during its continuance. We will direct attention only to those points in the condition or relations of the brain which, during sleep, must contrast with those which are present during the period of wakefulness. Some of them we will attempt not only to determine, but, to a certain extent, to show how they are produced.

The physiologist is well acquainted with a very sure means of so suspending the functions of the brain as to produce a state resembling that of sleep. The characteristic

phenomena of the latter may be induced by any circumstance that will cause a sufficient amount of pressure to be exerted on the nervous substance. If a portion of the brain be exposed, consciousness may be taken away and restored at pleasure, by regulating the amount of pressure to which it is subjected. In this fact we may perhaps find a clue to the direction in which to look for any explanation of ordinary sleep. If we can simply discover some physiological means by which the requisite amount of pressure may be produced on the surface of the cerebrum, we will so far be enabled to ascertain the proximate cause of its phenomena.

Nor have we far to seek for exactly such physical conditions as are required. They may be found in the relation which the encephalic veins hold to the brain. From the disposition of these vessels over the whole surface of the organ, no alteration can take place in the amount of blood contained in them without affecting the degree of pressure to which the nervous substance is subjected. If from any cause they become more distended with blood, their increased bulk will immediately affect the brain. The tissue of the latter is the only substance in contact with the vessels that will yield in these circumstances; and the amount of pressure exerted must, therefore, be in direct proportion to the extent to which the vessels become engorged.

It will now be our object to prove the following propositions: 1st, During the continuance of healthy sleep, the proportion of blood contained in the venous encephalic vessels must be greater than during the period of wakefulness;

and 2d, this state of the circulation is a necessary result of the mode in which nutrition in the substance of the brain is then modified.

One of the most interesting laws affecting the general circulation, is that by which the amount of blood determined to particular parts of the system is made to depend upon the demand that exists for nutritive material. The operations of nutrition are not only the final cause of the circulation, but they also regulate the amount of blood transmitted through particular organs. The mutual action that takes place between the blood and the tissue is the condition and an active cause of the circulation. It gives rise to a force, the assistance of which is necessary to the free transmission of blood through a part, and the amount of which, as a rule, corresponds with the necessities of the tissue. The demand for nutritive material depends upon the activity of the vital changes; and the more vigorous the latter are in any part, the more powerfully does the *vis a fronte* operate, and the greater, therefore, is the quantity of blood transmitted through its vessels.

In the brain we have no exception to this general rule. It is admitted, that in an active state it requires and receives a larger amount of blood than when the exercise of its functions is less vigorous. Within a given period, a greater quantity is made to circulate through its vessels in the one state than in the other. When from a dormant condition the nervous substance is roused to a state of activity, its nutrition must become very much modified. In what that

modification consists we do not attempt to determine, but assume there is some excitement in the process. The ultimate structures undergo change more rapidly, and disintegration especially goes on with greater energy. This excitement reacts on the circulation. The demand for nutritive fluid being increased, the force acting at the capillaries becomes more powerful, and the blood is more rapidly transmitted through the vessels.

Not only, however, will the amount of blood transmitted *through* the brain in a given time be increased when it is in active exercise, but the quantity of that fluid *in* the vessels of the nervous substance must, in the same circumstances, be also augmented. When an organ of secretion is stimulated, the amount of blood in its tissue is increased so long as its functional activity continues. In analogous conditions of the brain, the same causes are in operation, and the same result must be presented, unless the physical obstacles to its occurrence are too great to be overcome by the physiological action. If from more vigorous vital change the blood is caused to move more rapidly, the internal pressure against the walls of the vessels must be greater, and this, of course, must tend to enlarge their calibre.

If the vessels of the brain be made to contain more blood, the bulk of the organ will be greater; and it is well known that, in those instances where its substance is exposed by injury, it has been seen to expand when its function was excited. To prove, therefore, that any increase of blood can take place in its vessels, it is necessary to discover some

means by which its substance may be allowed to expand while the cranium remains entire. This leads us again to consider the anatomical relation of the venous vessels. Some of these are of considerable size, and they are lying supported on the surface of the brain. In one direction they are in close contact with the nervous tissue, and in the other they are only separated by the membranes from the unyielding bone. If, then, any action or force be operating in the brain, the tendency of which is to cause its substance to expand, it will at once be directed on these venous vessels. The support they were receiving will be converted into an actively compressing force. Yielding to this, they must become unable to contain the same quantity of fluid, and a certain amount of room may thus be readily gained. The substance of the brain will be enabled to contain an increased quantity of blood, by the amount in the veins being to a corresponding extent diminished.

