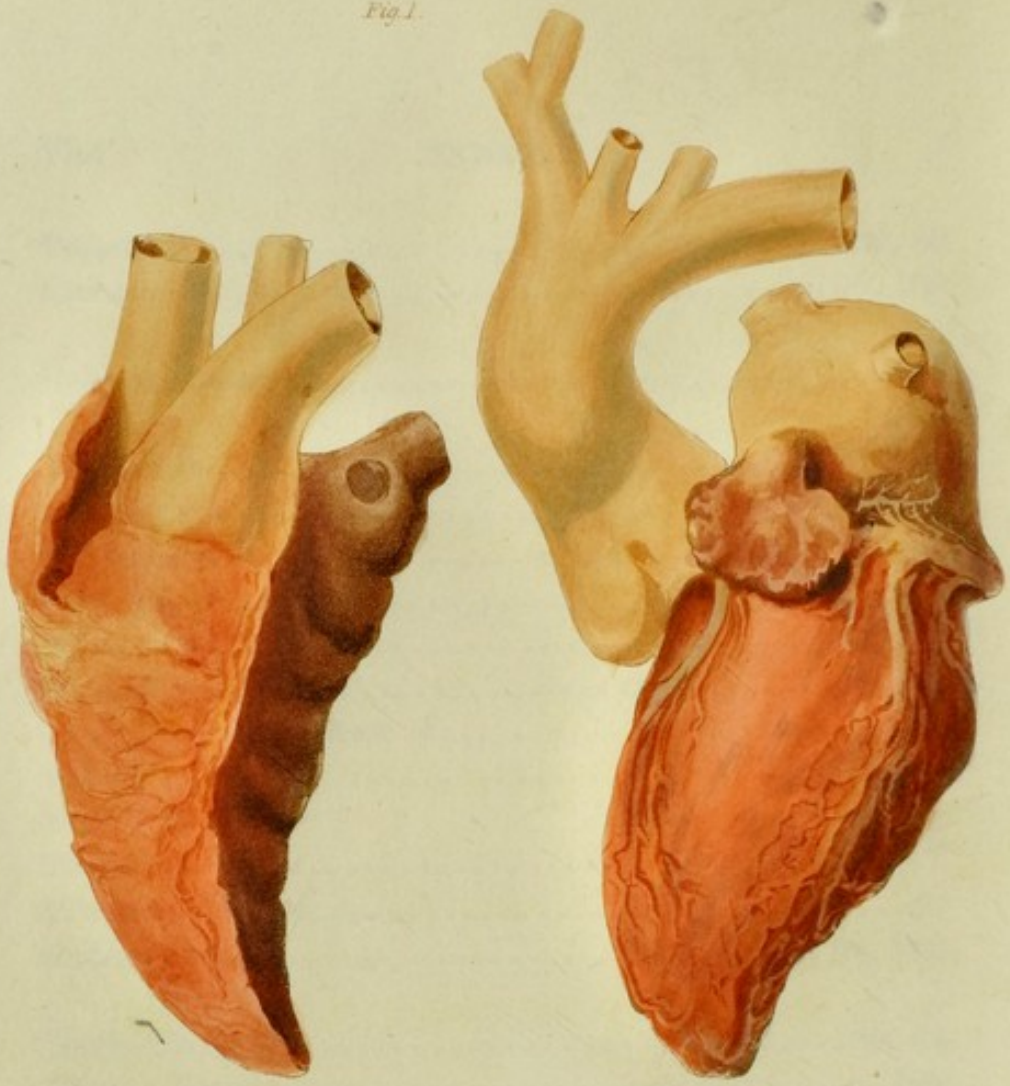
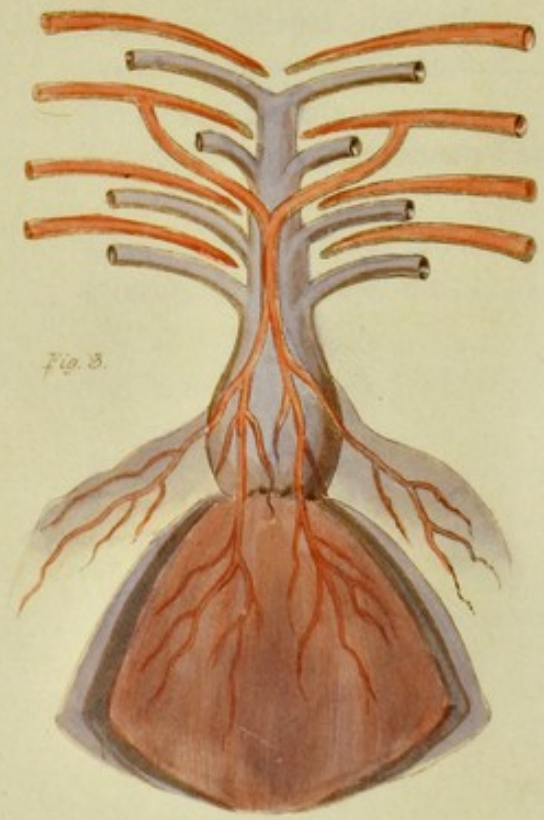
On the mutual relations between anatomy, physiology, pathology, and therapeutics, and the practice of medicine : being the Gulstonian Lectures for 1842 / by Marshall Hall.

Fig. 1.





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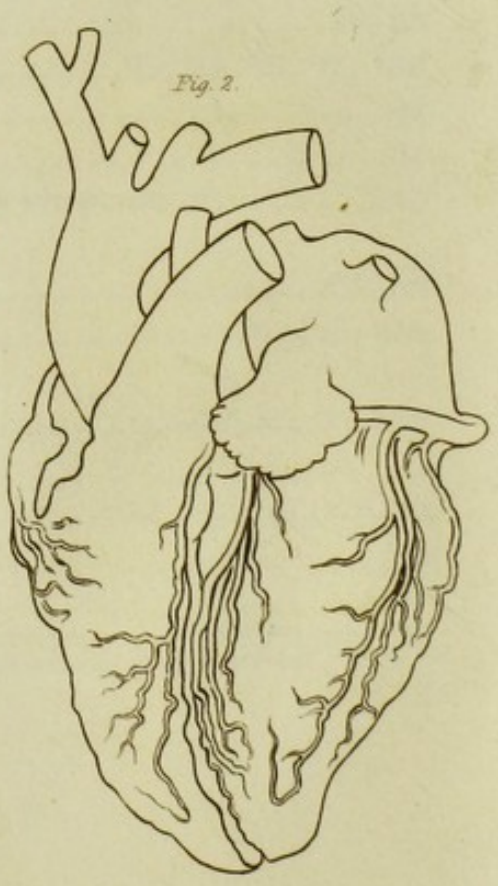

ON

THE MUTUAL RELATIONS BETWEEN

ANATOMY, PHYSIOLOGY, PATHOLOGY,

AND

THERAPEUTICS,

AND

THE PRACTICE OF MEDICINE.

BEING THE

GULSTONIAN LECTURES FOR MDCCCXLII.

BY

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ILLUSTRATED BY THREE ENGRAVED PLATES.

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LEIPSIG: T. O. WEIGEL.

1842.

TO

P. FLOURENS

PERPETUAL SECRETARY OF THE INSTITUTE OF FRANCE;

ETC. ETC.

TO

R. E. GRANT

M.D. F.R.S. L. AND E.

PROFESSOR OF ZOOLOGY AND COMPARATIVE ANATOMY AT

UNIVERSITY COLLEGE, LONDON; ETC.

AND TO

J. MÜLLER

PROFESSOR OF ANATOMY AND PHYSIOLOGY AT THE ROYAL

UNIVERSITY OF BERLIN; ETC.

THIS

LITTLE VOLUME IS DEDICATED,

AS TO

THE FIRST AUTHORITIES ON THE SUBJECTS

OF WHICH IT TREATS

IN THEIR RESPECTIVE COUNTRIES.

PREFACE.

The following pages, which I have abridged as much as possible, contain *sketches* to which I trust I shall one day be able to add the *lights* and *shadows*, so as to present a *picture* of the extensive and important subject to which they refer.

There are many other topics which ought to be discussed in a complete *treatise* on the subject of these lectures. The influence of *tissue* on the inflammatory and other morbid processes, pointed out successively by Smith, Hunter, and Bichat; the influence of *continuity* or discontinuity of tissues on the diffusion or limitation of diseases—observed in bronchitis, which is usually double, contrasted with pleuritis and pneumonia, which are usually single, are examples of the application of anatomy to pathology. Inflammation of the absorbents, and phlebitis, present other examples of the same kind, of intense interest. The creeping of cancer along *adjacent* tissues, and its diffusion through the medium of the absorbent vessels, and of the general circulation, are other examples still, of a terrific character.

A treatise on the subject of these lectures, in which each principle should be set forth by a *fact*,—an *observation*, or an *experiment*,—would be of incalculable value to our pupils: such a treatise I have long projected, and still hope to execute.

Every day, physiology becomes a more certain science, and more a science of phenomena and of principles. Theory is taking place of hypothesis, experiment and observation of conjecture. Every day, too, the bond which unites the science of physiology with the practice of medicine, is drawn tighter.

The public, as well as the profession, must be enlightened on these topics. We shall then see empiricism disappear, while ignorance and mystery and superstition in medicine, are dispelled together. There are no quacks amongst the engineers, because every one knows that an engine must be understood by him who would repair it. When this truth obtains in regard to medicine, then, and not till then, will that most complicated of machines, the human frame, cease to be confided, in the derangements of its functions, or the diseases of its structure, to any one who is ignorant of the many springs of its action and principles of its composition. When this truth prevails, then, and not till then, will labours devoted to investigation in our profession, obtain their just reward.

In the following pages, I have treated principally, and very briefly, the following questions:

1. The comparative importance of ingestion and egestion in a physiological and pathological point of view;

2. The application of the principle of the diffusion of gases to the physiology of respiration, as first made by Professor Graham; and to the pathology of this function, or asphyxia;

3. The single but diplo-cardiac circulation in man, with its application to the pathology of the 'arrière' circulation in certain diseases;

4. The coronary circulation, as implying the necessity of the conjunction of the systemic and pulmonic hearts, and as explaining the occurrence of certain cases of sudden death;

5. The condition of the blood in asphyxia, anæmia, chlorosis, erethismus, &c. in relation to sudden death;

6. The two-fold mode of operation of remedies and poisons, and of both internal and external agents generally, in different instances, through the *nervous* and *vascular* systems.

Other points of subsidiary importance have been noticed; many questions have been suggested for new investigation.

I adopt most sincerely the words of the celebrated Heberden on this occasion:—"Hæc fere sunt quæ usu magistro didici de natura morborum, et remediorum. Fateor equidem ea esse rudia, inchoata, et manca: cujus rei culpa, ut maximam partem in me recidat, partim tamen in ipsius artis conditionem erit rejicienda*."

* Commentarii, MDCCCVII, p. 416—417.

ERRATUM.

Page 69, line 3, for *res*piration read *ex*piration.

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THE

GULSTONIAN LECTURES

FOR

MDCCCXLII.