If we be correct, then, in supposing that the amount of blood in the substance of the brain is increased when its functional activity has been excited, it, of course, follows that the reverse phenomenon—a comparatively diminished circulation in the nervous tissue, with an increased proportion of blood in the veins—must be present during sleep. It is also obvious that this condition cannot occur without the brain itself being somewhat compressed, and we have now to consider how it is produced. Let the nature and precise sequence of the phenomena which intervene between the one condition and the other be described, and, so far as sleep is

a physiological phenomenon, we express the condition by which it is constituted, and the immediate steps by which it is produced.

In attempting to solve the above problem, it is necessary to consider for a moment how the blood in the encephalic veins is circumstanced. It is constantly being acted on by two antagonistic forces. On the one hand, the *vis a tergo*—the combined operation of the heart's action, and the nutritive forces—urges more blood into the vessels; and if these were rigid tubes, an equal amount would at the same moment be discharged from their distant openings. Then, opposed to this is the pressure of the atmosphere, tending to prevent the exit of any fluid from the cranium.

According to a well-known hydrostatic law, pressure applied to a fluid is communicated equally in all directions. Resistance offered to the exit of blood from the venous vessels must therefore extend backwards to their origin in the nervous substance, and against the internal surface of the vessels through their whole extent. It will offer resistance to fluids entering the veins from the capillaries, and it will directly tend to dilate the vessels themselves.

It is not difficult to perceive that these conditions must tend to produce engorgement of the veins, and that the immediate result must altogether depend upon the support which these vessels receive on their external surface. Before a single drop of blood can be expelled from the cranium, an equilibrium must be established between the support afforded by the nervous tissue on the one hand, and the

pressure exerted on the internal surface of the venous vessels on the other.

We are now enabled to perceive an important function of the venous sinuses. If so large a quantity of blood as they contain were not restricted by rigid tubes, the pressure exerted on the surface of the brain would be apt completely to paralyse the functions of the latter. Engorgement of all the encephalic veins would take place more readily than under present arrangements, and the operations of nutrition would less readily react against the pressure so occasioned.

We will now endeavour to determine how the encephalic circulation is affected in the following circumstances: First, In the case of mechanical obstruction to the return of blood from the brain; Second, In the occurrence of syncope; Third, In the production of that form of coma which is occasioned by the accumulation of carbonic acid or chloroform in the blood; and, Fourth, In the production of ordinary sleep. As in all these instances the more or less complete loss of consciousness is the characteristic phenomenon, so we will find that in all of them the circulation is ultimately affected in exactly the same manner.

1. It is very obvious how the circulation must be affected when obstruction to the return of blood by the internal jugular veins is sudden and complete. In the first place, the entrance of more blood by the carotids is at the same moment also checked. But all movement of blood in the vessels within the cranium is not necessarily suspended at once. As after death the arteries of the general circulation

are completely emptied into the veins by the aid of the forces acting at the capillaries, so within the cranium, in the circumstances we are speaking of, the blood in the arterial vessels may be drawn onwards by the same forces, and transmitted into the veins. As not a drop is expelled from the cranium, the veins must become engorged, and the brain itself compressed.

Again, let us suppose the obstruction is not complete, but only to such an extent as to interfere with the transmission of that amount of blood which is necessary to the functional activity of the brain. Here the additional force that is required to expel the former amount of blood from the sinuses will be thrown backwards on the internal surface of the veins. Through these, increased pressure will be directed on the surface of the brain, and the functions of the latter will thus be immediately suspended.