GENTLEMEN,

In accepting the office of Gulstonian Lecturer for the present year, I became anxious to select some subject for discussion which might not be unworthy of your attention. I have fixed upon that of—the Relation which subsists between Anatomy, Physiology, Pathology, and Therapeutics, and the actual Practice of Medicine—although I greatly fear that it may not admit of being compressed within the prescribed limits of these lectures.

It is well known to you, that an unfounded prejudice has long existed, and still exists, in the public mind, and, I fear I must say, in that of our profession, against the study of anatomy and physiology, on the part of the physician or the surgeon, as that which would be apt to lead him from *practical* views. We read in the biography even of the late Dr. Baillie* the following observation: "However unaccountable it may appear, yet it is not the less true, that many of the physicians then in London were of opinion, that his pre-eminence in anatomical knowledge, instead of establishing his fame as a practitioner, would be the means, not only of impeding, but of absolutely frustrating, his prospects; and he was, in consequence, repeatedly advised to relinquish his anatomical class†."

* The Works of Matthew Baillie, M.D. by James Wardrop, 1835, p. 35.

† I need scarcely remind you of the fate of the illustrious Harvey: "Ab Harveii enim familiari quodam habemus memoratum, se illi adfuisse querenti, quod multo rarius solito ad ægros invisendos accersitus esset, postquam librum de motu cordis ediderat."—Gulielmi Harveii Opera, a Col. Med. Lond. edita, 1756.

My object is, if possible, to remove a prejudice so unfounded, so injurious to our science, and so unjust towards its ardent cultivator, by demonstrating that the physiologist alone can become the truly able practitioner,—that *science* alone, properly pursued and applied, and not what has been fallaciously and, I fear too often, insidiously denominated *experience*, can lead to a just diagnosis, unfold the nature of disease, suggest new remedies, and guide us in the just employment of the old.

If it were necessary to adduce *examples* of the eminent practical physician and surgeon, formed in the school of anatomy and physiology, I could not do better than recall to your minds the name of that illustrious physician whom I have already mentioned, and of an equally illustrious living surgeon, well known as the author of some admirable physiological papers (his earliest labours) in the Philosophical Transactions. Or I might adduce the equally illustrious names of Hunter and Heberden, and contrast the rational and the empirical character, in their most perfect examples. Whilst Heberden observed most accurately the external phenomena of disease, Hunter penetrated more deeply and investigated Nature's most secret and hidden operations. To the former we owe some of the most exquisite histories of disease; to the latter we owe important new operations, the remedies of disease. To Hunter we are indebted for the best refutation of the saying of that eminent physician—"Quamobrem usum, tardum sane ducem, fere solum huc usque secuta est ars medendi; et nulla illustria incrementa ex ratione vel cepit, vel captura est, donec humano generi a Deo immortali tributus fuerit vir, qui, quemamodum Newtonus inanimata, sic animantia contemplando, principium illud vitæ detegat, a quo omnes naturales actiones pendent, et gubernantur*." Ages before the "principle of life" is detected, we may trace its phenomena, both by observation and experiment, and deduce from them important inferences both in regard to the nature, the prevention, and the cure of diseases. In this manner did the genius of Hunter both soar above and penetrate beneath the mere surface to which observation must confine its operations.

* Commentarii, ed 1807, p. 417.

But why should I attempt to exalt one of these modes of enquiry above the other, when they ought not to be separated as antagonists, but united as allies? As combining these two characters, I may recall to your minds the illustrious Jenner, one of the greatest benefactors of mankind, and one of the greatest philosophers and practitioners of whom our country and our profession can boast.

I conclude, then, as Celsus concluded nearly two thousand years ago—"Igitur, ut ad propositum meum redeam, rationalem quidem puto medicinam esse debere;" &c.*

But I leave these remarks, and proceed at once to the more immediate subject of these *Lectures*.

Medicine, as a branch of general science, has been subdivided into subsidiary branches, and the structure of the human frame, its functions, the derangements of structure and of function, and the mode of action of the causes and remedies of these, are treated of in our works and in our schools, under the designations of anatomy, physiology, pathology, and therapeutics. These subjects have been treated singly and exclusively; perhaps too exclusively. It is my present object to shew how essentially they are connected together and with actual practice.

When we take a general survey of man, we are struck with his powers of perception, judgment, combination, volition, &c. so exalted among created beings. By these powers he subdues all nature, as it were, to himself.

Viewed as a part of the animal creation, we find that, in common with it, he daily appropriates a portion of the elements of the external world to his own proper substance. In doing this, two essentially different orders of functions are in action. By the first, these elements are ingested *physically*, and *in masses;* by the second, they are disseminated through the animal frame, and assimilated to its substance, *chemically*, and *by particles*. This process is followed by others, in the inverse direction; and substances, which have performed their office in the animal œconomy, are re-absorbed, separated from the animal solids and fluids, and eventually ejected from the

* Præf. p. 22.

system; the first part of this process being performed upon the *particles*, the second upon the *masses;* the whole being destined for the purification or defæcation of the system, and being more immediately necessary to life even than the processes of ingestion and assimilation themselves. This fact will be illustrated in a subsequent lecture.

By these means the *blood* is formed and maintained in its perfect and purified state and fit for the higher purposes of organic life. In this state, it is carried by the circulatory system to the nervous system, whilst both are required for the muscular. These functions may be viewed as of an order superior to those of ingestion and egestion: they are the functions of *life*, as contrasted with functions which are only preparatory, however essential, to life; they are inferior to the highest functions of all, or those of the immortal *soul*.

All the rest of the structures and tissues of the animal frame, the bones, the cellular and other membranes, the parenchymatous substance of organs, are mere scaffolding, wonderfully nourished indeed by those very organs and powers to which they yield their support.

There are, in every animated being born into this world, the principles of growth, of vigour, of disease, decay, and death. In each of these, the three systems to which I have adverted perform their allotted functions. The precise order in which these systems, with their functions, are developed, and in which they subsequently fail and cease, presents one of the most interesting topics of enquiry to the philosophical physician.

There is another and most interesting question: it is that of *sudden death*. This question will occupy us hereafter.

The functions to which I have adverted are those on which the *Preservation of the Individual* depends. There is another series of functions on which the *Continuance of the Species* devolves; and these equally embrace acts of ingestion and egestion, whilst a new system of assimilation—a sort of imperium in imperio – is established.

The views of physiology which I have thus sketched are displayed in this Classification, which will at once serve to place them distinctly before the eye, and to guide us in our future course: (see the table at the close of this volume.)

LECTURE I.—ON PHYSIOLOGY.

1. *The Functions of Ingestion and of Egestion.*

THE department of *anatomy* is too vast, and too well known, to admit of being discussed within the narrow limits of these lectures, separately and distinctly. I therefore propose to advert to it incidentally in treating of the other branches of my subject, and proceed, at once, to treat of *physiology*.

The first part of the series of subjects comprised in physiology is the process of *Sanguification*. It embraces the ingestion, the digestion, and the assimilation of certain external elements, or the food. The second part of this series is *Respiration*. This function comprises the inhalation and exhalation of atmospheric air, from which one principle especially is absorbed, and to which a new principle is added; these changes constituting a double function of ingestion and egestion, of which it will be our office to determine hereafter the comparative importance. The third part of the series is *Purification*, or the separation from the œconomy of all that might be injurious if retained.

In discussing the subject of ingestion and of egestion, we shall proceed to consider, as I have already hinted, which of these important functions is the more immediately essential to life; and we shall have to point out more than one example of the final use made even of the excretions of the animal œconomy, as they are being expelled from the system—events affording, to the contemplative mind, beautiful examples of design and of the fitness of means to ends.

In relation to this latter *physiological* point, I may mention that the carbonic acid, at the very moment that it becomes excretory in the lungs, is, by its contact with the fine extremities of the pneumogastric nerve, the principal excitor nerve of respiration, the exciting cause of a new inspiration; whilst the bile, at the very moment it becomes an excretion, is a chief agent in the digestive process.

In regard to the food, it is to be observed that its different portions pursue two different courses between the first and last parts of the alimentary canal. Those parts of the food which remain undigested are carried along the whole tract of

that canal. But the digested portion—that portion which becomes first chyme and then chyle—is taken up by a series of absorbents which, from the milky hue of their contents, are termed *lacteals*, carried to the thoracic duct, and eventually into the jugular vein, where it mingles with the general mass of the blood, from which it is eventually deposited in the interstitial points of the animal tissues, in the final act of nutrition. From these points it is eventually re-absorbed by another series of absorbents, from the limpid character of their contents denominated *lymphatics*, again conveyed to the thoracic duct, the jugular vein, the blood, and along the general circulation, and eventually secreted or separated in the form of carbonic acid by the lungs and the skin, of urine by the kidney, and of bile by the liver, and, lastly, of the true fæces by the lower portion of the intestine, the colon, the proper depository of this excretion.

The influence of a poisoned condition of the blood, and of irritation of the nervous system, from retained excernenda, on the general health, and in inducing diseases of the organs, will be particularly noticed in another lecture.

To recur to the subject of *anatomy*, I may here observe, that the type or characteristic of the organs of purification is that afforded by their receiving at once *arterial* blood in moderate quantity for their own nutrition, &c. and *venous* blood in large quantity for the purpose of purification. (See note at the close of this lecture.)

The *lung* is supplied with arterial blood by the bronchial arteries from the descending thoracic aorta, besides receiving from the right side of the heart the entire venous blood of the body.

The *liver* receives arterial blood by the hepatic arteries, and venous blood in large quantity by the vena portæ, the whole being ultimately received into the hepatic vein.

Even the *kidney*, besides receiving arterial blood, is supplied with venous blood by a nephritic portal vein, in the lower order of animals, viz. the reptiles, the amphibia, and the fishes; that is, in a part of that class of animals in which the intestines and urinary apparatus equally issue in a cloaca.

By the ordinary process of digestion, then, blood is supplied; by respiration it is perfected; by the processes of defæ-

cation it is purified. Of these processes, as respiration is far more immediately essential to life than the other two, I shall occupy your time a little further with this important matter presently.

The three parts of the series of the functions of the animal body, to which I have adverted, constitute that "*tourbillon*" so beautifully described by CUVIER as constituting life. "Si, pour nous faire une idée juste de l'essence de la vie, nous la considérons dans les êtres où ses effets sont les plus simples, nous nous apercevons promptement qu'elle consiste dans la faculté qu'ont certaines combinaisons corporelles de durer pendant un temps, et sous une forme déterminée, en attirant sans cesse dans leur composition une partie des substances environnantes, et en rendant aux élémens des portions de leur propre substance.

"La vie est donc un tourbillon plus ou moins rapide, plus ou moins compliquée, dont la direction est constante, et qui entraîne toujours des molécules de mêmes sortes, mais où les molécules individuelles entrent, et d'où elles sortent continuellement, de manière que la *forme* du corps vivant lui est plus essentielle que sa *matière*.