2. In syncope, when the brain ceases suddenly to perform its functions from deficient supply of blood to its vessels, an altered balance of pressure within the cranium must also be produced. The conditions, again, are such as to favour engorgement of the venous vessels. The pressure within the arteries is weakened, and as nutrition in the nervous tissue is depressed, the capillary circulation is also less active. The support afforded to the veins must thus be diminished, and they will therefore more readily yield to the distending influence exerted on their internal surface. This sequence of phenomena will immediately be stated more in detail.

3. Among the conditions essential to the functional activity of the brain, none is more important than the union of oxygen with the elements of its tissue. If the blood be insufficiently charged with that agent, a depressing influence is exercised on the nervous system; and the greater the extent to which it is displaced by carbonic acid, or chloroform, or any other gaseous substance, the more completely are the powers of the tissue suspended. That form of nutrition that constitutes the exercise of function cannot be sustained. The action and reaction between the blood and the tissue are less active, and from this cause the capillary circulation is more languid. In this merely negative condition we have all that is necessary to produce engorgement of the venous vessels. Within the latter, as we have seen, a force is never-ceasingly reacting against the support they receive on their external surface; and, obviously, it must bear with greater effect in distending the vessels, if there be the least diminution in the amount of that support. And, as obviously, this diminution is accomplished if the capillary circulation in the substance of the brain be weakened. In such circumstances the blood will not bear with the same amount of expanding force within the arterial and capillary vessels, and their calibre, in consequence, will be more readily reduced. The veins on the surface of the brain may now be more easily distended, as one of the conditions that previously prevented this tendency is weakened. When the blood, therefore, is transmitted into the veins, part of it will accumulate in these. Until a new equilibrium be

established, more blood will enter the veins than is being expelled at their distant openings. In this process, again, pressure is necessarily exerted on the surface of the brain.

4. We come, lastly, to consider the sequence of phenomena as these are presented in the production of ordinary sleep. In doing so we fear we may be considered guilty of making considerable repetitions.

We have seen how the balance of the circulation is affected when obstruction is offered to the return of blood from the brain; when the supply furnished by the arteries is deficient; and when the blood is loaded with certain poisons. In ordinary sleep the succession of changes is, we believe, similar to what we have traced under the last of these instances,—the principal difference being, that it has its origin in an alteration in the ultimate structure of the nervous substance itself. That alteration results from the operation of laws affecting the constitution of the tissue. We do not pretend to determine precisely in what it consists; but it is certain that exercise of function produces a change of composition in the tissue, the continued progress of which interferes materially with the functional capacity of the organ. The destructive predominate so far over the reparative operations, or in some way the nutrition of the nervous substance is so affected, that a period of complete repose is necessary to restore to it such a composition that its function may be performed with proper facility.

The mere alteration in structure, however, will not secure the required extent of rest. Certainly we can suppose

nutrition to be so far depressed as to render the organ unfit for duty; but that the phenomena of sleep are not, in ordinary circumstances, dependent solely on this cause, may be easily proved. Sleep would, under such conditions, be always partial and irregular. The period of its accession would depend entirely upon the amount of exercise to which the brain might be subjected, and the functional capacity of some portions of its mass would be earlier exhausted than that of others. From the latter circumstance, that harmonious co-operation among different parts of the organ which is necessary to the unity of mind would be entirely lost. Then, the facility with which the deepest unconsciousness may be interrupted, and a transition made to a state of alert wakefulness, shows that the change in the nervous tissue is not the sole cause of sleep. Some complemental condition is necessary, and this will be found in the application of pressure to the surface of the brain. While that modification of nutrition which is necessary to mental activity is thereby suspended, the changes that constitute repair are rather favoured.

We have already seen that the amount of blood in the encephalic veins depends upon the vascularity of the brain; and this, again, is related to the activity or rapidity of the nutritive changes. The total amount of blood within the cranium is tolerably uniform; but the proportion in which it is distributed among the various vessels may undergo unceasing alteration. In the state of wakefulness the nutritive changes are most active, and the vascularity of the brain is

greatest. The amount of blood in the veins must then be at the minimum, and these vessels will at the same time be receiving a certain amount of support from the nervous substance. Within the veins, however, there is a force which reacts against that support. The nutritive operations behind are constantly bearing onwards into them more blood, and the pressure of the atmosphere before tends to prevent the exit of any from the cavity of the cranium, so that between these two agencies there is a constant distending pressure within the veins. If the support which these receive on their external surface be in the least relaxed, the internal pressure will cause them at once to become distended.