"Tant que ce mouvement subsiste, le corps où il s'exerce est *vivant; il vit.* Lorsque le mouvement s'arrête sans retour, le corps *meurt.* Après la mort, les élémens qui le composent, livrés aux affinités chimiques ordinaires, ne tardent point à se séparer, d'où résulte plus ou moins promptement la dissolution du corps qui a été vivant. C'était donc par le mouvement vital que la dissolution était arrêtée, et que les élémens du corps étaient momentanément réunis*."

In the lowest order of animated beings, the ingestion and egestion, both of food and of air, are performed by the same orifice. Higher in the scale, the food is received by one orifice, whilst the fæculent matters and the urine are ejected by another. Higher still in the scale, the urinary secretion is ejected by a third and distinct orifice. In the very highest part of the zoological scale, the two acts of respiration are performed by one orifice, the larynx.

* Règne Animal; Paris 1829, tome i, p. 11—12.

The Respiration.

The original opinion of philosophers, when the facts that oxygen disappeared and that carbonic acid appeared during respiration were first ascertained, was—that the oxygen inhaled united with carbon secreted in the lungs, and so formed the carbonic acid exhaled. Of this opinion were Goodwyn, Girtanner, &c.

It was first distinctly stated by Sir Humphry Davy, that, in inspiration and during the pulmonic circulation, the double function was performed of

1. *The absorption of oxygen, and*
2. *The exhalation of carbonic acid,*

by and from the circulating blood—a doctrine from which another doctrine flows—viz. that, during the systemic circulation, the oxygen absorbed is continually undergoing the transition into carbonic acid.

It would be inconsistent with the limits of these lectures to quote the words of this illustrious philosopher at length. But I may quote the general conclusion from his experiments: "Respiration, then, is a chemical process, the combination of phosoxygen (oxygen) with the venous blood, and the liberation of carbonic acid and aqueous gas from it*."

This important view of the nature of the chemical and physiological changes in respiration is confirmed by the recent experiments of M. Edwards†. This able philosopher observes—"L'oxigène qui disparaît dans la respiration de l'air atmosphérique est absorbé en entier. Il est ensuite porté en tout ou en partie dans le torrent de la circulation.

"Il est remplacé par une quantité plus ou moins semblable d'acide carbonique exhalé, qui provient en tout ou en partie de celui qui est contenu dans la masse du sang.

"En outre, l'animal respirant de l'air atmosphérique absorbe de l'azote; cet azote est porté en tout ou en partie dans la masse du sang.

"L'azote absorbé est remplacé par une quantité plus ou

* The Collected Works of Sir Humphry Davy, Bart. by John Davy, M.D. F.R.S. vol. ii, p. 79.

† De l'Influence des Agens Physiques sur la Vie; 1824, p. 465.

moins équivalente d'azote exhalé qui provient en tout ou en partie du sang.

" Voilà quatre points fondamentaux :

" 1. L'absorption de l'oxigène qui disparaît ;

" 2. L'exhalation de l'acide carbonique expiré ;

" 3. L'absorption d'azote ;

" 4. L'exhalation d'azote."

Regarding the function of respiration as consisting essentially of the *absorption* of oxygen, and of the *excretion* of carbonic acid, many momentous questions arise: and, first, we may ask—which of these two functions is the more immediately important to life? and, secondly, how are they affected respectively by various external circumstances?—questions which, according to the opinion of Goodwyn, &c. could not have been entertained in a separate form.

In the cases of submersion and of suspension, it is obvious that both the inhalation of oxygen and the exhalation of carbonic are arrested. But there is a case in which the inhalation of oxygen is excluded, whilst the exhalation of carbonic acid is secured: it is that in which an animal is placed in a *respirable* gas destitute of oxygen, as pure nitrogen, or pure hydrogen gas. It is much more difficult, and perhaps impossible, to institute an experiment in which the inhalation of oxygen shall be secured, whilst the exhalation of carbonic is excluded; for the absorption of oxygen may only be possible on the principle of *interchange*.

The discussion of this question requires that I should enter into a few details, to which I must earnestly solicit your patient attention.

An interesting subject has recently occupied the attention of the chemical philosopher under the designation of the *diffusion of gases*. Noticed successively by Priestley, Dalton, Dobereiner, Professor Graham, &c. it has acquired a special interest to the physiologist by its application to the explanation of the phenomena of respiration by the last-named philosopher*:

" I may mention," says Professor Graham, " an application of the law of diffusion in explanation of the mechanism of

* Transactions of the Royal Society of Edinburgh, vol. xii, p. 255.

respiration. The cavity into which air enters during respiration, consists, first, of a large tube, the windpipe; secondly, of smaller tubes, into which the windpipe diverges; and, thirdly, of a series of still smaller tubes, diverging from the last, themselves ramifying to an indeterminate extent, till at last the tubes cease to be of sensible magnitude, but are believed to terminate in shut sacs. The capacity of the whole cavity cannot easily be determined; but we may estimate it at three hundred cubic inches. In a natural expiration, about twenty cubic inches, or one fifteenth of the contents, are thrown out, from the application of a general pressure to the whole. But it is evident that these twenty cubic inches will be the twenty cubic inches nearest the outlet, or the contents of the larger tubes. The contents of the second-sized tubes will advance at the same time into the larger tubes, but no further, and will recede again into their original depositories on the next inspiration, which will fill the large tubes with fresh air; which identical quantity will again be expelled in the next expiration. This illustration is perhaps too strongly stated; but it is evident that, in ordinary respiration, the slight mechanical compression will have little or no effect in emptying the most distant tubes, or the ultimate air-cells, of their contents. The bulk of the air, also, is not altered during respiration, although, for a quantity of oxygen, carbonic acid gas is substituted. This substitution, which is the great end of respiration, undoubtedly takes place most abundantly in the minute and distant air-cells, which present the largest surface to the blood; and the carbonic acid there produced must be moved along the smaller tubes by the diffusion process (which we know to be extremely energetic, and also inevitable), till it is thrown into the larger tubes, from which it can be expelled by the ordinary action of respiration. But the action of diffusion is always twofold: at the same time that carbonic acid is being carried outward from the air-cells, oxygen is carried inward in exchange, and then the necessary circulation kept up through the whole lungs.

"Farther, by a forced expiration, from 160 to 178 cubic inches may be expelled; after which, there still remain in the lungs about 120 cubic inches which are not under the control of the respiratory action.

"There can be no doubt that much of this quantity occupies constantly and permanently the most minute tubes and air-cells; for it can scarcely be withdrawn by means of the air-pump. Now, the question has arisen, how these ultimate tubes and air-cells are so powerfully inflated; for they are not distended by the action of muscular fibre, of which they are known to be destitute. This state of distension must be highly useful by exposing surface; and the law of diffusion enables us to account for it. The heavy carbonic acid which these minute cells may contain is not merely exchanged for oxygen, but for a larger volume of oxygen, in the proportion of the diffusion-volumes of carbonic acid and oxygen; namely, 81 carbonic are replaced by 95 oxygen. The resistance to passage through the most minute tubes is overcome by the diffusion-action, as in the case of the pores of the stucco-plug, and there follows a tendency to accumulation on the side originally occupied by the carbonic acid. This accumulation is limited by the increased facility with which the air-vessels can empty themselves mechanically of a portion of their contents from their distended state.

"In the law of diffusion of gases, we have, therefore, a singular provision for the full and permanent inflation of the ultimate air-cells of the lungs.

"But it is in the respiration of insects, that the operation of this law will be most distinctly perceived. The minute air-tubes accompanying the blood-vessels to every organ, and like them ramifying till they cease to be visible under the most powerful microscope, are kept distended during the most lively movements of the little animals, and the necessary gaseous circulation maintained, wholly, we may presume, by the agency of diffusion."

But, as the diffusion of gases is regulated and limited by a fixed law, it occurred to me as possible to determine by what addition of carbonic acid to the atmospheric air the diffusion of this gas in the lungs, and its consequent exhalation from the blood, might be entirely prevented. In this manner, we might determine the effects of various admixtures of carbonic acid with the atmospheric air, and throw a ray of light upon one kind of asphyxia—that induced by the charcoal fire and the 'choke-damp.'

Deeply interested in this question, I addressed Professor Graham on the subject, and was favoured by that gentleman with the following reply :

"My dear Sir,

"In reply to the queries in your note of yesterday, I beg to say, that, if an animal were to breathe atmospheric air to which carbonic acid were added, in proportion to this addition the evolution of carbonic acid from the blood would, in my opinion, be impeded, the passage of the carbonic acid outwards at all from the blood depending upon the comparative absence of that gas from the air taken into the lungs. It would be difficult, however, to say, without trial, what proportion of carbonic acid in the atmosphere would entirely arrest the evolution of that gas from the lungs; for it is certainly not the ratio of equality in the proportion of carbonic acid in blood and air that is the proportion of equilibrium. In the sea, for instance, the proportion of free carbonic acid is (if I am not mistaken) two hundred times greater than in the air in contact with it.

"The enquiry which you start is certainly a curious one, and might be pursued by a chemist, although not, I believe, without an appeal to experiment. The direction of the enquiry might perhaps be reversed: given the proportion of carbonic acid in air which entirely prevents exhalation of that gas from the blood, to determine the proportion of the gas in question in the blood. Such appears to me the form in which the problem would be most easily dealt with by the chemist.

I remain,
My dear Sir,
Most faithfully yours,
Thomas Graham."

9, *Torrington Square, October* 17, 1841.

Dr. Marshall Hall.

The slightest addition of carbonic acid to the atmosphere presents an impediment to the *diffusion* of this acid from the lungs, and to the *equivalent absorption* of oxygen gas; and *asphyxia* may be said to commence. A certain proportion of

carbonic acid in the atmosphere would induce asphyxia as completely as submersion itself, by totally arresting the diffusion and absorption processes. It is this principle which must guide us in the investigation of asphyxia from charcoal fires, &c. By pursuing this investigation, we shall be able to establish the influence of the carbonic acid retained in the blood, in its poisonous agency on the different organs.

The investigation of this subject must be left for a future day: I can only now remark, that, when we compare the duration of life when an animal is made to respire pure nitrogen or hydrogen, with its speedy extinction in the case of submersion or suspension, we can scarcely resist the conclusion, that the exhalation of carbonic acid is a far more immediately vital process than the absorption of oxygen—a conclusion which we certainly should not regard, in the first instance, as the most probable one.

We may here briefly resume the question, whether, as a whole, and in general terms, ingestion or egestion be the more immediately necessary to life? and it may excite some surprise, that greater importance should be assigned to the latter process. But the question is, in other terms, whether the ingesta be more constantly necessary to life, or whether the egesta, if retained, be more poisonous or destructive?

An animal will live many minutes in pure nitrogen, deprived of the stimulus of oxygen; but, if the separation of the carbonic acid in the lungs be arrested, the vital powers are speedily extinguished by the poison.

The privation of food may be sustained for several weeks; it is pure inanition; but suppression of urine, of bile, of the secretion of the fæces, is fatal in a much shorter space of time, the egerenda, if retained in the blood, proving, like the retained carbonic acid in cases of asphyxia, positive poisons to the vital organs.