Physiologically as well as mentally, the transition from the state of activity to that of repose is effected, not at once, but slowly and gradually. The nutrition that accompanies mere growth or repair, is of a less active nature than that which accompanies functional activity. So soon as the vital changes begin to flag, at that moment also the forces affecting the capillary circulation begin to act with less vigour. The tendency to engorgement of the capillary vessels is weakened. The internal pressure on the walls of these and of the arteries is therefore less. The necessary consequence of this must be, that the support afforded to the veins is relaxed, and the dilating force within these vessels must immediately begin to act with greater effect. The quantity of blood in the substance of the brain must begin to be diminished, while that in the veins will be increased. A change will take place in the balance of pressure within the

encephalic vessels. The expanding force within the nervous tissue will be less, that exerted on the surface of the brain will be greater, than before. As the ultimate structures undergo change less rapidly, the balance of the circulation will become more and more altered, and the greater will be the pressure exerted by the venous vessels. When at last this pressure has amounted to a certain degree of intensity, consciousness will be suspended—sleep will be produced.

We thus see, that in the production of sleep there is a chain or combination of physiological conditions. The first link is a modified form of nutrition in the substance of the brain; the last is pressure exerted on the surface of the organ, by the veins becoming distended with blood. The principal intervening link is diminished vascular activity in the nervous tissue. No one of these conditions can by itself be regarded as the cause of sleep. All are necessary. They are all so related to one another, that distension of the veins and pressure on the brain are naturally evolved from the first step in the process.

We proceed to consider other modes, in which the balance of the encephalic circulation may be affected, and by which the action of the brain may be influenced. It will now be our object to show, that whenever the latter organ is functionally active—that is, during the whole period of wakefulness, and in dreaming—the proportion of blood sent to different parts of its mass must be liable to infinite varia-

tion; and as any alteration in the local distribution of blood through its substance must materially affect the mode in which its functions are discharged, we will endeavour to show how various phenomena, presented during its activity, may be referred to such an occurrence as their cause.

The encephalon, we assume, is composed of a number of organs. These are closely packed together; and although considerable obscurity may still rest on the precise function of some, there can be no doubt that their offices are various. When we reflect on the numerous functions to which the brain is subservient, it appears certain that there must be a subdivision of labour among different parts of its mass. Its substance is in some way affected by every operation which manifests itself to the consciousness. It is the centre of sensation and the storehouse of ideas; it is the medium through which emotion manifests itself, and the organ by which volition is expressed; and it is the instrument by which every act of reason and imagination is performed. It is extremely improbable, then, that every part of the nervous substance of the brain will be equally affected by every psychical operation. Whatever be the mode in which mental activity may manifest itself, some portions of the organ will, for the time being, be more vigorously exercised than others. When the mind is engrossed with a present sensation, or the contemplation of external phenomena, the nervous substance will be differently affected than when past impressions are recalled, or when the mind is disturbed by emotion, or the reason is adapting means to

ends, or the volition is calling into play a particular class of muscles.

Assuming, then, that when the brain is functionally active, this activity is more or less circumscribed,—that in healthy mental activity, the whole organ is never equally exercised,—we may also assume that the immediate seat of activity must have its vascularity increased. The arguments already advanced to prove that the brain, as a whole, must contain a larger quantity of blood during the period of wakefulness, than when its functions are suspended, apply with equal force to limited portions of the organ. When an impression is received through a nerve of sensation, when an emotion is excited, an intellectual effort sustained, or voluntary muscular actions are performed, that portion which is more immediately subservient to the particular condition or operation must become the seat of vascular excitement. Not only as compared with its own previous condition, but as compared with that of similar surrounding tissue, the function of which is not equally active, the amount of blood contained in its vessels must be augmented.