Next to the excretion of carbonic acid in the lungs, that of the urine by the kidney is most important. If either be defective, dozing, followed by coma and convulsions and death, takes place. In albuminous urine, we have cerebral or true-spinal attacks, hemiplegia, or epilepsy.

The whole question is one of the deepest interest in a hygienic and jurisprudential point of view, and well worthy

of attention and investigation on the part of the younger portion of my audience. I have, myself, long *meditated* an investigation of the subject.

I must not occupy much more of your time with the subject of respiration, however important. And yet if you will cast your eyes over this table (see last page), you will see how many momentous questions remain for discussion.

I may briefly notice, that it is now generally admitted, that the absorption and exhalation of nitrogen form little or no part of the function of respiration; and that the formation of carbonic acid is proved to be nearly, if not entirely, the sole source of animal temperature.

One point I must notice a little more at length. It has been observed, that a peculiar ratio exists between the number of pulsations and of the acts of respiration in all *physiological* conditions of the animal frame. When this ratio is disturbed, it may consequently be regarded as a *pathological* condition.

In sleep, in the long-continued sleep of hibernation, the pulsations, and the acts of respiration, are both reduced in number, their *relative* frequency being maintained.

In a state of activity, or of exertion, the number of pulsations of the heart and that of the acts of respiration, are much and proportionately augmented.

But in morbid conditions, in apoplexy, in hydrocephalus, we have constantly to observe the pulse becoming more and more frequent, whilst the acts of respiration become slower and irregular. The physiological ratio between the number of the beats of the heart and of the acts of respiration is disturbed: it is a pathological condition, a symptom of disease, not unworthy the attention of the physician.

The rationale of the phenomenon appears to be this: by every act of the muscular system the venous blood is propelled onwards to the heart, the rapidity of the pulmonary circulation is augmented; there is consequently a greater exhalation of carbonic acid in the lungs, the excitor of the renewed acts of the respiration. In the various morbid conditions in which this ratio is disturbed, the evolution of carbonic acid, or the

excitability of the nervous system, may be pathologically affected.

But whether we view this matter physiologically and pathologically, or as mere observers, it equally presents us with a subject of enquiry of the deepest interest.

I shall conclude the subject of respiration with one interesting fact. In an investigation in which I was engaged some years ago, I ascertained that, throughout the animal kingdom, the quantity of respiration—or of the exchange of oxygen gas for carbonic acid gas—was inversely as the irritability of the muscular fibre. Animals of low respiration present a degree of irritability of the muscular fibre which renders it a *test* even of the evolution of galvanism. Whereas those species which have a high respiration, as birds, have proportionately a low degree of muscular irritability, as *tested* in its turn by the galvanic influence.

During the sleep of the human subject, and still more during the deep and long-continued sleep of the hibernant animal, the quantity of respiration is diminished, in the manner already explained, and the irritability of the muscular fibre becomes augmented—a part of the principle of the restoration from fatigue during this balmy state.

But, cæteris paribus, the number of the beats of the heart is proportionate to the stimulus of the blood; and I may here briefly adduce an illustrative fact, for which the profession is indebted to my friend Dr. Heming. It was formerly supposed that, in the full-grown fœtus in utero, the heart beats one hundred and twenty times in a minute. Dr. Heming has acertained that the pulsations of the funis umbilicalis before birth are precisely half this number, or sixty. The pulsation of the fœtal heart presents us, therefore, with the phenomenon of sixty beats and sixty *double* sounds, which have been mistaken for one hundred and twenty beats. Soon after respiration has been established, the number of the pulsations of the heart becomes augmented with the augmented stimulus to nearly double the original number.

II. *The Higher Vital Functions.*

The Circulatory System.

We now proceed to notice the other functions of the series. They may be considered as functions of a higher order, as being developed in their most perfect forms only in the higher orders of animated being. The *first* of these is the circulation; the *second* those parts of the nervous system designated the true-spinal and the ganglionic; and the *third*, to which the two former are essential, is the muscular system.

The blood is now supposed to be duly formed, to be supplied with oxygen, and purified of its carbonic acid and other excernenda. It is essential to every part of the œconomy, through which it is, therefore, disseminated with apparently peculiar care.

The Adult Circulation.

The circulation in the adult has been described as double —pulmonic and systemic. This view of the subject is inaccurate. There is in reality but *one* single circulation; but this is *diplo-cardiac* (if I may use that term), and divided into pulmonic and systemic portions. The circle is only completed when the blood, from leaving one point, as the left ventricle, returns to that ventricle again. It is still very different, as I shall explain hereafter, with the fœtus, in which the circulation within the body is *aplo-cardiac* and systemic only.

I here present you with a heart which has been severed, by carefully dividing the layers of its septum, into two hearts, the right and the left, the pulmonic and the systemic. Each is complete, except in regard to the coronary circulation, of which I shall have to treat at some length shortly. There are therefore, in reality, two distinct hearts, of which one is destined entirely and exclusively to the pulmonic, and the other to the systemic portion of the entire circulation.

The idea of a double or two-fold circulation is not only erroneous in itself, but leads to incorrect views of pathology. It is only by justly considering the circulation, in its systemic and pulmonic portions, as one and indivisible, that we clearly discover the influence which defect or interruption in one part

of the course of the blood affects its movements in another, remote from the first—a most important principle in the pathology of the vascular system, to which I shall advert in my second lecture.

The General Circulation.

I shall now briefly describe the general circulation. I need not recall to your minds the beautiful *mechanism* of the heart, its valves, the valves at the origin of the principal arteries. A point less known and acknowledged is, that the power of this mighty vital organ extends to the most remote parts of the circulatory system, to the ultimate divisions of the arteries, beyond these to the true capillary vessels, and, beyond these even, to the veins!—nay, in the case of the hepatic circulation, beyond the veins, to a second series of capillaries, and, through and beyond these, to the hepatic vein and vena cava! The latter part of this proposition is not demonstrable; but the former is capable of the most indubitable demonstration which light can present to the eye.

The idea of Bichat, of Dr. W. Philip, &c. that the force of the heart extends to the capillary vessels only, and that these possess a power of propelling the blood onwards in its course, is a mere chimera, destitute of all proof of course, and opposed to the most glaring phenomena. In a disputed point of this kind, high authorities may be found on each side of the question; otherwise I would quote the opinion of Professor Müller, of M. Poiseuille, &c. Our appeal must therefore be to phenomena. In regard to these, I can only affirm, that the force of each pulsation of the heart is perfectly obvious, not only in the minutest arteries, but in the capillary vessels and in the veins themselves, in the web of the frog and other transparent parts of animals.

The arteries, with one single and remarkable exception, receive the blood impelled by the heart, and are distended by it at each systole of that organ. Their *elastic* coat yields for an instant, but immediately, though gradually, recovers its former condition. In this manner, the blood, from having a pulsatory movement, acquires one of an equable character, on principles well known to the mechanician—a fact perfectly obvious in well-directed physiological experiments.

The pulsatory movements of the blood, in the minute arteries, in the capillaries, and in the veins, of which I have spoken, is only seen, in other well-devised experiments, as a pathological condition. They have thus escaped the observation of many physiologists, who have been too ready to deny the existence of what they themselves had not observed. A similar principle of reasoning would lead to the denial of all undiscovered phenomena.

But not only have the most obvious phenomena been overlooked, and, because overlooked, denied, but other phenomena, which have their existence only in the imagination, or in a defective observation, have been set forth as realities. The following are glaring statements of this kind:

"The destruction of the heart does not immediately influence the motion of the blood in the capillaries!" and "The action of this organ (the heart), when in full vigour, can produce no motion in the blood in the capillaries, when these vessels are themselves deprived of power!" On the contrary—

The true capillary vessels are obviously inert. To this day it is uncertain even whether the true capillaries be really *vessels*, with distinct parietes, or only *canals*, formed in and by the other tissues.

The physiological condition of the minute and capillary vessels in the act of *blushing*, and the pathological augmentation of their size in inflammation, if indeed both of these phenomena be not the effect of obstruction to the flow of the blood—of impeded capillary circulation—remain unexplained.

On the subject of the capillary circulation, I must here enter into a few details:

In 1831, I read a paper before the Royal Society, of which the following is a part of the Abstract made by the Secretary, Dr. Roget*:

"The author concludes from his observations, that the capillaries, properly so called, have no power to contribute to the motion of the blood, and that the capillary circulation depends altogether upon the action of the heart and arteries. In cases of impeded circulation, he observes, the pulsatory

* Abstracts of papers printed in the Philosophical Transactions of the Royal Society, 1837, p. 46.

movement of the blood may be seen, not only in the arteries, but also in the capillary vessels, and even in the veins."

Immediately afterwards, Dr. P. W. Philip read a paper to the same Society, from the abstract of which, made in like manner by Dr. Roget, I extract the following paragraph:

"The capillaries, he observes, maintain the motion of their blood, long after the heart has ceased to beat; this motion not being immediately affected even by the entire removal of the heart; but being accelerated, retarded, or arrested, according as the action of the capillaries is increased, impaired, or destroyed, by agents of which the operation is wholly confined to the vessels themselves*."

I must think that my views are correct, and, consequently, that those of Dr. Philip are erroneous. They coincide with those of M. Poiseuille, given in his recent most beautiful work†, and with those of Prof. Müller, given in his "Elements of Physiology." M. Poiseuille observes—"Nous croyons donc devoir conclure que le cœur et l'élasticité des parois arterielles sont les principaux agents de la circulation artérielle, capillaire et veineuse," and "Dans toutes les expériences que nous venons de rapporter dans ce chapître les vaisseaux capillaires sont d'une inertie complète."

Prof. Müller states—"Many physiologists, believing that the power of the heart is not sufficient to propel the blood through the capillary system, have imagined the existence of other auxiliary forces, such as contractions of the capillaries themselves, or a spontaneous motion of the blood,—neither of which has been demonstrated by direct observation. On the contrary, it is irrefragably proved, that the motion of the blood through the capillaries is effected *solely by the action* of the heart‡."

I. The true capillaries are perfectly different and distinct, in form, character, and distribution, from the minute arteries and the minute veins.

1. The minute arteries subdivide into smaller and smaller branches.

2. The minute veins unite into larger and larger branches.

3. The true capillary vessels unite and divide in turns,

* Ibid, p. 64

† Du mouvement du Sang dans les vaisseaux capillaires, pp. 43, 45.

‡ Trans. by Dr. Baly, ed 1, vol. i, p. 226.

maintain a uniform character, and might, with great propriety, be denominated *iso-metric.*

II. The character of the circulation of the true capillaries is not less distinct from that of the circulation in the minute arteries and veins.

1. The circulation in the minute arteries is so rapid, that it is difficult to distinguish the globules, and the artery itself is so pale as to escape the attention of the inexperienced observer; the streams of blood divide continually.

2. The minute veins are comparatively larger than the arteries, and first strike the eye of the observer; the streams of blood are slower, and continually unite into larger.

3. The true capillaries are pale, like the arteries; but their circulation is slower, and they are consequently more obvious to the eye, through the microscope; the streams of blood divide and re-unite continually, and remain of the same magnitude.

III. The circulation in the true capillaries is singularly affected by various agents. As I venture to affirm that they possess no power of action in themselves, I must believe that they are incapable of being affected by stimuli of any kind.

In regard to the circulation in the veins, it is obviously under the influence of the heart. The effect of the systole of this organ is distinctly seen in each venous trunk. The number of beats of the heart may be counted by watching the movements of the blood in the veins, as distinctly as by applying the finger to the artery in the human subject.

But I must dismiss this subject, and, in doing so, I beg briefly to notice two points of the utmost importance in the physiology and pathology of the circulatory system.

The *first* of these is the physical condition of the internal lining membrane of the whole order of the minute vessels, arteries, capillaries, and veins; but especially the capillaries and veins. In my "Essay on the Circulation of the Blood" (see p. 162), published in 1831, I particularly called the attention of the profession to the effect of the application of alcohol and other agents, and even of blotting-paper, to the web of the frog: the globules of blood became adherent to the internal surface of the capillary vessels and the minutest

veins; some *physical* change had taken place. M. Poiseuille has since shown that, in the physiological condition, the capillary vessels are lined by a fine layer of serum: it is this, doubtless, which is absorbed, or removed by exosmosis, in the experiments to which I have adverted.

I believe the *first* effect of the causes of inflammation generally, and of some other diseases, to be this physical change in the internal lining of the capillary vessels—a statement, if correct, of vast importance in pathology. But the discussion of this point must be reserved for my next lecture.

The *second* point to which I beg to advert briefly in this place, is an *anatomical* one. It is expressed in the following words in my "Essay," p. xiv: "It is a remarkable fact, observed in the web of the frog, that minute *nerves* pursue a course close to the minute arteries. The terminal nerves and arteries may ultimately form the immediate secreting organs." This distribution is observed in other tissues.

I shall add but one remark; whilst the minute nerves and vessels are thus *adjacent* to each other, the blood passes from arterial to venous. During this transition, the galvanic agency may be evolved, may become the immediate active power in affecting the secretions, &c. In this again we have a subject to which I must revert hereafter, and which is open to new investigation.

The Coronary Circulation.

In treating of the coronary circulation, the first remark which I have to make will relate to the apparent reason, and the inteteresting question,—why the two hearts are conjoined together?

The reason for this conjunction has, I think, escaped physiologists. By one recent writer it is supposed to serve the purpose of "economy." But Mr. Mayo states expressly—(in his Outlines of Human Physiology, ed. iv, p. 41), "In adult human beings, the heart is a double organ, or it contains two cavities which do not communicate, and which, for every purpose answered in the animal œconomy, might as well have been disunited."

But there *is* a physiological reason, a physiological purpose,

in this conjunction of the two hearts, of the utmost interest. The coronary arteries convey to the entire double heart the stimulus of arterial blood. By its circulation in this substance, it acquires, as in every other part of the system, the venous character. It is become a poison, until its arterial character is renewed. How is it to be disposed of?

Now, if the two hearts were really planted severally and separately in the animal frame, the *left* heart might be supplied by arterial blood; but the right heart could not receive arterial blood without a special distribution of vessels for this purpose. And, on the other hand, when the blood in the left heart had assumed a venous character, it could not, without a similar provision, be conveyed into the veins. Both these objects—the supply of arterial blood to both hearts, and the course of the venous blood from both hearts—are accomplished in the most beautiful, admirable, and simple manner, by the conjunction of both hearts together.

But other objects are attained by this arrangement. In the first place, the power of the heart is, by means of the elasticity and reaction of the aorta, impressed upon the coronary blood, the coronary arteries, capillaries, and veins are distended; and the erection of all its tissues, its parietes, its columnæ carneæ, and its valves, and the diastole of its several cavities, are accomplished with the accuracy and at the very moment required. The very contractile force of the heart is thus applied for its own dilatation!

The aorta, by its reaction, impresses upon the coronary blood precisely the force of the heart itself; so that the diastole of this organ may be said to be effected by a force equal to that of its systole; nay, by that very systole itself, though not acting so advantageously. The tissues of the heart are erected; the parietes are distended and separated; the columnæ carneæ, especially those attached to the valves, are elongated. The opposite phenomena take place when the interstitial and contained blood has excited the systole.

I have observed actual facts analogous to that I have been supposing. On examining the circulation in the lung of the frog and toad, I have distinctly observed the organ to be elongated, its parietes separated, and its apex raised at each pulsation of the heart. In sitting with the popliteal

artery of one leg resting on the patella of the other, we observe the whole limb moved by each systole of the heart.

It is further observed that the contraction of the auricles immediately precedes that of the ventricles; and that the contraction of the auricles, and that of the two ventricles, are accurately synchronous.

These remarkable effects are, doubtless, produced by the accurately proportionate and simultaneous supply of arterial blood to the coronary arteries of both auricles and both ventricles. Thus is the beautiful rhythm of the heart's action insured—a rhythm which is too apt to be disarranged by changes in the condition of the nervous and vascular supplies, and by organic changes in the heart itself. Had the two hearts been placed at a distance from each other, this regularity of its action would have been impaired by a variety of circumstances, of posture, of muscular action, &c.

In the last place, we may advert to the condition of the animal œconomy in the fœtus, and observe that the two hearts could not, in that period of life, have been separate,—for it is essential to fœtal existence that the two hearts should be conjoined in function as well as in position. In that early condition of existence, the lung is only supplied with arterial blood, like the other organs of the body. It would have been contrary to every principle in physiology for the whole of the blood of the system to have been sent through the lungs without object or purpose.

Thus, then, are we led to see and admire, in the conjunction of the two hearts in the higher order of animals, the hand of Him who fashioneth all things after His own will!

But the heart in fishes and in the mollusca, is single; the former being *systemic*, the latter *pulmonic*. Wishing to know the provision made in these animals for the due supply of arterial blood, and the due course of venous blood, respectively, I addressed a letter to Professor Grant, to whom I am indebted for the following interesting note:

"My dear Sir,

"The heart of Mollusca circulates arterial blood, received from the gills, through the system; and its coronaries are given off from the aorta, as in air-breathing

Vertebrata. But in fishes, where the heart circulates venous blood only, the coronaries originate from the beginning of the anterior bronchial *veins* (conveying arterial blood), and pass backwards over the muscular bulb and the heart, as in the annexed sketch.—(See plate I, fig. 2.)

"The heart of the cod is here seen from below, or on its ventral aspect. This front view, which I have taken from some injected gills of the cod now before me, will, perhaps, form a more distinct diagram of the mode of origin of the coronary arteries than the lateral view, which only exhibits one of these vessels. In Tiedeman's view of the openings of the two coronary veins into the *venæ cavæ*, you will perceive the small semilunar valve defending each orifice.

I remain, my dear Sir, yours most truly,

ROBERT E. GRANT."

10, *Seymour Place North, Euston Square,*
25 *November*, 1841.
DR. MARSHALL HALL.

In the fishes then, which are aplo-cardiac, with a *pulmonic* or bronchial heart only, there is a distinct provision for supplying the heart with arterial blood; the venous blood is doubtless conveyed into the sinus venosus or the auricle. In the *mollusca*, which are aplo-cardiac with a *systemic* heart, the coronary arteries must be supposed to arise from the aorta, and the coronary venous blood must be conveyed, like the respired blood in fishes, by a distinct and appropriate channel. These two series of vessels must have existed distinctly in the human subject, the mammalia and birds, had not the two hearts in these parts of creation been conjoined together,—a complexity of structure not in accordance with the usual beautiful simplicity of Nature's operations, and entirely avoided by the conjunction of the two hearts in the higher orders of the animal creation.

I now proceed to treat of the ultimate parts of the coronary circulation, or that of the minute and capillary vessels.

The coronary circulation has this peculiarity:—the coronary artery alone, of all the arteries in the animal frame, is supplied with blood, not during the systole, but during the diastole, of the systemic ventricle.

At the moment, and as a necessary effect, of the systole or contraction of the heart, the capillary vessels are emptied and all flow into them interrupted.

That this is really the case, is made evident by actual observation. If the heart of the frog be removed and laid upon a plate, it is found to become *pale*-coloured at each systole, especially at its apex, the blood being driven from its tissues, its capillary vessels, into the large veins, placed chiefly at the base of the heart.

Let us consider what would have been the result had the converse of this obtained. The very same contractile force of the ventricle would have impelled the blood along the course of the coronary arteries, and have arrested its course in the compressed capillaries; or, if we imagine the coronary circulation to be effected, the stimulus of the coronary blood would have acted inopportunely at the very moment of the *systole* of the heart. This systole must have remained permanent! I need scarcely observe, that death would have been the infallible consequence.

But as it is, the systole of the ventricle propels the blood from its cavity and from its vessels; during the systole of the auricle, the blood flows into the cavity of the ventricle, now in the state of systole, and into the coronary system of vessels by the simultaneous reflux of blood in the aorta. The *double* stimulus of the blood in the cavity of the ventricle, and of the blood in the coronary vessels, induces a new ventricular systole.

The view which I have presented to you assumes a still more interesting character when we examine it more closely in detail.

It is now well known that the auricles are more irritable than the corresponding ventricles. This may be owing to a comparative greater supply of blood. It is also known, since the publication of the valuable paper by Mr. Turner, that, contrary to the opinion of Laënnec, the systole of the auricle immediately *precedes* that of the ventricle; or rather that the former is but the first part of the general systole of the heart,—which may be said to *begin* with that of the auricle, but to finish with that of the ventricle, in such a manner that the latter itself begins before the former is quite completed.

This, then, is the rationale of the entire systole of the heart. The reflux aortic blood passes along the coronary vessels, and supplies the substance of the auricles and ventricles in such a manner as to induce greater irritability in the former than in the latter; and, at the same time, to excite the former into systole an instant before the latter. The auricle contracts. Immediately afterwards, and almost continuously with the systole, the ventricle contracts. And then the phenomena are renewed in their beautiful order!

Further, the left ventricle is more powerful than the right auricle. The course of the blood along the coronary veins is therefore continuous, and not arrested, as it would otherwise have been, on the systole of the right auricle, into which those veins open.

There is another subject of great interest; the systole of both auricles and both ventricles is synchronous. This is, doubtless, chiefly induced by the synchronous supply of blood to both sides of the heart by the coronary arteries.

In confirmation of these views in regard to the coronary circulation, I may mention an anatomical fact of some interest. It is well known that the veins in every part of the body except the large cavities are endowed with valves. When situated in the substance, or in the midst of muscles, the contraction of these propels the blood from the space occupied within these muscles; and, as it cannot move in a retrograde direction, on account of the valves, it is necessarily carried towards the heart.

I imagined that, for a similar reason, the coronary veins must be supplied with valves; and I carefully examined them in the human subject, and in the horse. As in the limbs, at each junction of two veins, and also in other parts of the course and at the termination of the coronary veins, valves are placed. At each contraction or systole of the heart, the blood is therefore driven from the capillary vessels and minute veins into the larger veins, whilst it is prevented from returning during the diastole, which must rather ingurgitate the blood from the coronary arteries along which it is already propelled by the force of the heart through the resilience of the aorta.