Here, then, we have one condition or cause by which the balance of the circulation through the brain itself may be actively influenced. Some of the immediate consequences of any alteration that may take place will be at once perceived. In the first place, no sooner will one portion of the brain become more vascular, than some other part must become less so. The more freely the blood is determined

into the anterior cerebral arteries, for example, the smaller must be the amount transmitted through other vessels. The extent to which the circulation may be thus altered, will be in proportion to the intensity of the action that is the immediate cause, and the amount of tissue involved in its performance. Secondly, a certain amount of pressure must be exerted on the surrounding tissue. If any set of vessels becomes more filled with blood, the part involved must, of course, take up more room than before.

In these two conditions we have a means by which one part of the brain may affect all the rest, independently of any communication through commissural fibres. We need not here do more than allude to the important law, by which the functional capacity of the nervous substance is related to its vascularity. The more vascular, within certain limits, any organ is, the greater is the facility or intensity with which its function may be exercised; while, on the other hand, any circumstance that interferes with the supply of blood diminishes the functional vigour of the part.

One of the simplest illustrations we can give of the application of these data is in explaining the remarkable effect of circumstances in modifying the intensity of sensations. It is well known that any sensation is much increased in intensity when the mind is strongly directed towards it; whereas the consciousness is much less affected, or an impression fitted to occasion sensation is not at all recognised, when the mind is earnestly engaged on some other object, when

an emotion is strongly excited, or when some other sensation "obscures or overpowers" it.

Now, in these various instances, there are not only psychical, but important physiological laws to be taken into account. The influence of the will or attention is certainly not to be overlooked; but the modified condition of the brain, especially in its relation to the circulation, must constitute a most important element in the causation of the phenomena. In the one instance, that portion of the encephalon where the impression is received is placed in circumstances most favourable to a free supply of blood being determined towards it, while in the other the reverse of this is the case. When the mind is directed towards any sensation—to the mere feeling or effect on the consciousness—then all that part of the brain which is subservient to the powers of intellect, to emotion, etc., is in a state of comparative repose. At one point principally—that where the impression is received—is there an active stimulus in operation. In consequence of the passive state of other parts, a free determination of blood is permitted towards it, and the intensity of the sensation will be in proportion to the degree of vascularity. But let the attention be directed towards some other object,—let the mental activity be diverted into any other channel whatever, and immediately a new sphere of organic activity is created in the brain, and a demand is set up in other quarters for nutrient or stimulating material. To satisfy this demand, a derivation of blood will be occasioned from that part which was previously the almost sole

seat of vascular excitement; and, of course, as the vascularity of the latter diminishes, the power of the impression to affect the consciousness also becomes less.

Let us give a more particular illustration of this. An individual "has been known to be so engaged in thinking upon a particular subject, that his horse has waded through the corner of a pond, yet, though the water covered the saddle, he was wholly insensible to the cause of his being wet." In such an instance, all that the metaphysician can say is, that the mind cannot attend to more than one thing at a time. This, however, is only half the explanation. Perhaps the principal cause is to be found in the physiological conditions that are present. The process of thought involves the activity of certain portions of the encephalon, and these attract the blood towards them with a certain amount of force. The circulation, therefore, receives an impulse in that direction, and is most active in a particular set of vessels. Now the proper exercise of function in other portions of the brain is incompatible with this condition of the circulation. If, during its continuance, an impression is made on an organ of sense, that part of the brain where it is received is in a comparatively dormant state. Its relation to the circulation is not such as to allow its function to be actively exercised. Before its proper vascular conditions can be fulfilled, it must overcome the hold which, so to speak, other parts already have of the circulating fluid. The momentum with which the blood is rushing in another direction must be overcome. If this is not accomplished, the

functional capacity of the part continues to be influenced. The effect of the impression on the nervous substance is positively less than in ordinary circumstances. The mind then remains unconscious of impressions on the peripheral extremities of the nerves, not only because the attention is wanting, but also because the part where the impression is received is not in a state in which it can with ordinary facility affect the consciousness. Its function is performed with deficient vigour, in consequence of diminished activity in its circulation.