The Systemic Circulation.

By the systemic circulation the arterialized blood is carried into every organ of the body. The blood moved by each systole of the heart is received into the aorta and its principal branches; these are distended, and their elastic tissue is put upon the stretch; this tissue gradually returns to its former state, and so gradually propels the blood onwards in an equable stream.

The power of the heart is thus extended to the extreme parts of the œconomy. It has been shewn to extend to the capillary vessels and even to the veins.

In *one* case, the power of the heart extends even beyond the capillaries and veins. The vena portæ is again subdivided into capillary vessels, and the force of the heart carries the blood through this *secondary* division into capillaries, and eventually through the hepatic vein to the heart.

This *secondary* circulation, unique in the vena portæ in the human subject, is observed in other organs in other classes of animals. Thus the pulmonary or branchial heart of fishes propels the blood through the branchial arteries, capillaries, and veins, and then through the aorta, which results from the rejunction of these, to the different organs and parts of the system. In the mollusca, the heart is systemic, the primary circulation is performed through the systemic, the secondary through the pulmonary, apparatus.

But there is in the human subject another instance of a secondary circulation. This occurs in the fœtus in utero, and will come to be treated of hereafter. I may now just mention, however, that this secondary circulation is that of the fœtal blood in the substance of the placenta.

There is still another example of secondary circulation in the fœtus in utero, which occurs under extraordinary circumstances, and has been the source of much difficulty to physiologists.

It has occurred that the human fœtus has been born at the full period *acardiac*. What, in this case, was the force which moved the blood? This question was long one of great difficulty, and the fact was constantly opposed, with that of the acardiac animal, to the opinion that the heart was the sole or principal cause of the circulation of the blood. The

solution of this difficulty was first suggested by the late Dr. Young. The fact is stated in the most interesting manner in the following note of Sir B. Brodie to the late Sir Astley Cooper:

"My dear Sir Astley,

"As long ago as the year 1809, I published an account of the dissection of a fœtus, in which there was no heart, and in which, from such knowledge as I then had on the subject, I was led to believe that the circution of the blood had been carried on by the agency of the vessels only. Dr. Young afterwards offered it as his opinion, that the circulation in a fœtus of this kind is maintained by the heart of the twin fœtus with which* such a monster is uniformly associated. I forget the arguments which Dr. Young used; but I know that they satisfied me at the time, and that I expressed myself to that effect in my lectures at the College of Surgeons.

"I am not aware that any one else has investigated the subject; and I believe that it has been reserved for you, by the interesting dissection which you mentioned to me yesterday, to prove the accuracy of the conclusion at which Dr. Young had arrived in other ways.

"I am, dear Sir, yours always truly,

B. C. Brodie†."

14, *Saville Row, March* 19, 1836.

Nothing can be more interesting in the history of the discoveries in physiology, than this candid note.

It is probable that, in all cases of twins with united placentæ, there is a community of circulation between the two fœtuses. This point is illustrated by the following facts from the thesis of M. Lallemand ‡:

"Après un travail de quelques heures il sortit naturellement un fœtus bienportant, qui parassait avoir sept ou huit mois. Quand on eut coupé le cordon ombilical, et lié le bout qui tenait à l'enfant, M. Patissier, qui tenait celui qui répond

* And with *united* placentæ.—M.H.

† Guy's Hospital Reports, vol. i, p. 238.

‡ "Observations Pathologiques," Paris, ed. 2, 1825, p. 34.

au placenta, s'aperçut qu'il donnait plus de sang que de coutume ; ce qui fit examiner la chose de plus près. Alors tous ceux qui étaient présens purent se convaincre que le sang qui sortait était lancé par saccade à une assez grande distance, absolument comme le ferait, dans une amputation, une artère d'un petit calibre. Quelle pouvait en être la source ? Le sang ne pouvait venir de la mère avec cette impétuosité et ces jets interrompus qui annonçaient l'influence du cœur : d'ailleurs, quand le fœtus est sorti, la circulation cesse ordinairement dans le placenta. Nous pensâmes donc aussitôt qu'il existait un second fœtus dans la matrice, surtout en nous rappelant la forme qu'elle avait au commencement du travail ; et le toucher confirma cette présomption. Comme le jet de sang était considérable chaque fois qu'on cessait de comprimer le cordon, il fut lié. Les contractions de la matrice devenant plus fortes et plus rapprochées, l'enfant se présentant bien, l'accouchement se termina naturellement. Le second fœtus était semblable au premier. Après la section du cordon, il ne sortit pas de sang par le bout qui tenait au placenta : la délivrance n'offrit rien de particulier. Les deux placenta étaient réunis en une masse commune, quoique les membranes adossées ne fussent que contiguës. L'un des cordons s'implantait au centre de la masse, et l'autre sur la circonférence. On n'essaya pas d'interjecter le placenta, parce qu'une portion avait été déchirée ; mais il était évident que non-seulement il existait pendant la vie des deux fœtus une communication de l'un avec l'autre, mais encore qu'elle avait lieu par de gros vaisseaux, puisque le sang sortait du cordon ombilical coupé, comme s'il n'eut été qu'une continuation de l'autre. Cela peut encore donner une idée de la force de contraction du cœur chez un fœtus de sept mois environ."

M. —— appelé près d'une femme en travail, reconnut, après la sortie d'un premier fœtus né vivant, qu'il en existait un second dans l'utérus. Occupé de l'enfant, il n'examina pas la portion du cordon qui tenait au placenta. Bientôt le fœtus resté dans la matrice exécuta des mouvemens brusques et comme convulsifs, que le praticien reconnut, sa main étant appliquée sur l'abdomen ; ils étaient si violens, qu'ils causaient à sa mère des secousses fort douloureuses ; mais au bout d'un instant ils cessèrent tout-à-coup. La tête était alors

descendue dans l'excavation du bassin : l'application du forceps paraissant indiquée, elle fut faite promptement et sans difficulté. Ce second fœtus était aussi fort, aussi bien conformé que le premier, mais il était pâle, décoloré, tout-à-fait exsangue ; aucun secours ne put le rappeler à la vie. La délivrance n'offrit rien de particulier : les deux placenta ne formaient qu'une seule masse, au centre de laquelle s'insérait un des cordons, tandis que l'autre s'implantait à la circonférence."

The Pulmonic Circulation.

The pulmonic circulation is simply that of the right or pulmonic heart. The blood is propelled by the force of this through the pulmonary artery, the capillary vessels, and the pulmonary veins. This circulation is interrupted in cases of asphyxia, by the contact of blood too venous, or surcharged with carbonic acid, in the same manner that the capillary circulation in the web of the frog is arrested by the application of alcohol and other reagents.

The pulmonary circulation in the toad, when becoming languid, is, in like manner, arrested by the application of water to the external surface of the lung.

The pulmonary circulation consists of that of the *bronchial* arteries, a part of the systemic, and of the *pulmonary* arteries. The former may be compared to the coronary circulation of the heart; it is for the *nutrition*, &c. of the pulmonary tissues.

The Circulation—a Carrier.

It is scarcely necessary for me to advert to the circulation in its office of a carrier of oxygen, of heat, and of nutrition, to the different parts of the system.

But there is a principle in the circulation which has not, I think, obtained the consideration it deserves—it is the diffused pressure and tension, if I may so designate it, imparted by the circulating blood. By this pressure, the substance of all the organs is held in a state of *distension*, I had almost said of erection. For want of this force, which is that of the heart, the eye becomes dim and presbyopic in old age, and the whole of the functions become impaired in the climacteric disease.

This impress of blood is requisite to the action of all the organs. It is that which, in fact, induces the diastole of the heart, which maintains the proper, active condition of the brain, the medulla oblongata, in a word, of all the organs. The effects of a considerable diminution of this pressure are seen in the case of blood-letting to syncope: the functions of the heart, the brain, the medulla oblongata, fail, and are temporarily annihilated, presenting a series of phenomena of the utmost interest to the physiological observer.

The Nervous System.

From the circulatory, I pass to the nervous system. I propose, first, to point out the principal functions of the latter system, and then to draw your attention to the continual dependance and reciprocal action and reaction of the two.

In 1813, I read a paper before the Royal Society, entitled, "On the Reflex Function of the Medulla Oblongata and Medulla Spinalis," and in 1837, another, entitled, "On the Spinal Marrow, and its Excito-motory System of Nerves."

My object in these two Memoirs was to unfold the special function, the principle of action, and the physiological relations, of the true spinal marrow, as distinguished from the cerebral and the ganglionic systems.

The cerebral system is that of *mind*, or the ψυκη, that of sensation and voluntary motion.

The ganglionic system is that of assimilation, of nutrition, &c., that of *atomic* action.

In regard to the true spinal marrow, its principle of action is the *vis nervosa* of Haller, its peculiar function is reflex and excito-motory, and performed through a special system of incident, excitor, and reflex, motor, nerves, and its physiological relation is that of the acts of ingestion and egestion, by which external objects, whether air or food, are appropriated, in the form of *masses*.

Before the publication of these papers, I believe the real function of the spinal marrow, the real principle and form of action in it, and the dependence of *all* the acts of egestion and ingestion upon it, were not understood.

Intermediate between the cerebral and the true spinal and the ganglionic systems, I have ventured to place the in-

fluence of *emotion, passion,* &c. They originate in the first, and act through the second and third.

The *irritability* of the muscular fibre is dependent on the true spinal and ganglionic systems with the due impress of arterial blood.

The *tone* of the muscular system seems to be immediately dependent on the same influences.

It *must,* I think, be considered as remarkable, that the distinction between the true spinal marrow with its incident and reflex nerves, and the cord of cerebral nerves, and that the true office of the true spinal marrow, as the central nervous organ of the acts of ingestion and egestion,—and the dependence of *all* these acts upon the true spinal marrow, had scarce been detected. That deglutition is a reflex *spinal* act; that certain expulsions are equally reflex *spinal* acts, are facts so obvious now, that we may well wonder that they were not earlier classed with respiration, and that respiration was not earlier seen to be a reflex act.

The True-Spinal System.

The first division of the nervous system, I have ventured to designate the true-spinal, to distinguish it from the cerebral, which belongs to a higher order of phenomena still, and from the ganglionic.

The true-spinal system is the *nervous* agent in all those acts of ingestion and of egestion of which I have spoken in the former part of this lecture. I have treated of this subject, in other works, so much at length, that I may, with great propriety, dismiss it after a few brief remarks on the present occasion.

The true-spinal system consists of a series of nerves passing principally from the cutaneous surface, and the surface of the mucous membranes, to the spinal marrow; and of another series of nerves passing from the spinal marrow to a series of muscles, destined to be moved simultaneously. The former, thence designated the *incident* nerves; the latter, *reflex* nerves: the spinal marrow is their common *centre.* Such is the *anatomy* of this system.

An appropriate stimulus acts, first, upon the incident nerves, then upon the spinal centre, then upon the reflex nerves, and eventually upon the muscles to be moved.

The *physiological* effects are certain distinct *acts* of *ingestion* and *egestion*, as deglutition, inspiration, and the various acts of expulsion from the œconomy, acts, for the first time, traced to the agency of a series of incident and reflex nerves, and to the true *spinal marrow*.

The Ganglionic System.

The substances which are ingested in the form of *mass*, under the agency of the true spinal system, are disseminated and assimilated to the different organs under the influence of the ganglionic. The circulation,—formation and nutrition,—secretion, &c.—are thus accomplished. The mode of action is *atomic*.

I here present you with a fœtus of six months, and with an accurate drawing. It will be observed that both cerebrum and spinal marrow are entirely wanting. But all the nerves and the ganglionic system are perfect, and all the organs and the limbs are perfectly developed,—the cranial and the spinal vertebræ alone being deficient.

But, as I have said, these subjects have been discussed in several recent publications. I shall, therefore, proceed to notice another point of great interest,—viz. the reciprocal influence of the circulatory and nervous systems.

First, the presence of the circulating blood is absolutely necessary to the due performance of the functions of the nervous system.

Secondly, the presence of the nerve is absolutely necessary to the due performance of the functions of the circulating system.

Necessity for the due supply of Arterial Blood.

The first of these principles is displayed, by inference, in the pathological effects of hæmorrhage or other loss of blood. The influence exerted on the true spinal system, especially the respiration, the sphincters, &c. is most remarkable.

A similar proof of the necessity of the due supply of arterial blood, for the due performance of the functions of the medulla oblongata, is afforded by the interesting experiments

of Legallois, and of the late Sir Astley Cooper, on compression, or ligature, of the aorta, the carotid, and the vertebral arteries.

" J'ai lié," says the former writer, " l'aorte abdominale dans un lapin de 8 jours, au niveau du bord postérieur du rein gauche; les mouvements et la sensibilité des cuisses et de la queue out entièrement disparu au bout de 12 min.; le reste du corps était encore bien vivant au bout de trois quarts d'heure, lorsque je tuai l'animal. Dans un antre lapin de la même portée, dont j'avais lié le même jour l'aorte pectorale, les mouvements et la sensibilité des parties postérieures avaient disparu au bout de 6 min." And

" J'ai lié les deux carotides, prévoyant bien que les artères vertébrales, suppléant en grande partie à ces vaisseaux, surtout par rapport au mobile en question, qui n'exige pas une circulation fort active, l'effet ne serait ni aussi prononcé, ni aussi prompt qu'après la ligature de l'aorte. Voici quel en a été le résultat: quand la moëlle n'avait pas été coupée, la respiration n'en était que médiocrement affectée; quand elle l'avait été, dans certains cas les bâillements ne tardaient pas à s'arrêter, et ne revenaient plus, malgré que j'eusse recours à l'insufflation; dans d'autres, ils continuaient comme auparavant, seulement ils étaient plus faibles et plus rares; différences qui m'ont semblé dépendre du lieu où la moelle avait été coupée, et de la lésion ou de l'intégrité des artères vertébrales*."

" I placed a ligature," says Sir Astley Cooper, " around both vertebral arteries" (in a rabbit). " When I had tied the first, there was some difficulty in breathing; but, when I had tightened the second ligature, this difficulty was greatly increased. The respiration was at first slow, but it afterwards became quick. The animal retained volition and sensation, but its fore legs were weakened†." And—

" I tied the two carotid arteries. Respiration was somewhat quickened, and the heart's action increased; but no other effect was produced. In five minutes, the vertebral arteries were compressed by the thumbs, the trachea being completely excluded. Respiration stopped almost directly;

* Expériences sur les Animaux. Paris, 1835, p. 152, 155.

† Guy's Hospital Reports, vol. i, p. 463.

convulsive struggles succeeded, the animal lost its consciousness, and appeared dead. The pressure was removed, and it recovered, with a convulsive respiration*," &c

It is not the altered supply of blood to an organ merely which induces changes in its function; the altered impetus and quality of that blood are sufficient to produce this effect.

The subject appears to me to require new investigation.

Legallois observed, that, after the division of the spinal marrow near the occiput, in young animals, the reflex power (the "sensibilité et mouvemens" of this author) ceases and reappears according as artificial respiration is suspended or renewed. He observes†—

"J'ai répété sur plusieurs l'expérience de l'insufflation de l'air dans les poumons, après avoir attendu que la sensibilité fût éteinte, et je suis parvenu à la ranimer ainsi que les mouvemens du corps à un tel degré que les animaux s'agitaient non-seulement par le plus léger pincement, mais encore sans aucune irritation extérieure; les battemens du cœur avaient repris en même temps une aussi grande fréquence, que s'ils eussent respiré. En cessant l'insufflation,ces battemens retombaient dans l'espace d'un ou deux minutes à l'état où ils étaient en la commençant, mais la sensibilité ne redisparaissait qu'au bout de sept et même neuf minutes. Tous ces phénomènes renaissaient en recommençant l'insufflation. Je les ai reproduits ainsi à plusieurs reprises sur le même individu, et les ai entretenus au-delà de quarante-cinq minutes, sans qu'il ait fait une seule respiration; l'examen anatomique me fit voir que la moëlle épinière était entièrement divisée."

Contiguity of the Minute Arteries and Nerves.

The second point to which I have called the attention of physiologists is not less interesting. The influence of the nerves upon the secretions—especially that of the pneumogastric—is well known to physiologists. But there is an anatomical fact, already briefly noticed, the existence and importance of which are less known.

Having ascertained the fact, that, in the web of the frog, the minute arteries and veins pursue an adjacent course, there could be little doubt that a similar disposition of these organs

* Ibid, p. 495. † Op. cit. p. 57.

obtains in other parts of the œconomy, both in that species and in the animal kingdom generally. I accordingly found that the integuments in general and the muscular structures displayed an arrangement of this kind. (See plate II, figures 4 and 5.)

That the nerves observed then accompany the arteries,—and that the veins should be unaccompanied by nerves,—are facts of the most intense physiological import. It is in the minute arteries and the capillary vessels that the blood is changed from arterial to venous; the veins seem to be mere tubes to reconvey the blood to the lungs for re-arterialization. The nerve probably affects, or is affected by, this change: hence its proximity to that series of vessels alone in which that change occurs.

The Muscular System.

I proceed to notice the last of the higher vital functions; viz. that of the muscular system. As the property peculiar to the nervous system has been designated the *vis nervosa*, that of the muscular fibre might, with great advantage, be denominated the *vis muscularis*, the term irritability being applied in other senses, and the term contractility being equally applicable, unless the epithet muscular be added, to the elastic tissues.

The Sources of Irritability.

The sources of this power appear to be the spinal marrow, and the arterial blood. If a muscle be severed from its connection with the spinal marrow, it gradually loses its peculiar power of contracting on the application of a stimulus. I have treated this subject in my last work on the nervous system (p. 207) at considerable length. But I have also observed, that, if a muscle be deprived of its due supply of arterial blood, its power equally fails.

I tied a ligature round the femoral artery in a frog. In a short time that limb became less affected by the influence of galvanism than the other limb. Having placed the animal in water, I passed a slight galvanic shock through the liquid, and observed that the limb which was left in its natural state moved much more actively than that of which the artery had been tied.

A series of experiments has been made by Prof. J. Reid, in which the nerves of a muscle being divided, and its irritability exhausted by the agency of galvanism, that irritability was regained by repose*. It has been concluded that this power is, therefore, to a certain extent, independent of the nervous system.

It appears to me that the repeated influence of galvanism may affect the condition of the minute and capillary vessels, emptying them of their arterial blood. This morbid condition may be corrected by time and repose. In this manner we may explain the apparent contradiction between the results of Prof. J. Reid's experiments and those of my own.

The Source of Muscular Tone.

That the true spinal marrow is the source of tone in the muscular system is proved by an easy experiment. Let two rabbits be killed, and whilst the spinal marrow is left untouched in one, let it be carefully removed from the other. The tone perceptible on moving the limbs of the former one is singularly contrasted with the flaccid condition of the muscles in the latter. The former is also found, after a time, to be rigid from the cadaveric spasm; in the latter, this phenomenon is entirely absent.

The Source of Muscular Action.

I have only briefly to state, in concluding my remarks on the physiology of the nervous system, the sources whence muscular action springs. These are, physiologically speaking, volition, and the reflex, and immediate application of stimuli. The first occurs in all voluntary motion, the second in all the acts of ingestion and of egestion, and the third in the action of the heart, the stomach, the intestines, &c.

Of these, the second, in its relation to the spinal marrow, on the one hand, and to the acts of ingestion and egestion, on the other, have, I imagine, been brought to light in the course of my own investigations.

The Intellectual Faculties and the Passions.

Of the intellectual faculties and the passions I have little

* See the Report of the British Association, p. 671.

to observe, except that the former are seated in the cerebrum, and manifested through the cerebral system of nerves; whilst the latter are probably seated lower down,—in the medulla oblongata,—and manifested in, and act through, the spinal system and reflex spinal nerves.

For the development of these views, I must refer to my volume on the Diseases and Derangements of the Nervous System, recently published, and to my forth-coming volume on the Anatomy, Physiology, &c. of that system.

In speaking of the anatomy of the organs of purification (p. 26), I had at first added, as a characteristic, that there were generally *no veins* corresponding with the *nutrient arteries*. This is the case with the liver. I suspected it might be so with the lungs. But still I heard of the bronchial veins, terminating, one series in the jugular vein, the other in the vena azygos. In the midst of my doubt, and before I could examine the subject for myself, I was informed by Dr. Thomas Williams, who had been recently devoting much attention to the minute anatomy of the lungs, that there really are no bronchial veins. I append a note from Dr. Williams:

"My dear Sir,

I have recently ascertained, by injections and dissections, the absence of bronchial veins in the human subject, the calf, and the rabbit.

I think you will now admit that your first conjecture was *correct*.

I remain, my dear Sir, yours truly,

Thomas Williams."

Webb Street, Borough,
January 1, 1842.

Prof. Müller incidentally makes a most interesting observation:—

"The pulmonary circulation would be perfectly isolated from that of the body, were it not that the bronchial arteries communicate with the small branches of the pulmonary artery*."

* Dr. Baly's Trans. ed. 1, vol. i, p. 181.

LECTURE II.—ON PATHOLOGY.

1. *The Functions of Ingestion and Egestion.*

THE subject of the present lecture is one which leads us still nearer to our general object—*the actual Practice of Medicine.* Nothing, indeed, can be more important to the practitioner than a distinct idea of the first question to be considered, or that relating to the condition of *the blood.*

Sanguification, and the *Respiration* and *Purification* of the blood, are most nearly allied to many questions which daily occur in practice.