But there is another mode in which, as we have stated, the activity of one portion of the brain may affect that of other parts. When any portion becomes more vascular, it increases in bulk, and in making room for itself it must cause the surrounding nervous tissue to be subjected to pressure. This circumstance cannot be unimportant, and though we are less prepared to say much regarding its influence, a remark or two may be ventured.

It has been laid down as a general principle, that "incipient disease or irritation, *by means of moderate or partial pressure* on any portion of the nervous system more immediately connected with motion, sensibility, and intelligence, produces excitement of that part, followed by an increased or augmented action."[1] If this statement be correct, it affords a very simple means by which the increased bulk of one part of the brain may affect the action of another beside it. The "moderate or partial pressure" so exerted on the latter

[1] Bennett: Library of Medicine, Vol. ii., p. 8.

may prove a direct stimulus, and arouse its functions to activity.

When a sensation is of such intensity as to occasion acute pain, various portions of the muscular system are frequently excited to violent action, and this in spite of strong efforts of the will to control them. Here the final cause of the excitement may be readily recognised. The nervous action necessary to produce such vigorous muscular contractions, modifies the vascular condition of the nervous centre, and, in the manner already explained, the effect of the impression on the mind is rendered less acute. In determining the immediate cause of the nervous action, the principle stated above may possibly give us some assistance. When a sensory ganglion is moderately impressed, it of course becomes more vascular, but the consciousness may be affected without any outward physiological phenomenon being produced. If the impression be more intense, however, the vascularity becomes greater, and the bulk of the ganglion is increased in proportion. If the pressure which must be thus occasioned be exerted immediately or indirectly on some part of the brain connected with the nerves of motion, the action of that part will be stimulated, and muscular contraction must immediately result.

We have now attempted to illustrate some modes in which the brain and its circulation mutually affect one another, and to show in what manner a change in their relations may modify the manifestations of mind. To extend their application to such states as Insanity, Emotional Excitement,

Hysteria, Epilepsy, etc., presents a tempting field for speculation. From this we refrain in the meantime, and conclude our Essay with a few remarks on the physiology of Mesmerism.

It will readily be admitted that, to give a full exposition of the physiological causes of those phenomena which characterise the mesmeric trance, is a task of no ordinary difficulty. Scarcely any attempt, indeed, has been made to do so. They have been referred, and we believe quite correctly, to the influence of "dominant ideas," "mental abstraction, or concentration of the attention;" but this is regarding them simply as psychical phenomena. Such a view is, of course, most important in permitting us to disregard other erroneous methods of explanation; but it throws no light whatever on that abnormal condition of the nervous system in which, there can be no doubt, they have their origin. It will not be unimportant to establish even a small portion of the truth in regard to its nature, and this is all we hope at present to accomplish.

When the fully educated mind is in healthy activity, the succession of its various states is in accordance with certain psychical laws. The brain is at the same time the subject of corresponding activity, and each and every portion of its mass must be ready to take on itself its own particular duty. When an individual has been mesmerised, however, the mental phenomena cease to be in accordance with the ordinary laws of mind. Sensation, belief, and volition, are more or less easily deranged. Memory becomes treacherous,

consciousness and volition are suspended or perverted, and belief is influenced in opposition to the results of former experience. This mental derangement is evidently owing to some anterior change in the nervous system. To determine in what this consists it will be necessary to trace the chain of causation in its production, or at least to discover as many as possible of the connecting links.

The first incident in the series of causes is a steady, prolonged effort of volition. For a longer or shorter period the attention is concentrated in one direction. This effort is strongly opposed to natural instinct, and calls into activity a circumscribed or limited portion of the encephalon. At present we need not consider it a matter of consequence to determine precisely what portions of the nervous mass are thus exercised. If we attempt to be too detailed, or to speak positively on this point, we can scarcely avoid falling into error. Perhaps, however, one of the sensory ganglia, perhaps the thalimus opticus and a portion of the cerebrum connected with the expression of volition, are principally involved.

The immediate consequence of this prolonged strain is exhaustion, to a greater or less extent, of the irritability of the parts involved. They are reduced to a condition in which they can, with less than ordinary facility, respond to their accustomed stimuli. This condition probably approaches, or is identical with, that which is present during sleep.

The next physiological result produced, is instability of

the encephalic circulation. In ordinary circumstances, every portion of the brain exercises a certain amount of controlling influence on the mode in which the blood is distributed through its mass. During mere wakefulness, when every part is ready to respond to its appropriate stimulus, nutrition is probably in a medium state between that which is characteristic of sleep and that which accompanies active functional exercise. Every portion of the nervous tissue has then a certain hold, as it were, of the circulating fluid; it attracts the latter towards it with a certain amount of force, and is less easily deprived of it than during a less excited state of nutrition.

In the circumstances we have been speaking of, however, the attractive force which different parts of the brain exercise towards the circulating fluid, fails to be possessed in the usual relative proportions. Where the irritability of the nervous tissue has been exhausted, there also will the attraction be less strong. Previously the balance of the circulation had been too much inclined towards that part; but now, when the stimulus is withdrawn, its power to affect the circulation is much less than its ordinary average.

In such circumstances, let a stimulus call into brisk functional activity any part of the encephalon whose irritability has not been exhausted, and in answer to the demand for nutritive material which is immediately created, the determination of blood towards the part will be greater than usual. The antagonism exerted by the rest of the brain is, as we have seen, on the whole, less than in ordinary circum-

stances; and a more abundant supply is thus permitted to the seat of activity. This increased determination of blood must react on the tissue, and modify its action. Its function will be performed with increased intensity. A weak stimulus will now have as much effect as a more powerful one would have in a less vascular state. The effect on the brain as a whole, and consequently on the mind, will not stop here. The very intensity of the action will again react on the circulation. The latter may be so affected through the whole brain, that its equilibrium may again predominate too much in one direction, and thus the facility with which other parts may be called into activity will be materially interfered with.

Whatever favours the flow of blood to the cerebrum will increase the facility or intensity with which the mind contemplates its own ideas. When we wish to pursue any train of thought without interruption, we remove, as far as may be possible, all distracting impressions from the organs of sensation. Contemplation is thus favoured, not only by the attention being undisturbed, but also because the flow of blood to the organ of intellect is promoted.

In dreaming, a limited portion of the brain is active, while the rest is completely dormant. This partial activity of the material organ prevents the mind from correcting the erroneous notions that then possess it. Perhaps the principal reason why ideas are then presented with all the vividness of immediate perception, is the unusually free supply of blood that may then be permitted to those parts which are active.

From the passive state of the rest of the organ, it will be much greater than can possibly occur during wakefulness.

Again, when in complete darkness some unknown object is obscurely seen, or the attention is attracted towards indistinct sounds, it frequently requires a considerable amount of self-control to prevent the mind from being agitated. It is difficult to resist entertaining the notions that then rush on the imagination with extreme vividness. It is well known that in such circumstances the fancy can frame in complete detail, and with remarkable distinctness, almost any object, or hear any expressions, that may be suddenly suggested. If these are associated with feelings of fear, self-possession may be entirely lost, and that notwithstanding the glimmerings of conviction that there is really no occasion for dread. Here also we have a cause in operation by which the balance of the circulation is affected. From the absence of the stimulus of light, a portion of the brain has not that amount of control over it that it usually exerts when the mind is active. Particular ideas, therefore, take hold of the latter with greater intensity than usual, from the preternatural flow of blood permitted to the cerebrum.

In mesmerism we have physiological conditions precisely analogous. In the manner already explained, those forces are deranged by which the equilibrium of the circulation through the brain is preserved. The blood is determined too freely towards particular parts of the organ; and thus while some actions may be performed with unnatural inten-

sity, that ready co-operation in all parts which is essential for reflection and judgment is, for the time being, to a greater or less extent destroyed.

We make no attempt to explain in detail particular instances of mesmeric phenomena; but we have said enough to show that in any theory that may be advanced for their explanation, a consideration of the reciprocal action of the brain and its circulation must constitute a very prominent element.

ERRATUM.

At page 37, first line of note 1, *for* 1850 *r ad* 1854.

THE END.

MURRAY AND GIBB, PRINTERS, EDINBURGH.