Food may be deficient, when sanguification must be so too; or it may be actually poisonous, imparting its destructive qualities to the blood. I may, in this place, refer to the admirable work of Professor Liebig*. M. Liebig particularly notices the poisonous effects of bad sausages. He observes—

"Several hundred cases are known, in which death has occurred from the use of this kind of food. In Wirtemberg especially these cases are frequent; for there the sausages are prepared from very various materials. Blood, liver, bacon, brains, milk, meal, and bread, are mixed together with salt and spices; the mixture is then put into bladders or intestines, and, after being boiled, is smoked.

"When these sausages are well prepared, they may be preserved for months, and furnish a nourishing, savoury food; but when the spices and salt are deficient, and particularly when they are smoked too late, or not sufficiently, they undergo a peculiar kind of putrefaction, which begins at the centre of the sausage."—"Sausages in this state exercise an action upon the organism, in consequence of the stomach and other parts with which they come in contact not having the power to arrest their decomposition; and entering the blood in some way or other, while still possessing their whole power, they impart their peculiar action to the constituents of that fluid†."

The baneful effects of venison and game, kept until they are "high," are little appreciated by the votaries of epicurism.

* Chemistry in its application to Agriculture and Physiology, ed. 2, 1842.

† Ibid. p. 368, 369.

The poisonous effect of ergoted corn is well known.

But if the morbid effects of unwholesome food are considerable, those of retained excernenda are still more frequent and formidable. If the contents of the intestines be unduly retained, the tongue becomes loaded and the breath tainted, the skin exhales an offensive odour, the urine is high coloured, of morbid smell, and various deposites occur on cooling,—effects which a course of the simplest aperients removes.

But if the bile be retained in the blood, this fluid, so essential to the well-being of the œconomy when healthy, becomes a poison. The patient is frequently affected as by a narcotic, and becomes dozy, and even delirious.

But the deadliest poison of all the retained excernenda is the urine. The suppression of this secretion is followed, in a few days, by coma and convulsions. And when the urine is not suppressed, but the morbid condition of the secretory process is marked by its albuminous character, hemiplegia and epilepsia are too frequently observed.

But, of all the ingesta and egesta, those accomplished by the lungs are the most immediately essential to life. I propose, therefore, to treat of this subject a little at length in the present lecture.

Asphyxia.

Asphyxia is presented to our observation under three forms: first, the *gradual;* secondly, the *sudden* and *complete;* and thirdly, the *secondary*.

In order to form a just idea of asphyxia, we must recall to our minds the nature and office of respiration, and its effects on the circulating blood. The absorption of oxygen, or the evolution of carbonic acid, or both, are impeded or interrupted in every case of asphyxia. From the want of oxygen, the blood is deficient in stimulus; by the presence of carbonic acid, it is positively poisonous. Throughout the whole arterial and capillary systems, the blood is constantly undergoing the change from the arterial to the venous. It is probable that, during this change, the evolution of the galvanic agency, as well as of caloric, is taking place, with the peculiar vital properties of the nervous and muscular systems, whilst the processes of nutrition and of secretion are effected. These

changes cease to be accomplished when venous instead of arterial blood is circulated in asphyxia, and disease and death occur.

By bearing in mind these various facts, we are enabled to appreciate the effects of partial as well as complete asphyxia, and to understand the secondary as well as the primary forms of that pathological condition.

Venous blood, being deficient in oxygen, ceases to stimulate all the organs, the cerebrum, the medulla oblongata, the heart itself; and hence the loss of consciousness, the impaired respiration, the impaired action of the heart; but being also surcharged with carbonic acid, it actually poisons or morbidly irritates these same organs; and hence the gaspings, the convulsive acts of expiration, and other forms of convulsion; and we are not surprised to find that it ceases to flow along the minute and capillary vessels.

I proceed to notice the different forms of asphyxia.

Gradual Asphyxia.

Gradual asphyxia occurs in the cases in which the atmosphere has become surcharged with carbonic acid, from the use of a charcoal fire without sufficient exit for the smoke, or ventilation. Interesting questions are—With what degree of addition of carbonic acid does asphyxia *begin?* and—With what further addition of carbonic acid is asphyxia sudden and complete? and—May asphyxia be so sudden and complete with a proportion of carbonic acid which still admits of the air in which it is contained being inspired through the larynx? —or sustain the combustion of a lighted candle? Other interesting questions are—Whether gradual and sudden asphyxia are the same disease—the same pathological condition? and especially—Whether the modes of treatment, under apparently similar circumstances, should be the same?

These questions present a subject of inquiry which can be fully pursued by experiment alone, and which justifies, by its vital importance, such a mode of investigation.

It is obvious that, in gradual asphyxia, the blood, deprived of its oxygen, and surcharged with carbonic acid, is the object of our remedies. It is by acts of respiration, spontaneously augmented, that the healthy condition of the blood is to be restored. But important questions present themselves.—Is

the addition of oxygen gas to the ordinary atmospheric air important? Is any other gas, as hydrogen, added to the atmospheric air, of value, as inducing more rapid diffusion, and consequently the more effectual evolution of the carbonic acid from the blood and the lungs? In a word—Is any form or mixture of artificial airs more efficacious in restoring the healthy condition of the blood than the ordinary atmosphere?

Sudden Asphyxia.

Sudden asphyxia is that induced by submersion, suspension, or such an admixture of carbonic acid with the atmospheric air as either closes the larynx at once, or effectually arrests the diffusion of carbonic acid, and its evolution from the blood.

There are many circumstances connected with this form of asphyxia not yet fully understood, and especially, the nature of some of the actions of the muscles of respiration has been absolutely mistaken, pathological phenomena having been regarded as physiological acts. It is to this distinction that I beg now to draw your attention.

The first act of inspiration appears to me to be induced by the impression made by the external atmosphere on the trifacial and spinal nerves, or the nerves of the face and general surface, of the new-born infant.

Ordinary inspiration seems to be induced by the excitement of the pneumogastric by the carbonic acid evolved in the lungs and brought into contact with the fine and ultimate fibrillæ of that nerve.

In both these cases, the act is one of inspiration; it is an excited reflex act, and it is a physiological act.

But it is well known that respiratory movements take place under other circumstances. For example: gaspings are observed after the division of the spinal marrow high in the neck, and in the separated head of the young animal. Similar gaspings occur in the young animal, associated with other actions of the respiratory muscles, during asphyxia by submersion. These phenomena have been regarded as really *res*piratory*. This view of the subject is, however, not only

* See Legallois, Op. cit p. 140; M. Edwards, Influence des Agens Physiques, pp. 266, 454; Prof. J. Reid, in Edin. Med. Journ. vol. i, p. 15—.

erroneous in itself, but has proved the source of other erroneous conclusions.

In the first place, *gasping* forms no part of ordinary, normal, or physiological respiration. It is an abnormal, pathological act, allied to convulsion.

In the second place, it is so far from being a physiological act, that it is probably never a *reflex* act, but an act always excited by impressions of a pathological character, made upon the medulla oblongata itself, the *central* organ of the physiological acts. We have an unequivocal example of this kind in the extreme morbid efforts of hæmorrhagy, in which, phenomena similar to those observed in asphyxia, and equally combining gasping with convulsive expiratory efforts, are observed.

This distinction between the physiological, reflex action of respiration, and the pathological, centric acts of asphyxia, has not been made; and, without this distinction, the two subjects cannot be properly investigated, or their distinct phenomena understood. I may, on this account, be allowed to discuss the question somewhat at length.

I cannot introduce the subject to your notice better than by contrasting the phenomena of asphyxia by submersion, with those of the similar, not to say identical, phenomena arising from extreme hæmorrhage.

My friend Mr. Henry Smith and I immersed young kittens in water of the temperature of their blood. The phenomena observed were—first, struggles to escape,—acts of volition; and, secondly, when these had ceased for a few moments, an act of gasping, accompanied by an act of expiration so forcible as to expel bubbles of air and mucus from the lung, and small fragments of curdled milk from the stomach! —and by an equally forcible action of the flexors of the trunk. These symptoms then subsided, to be renewed after irregular intervals.

With these phenomena may be compared those which result from profuse hæmorrhagy. In my Experimental Inquiry into the effects of loss of blood, published in the Transactions of the Medical and Chirurgical Society (vol. xvii, pp. 270, 282), I have thus described these phenomena:

A dog had been bled to 16, 8 and 8 ounces, on three suc-

cessive days, incipient syncope having been induced by each blood-letting.

"Soon after the third and last abstraction of blood, the animal evacuated the fæces, and, in two minutes more, the urine. The pupils were dilated; the pulse sank to 93, the temperature to 94° Faht.; the respiration was first quick for three times, and then followed by a full inspiration, and this by a full expiration; completed by a strong action of the abdominal muscles. The heart, before the blood-letting, beat loudly and clearly, afterwards feebly; in half an hour, again loudly."

"The under-lip fell; there was a peculiar moan; the angle of the mouth was convulsed; one leg was convulsively drawn; it was difficult to separate the teeth; and there was stiffness of the limbs. The respiration became deeper and more laborious, inspiration being performed by a strong contraction of the diaphragm, and expiration by that of the abdominal muscles; the respiration then became gasping, and the gasps then occurred at longer and longer intervals. There was once a loud whine. At another time, the dog lay still, and as if dozing. The expired air was cold. There was no sickness. The rectum was evacuated."

The gasping, the forcible expiration, the convulsive action of the trunk, &c. are all peculiar, abnormal, and pathological. They are also all doubtless of *centric* origin; and are similar to those observed in asphyxia!

If we do not distinguish these pathological phenomena from those of the physiological actions of respiration, we shall scarcely proceed a step in either science.

Nothing can be more obvious—as nothing is more necessary—than this distinction. In normal respiration, the movements of the nostiril, of the intercostal muscles, and of the diaphragm, and of the abdominal muscles, are gentle and equable; in the abnormal acts of the respiratory muscles, the gaspings, the sudden inspirations, and the violent expirations, with the flexion of the trunk and limbs, are all of a frightful, spasmodic, or convulsive character.

I may illustrate this subject by a reference to a recent paper of Professor Volkmann, published in the "Archiv für Physiologie" of Prof. Müller, for 1841.

In several works I had quoted and explained an experiment of M. Cruveilhier: if the cerebrum be first removed, and then the pneumo-gastric nerves be divided, respiration ceases, although either of these operations may be performed exclusively, without arresting the respiratory movements. I concluded that, viewing respiration as a *mixed* voluntary and excito-motory function, the influence of volition is removed by removing the cerebrum, whilst respiration may continue as a reflex, excito-motory function, and that the reflex part of this function is destroyed by dividing the pneumogastric nerve, whilst respiration continues as a voluntary act; but that, if *both* the cerebrum be removed, and the pneumogastric nerves be divided, *both* the voluntary and the excito-motory portion of respiration are annihilated, and the function ceases.

But it was very far from my intention to express the idea that the pneumogastric nerves were the *sole* excitor nerves of respiration, as Dr. J. Reid formerly*, and Prof. Volkmann, in his recent paper (p. 337), seem to imagine. Every thing which I have published on this subject bears evidence to this statement. Besides the pneumogastric nerves, the trifacial have constantly been maintained by me as being, with the spinal nerves, the excitors of the *first* inspiration, and as the excitors of respiration when an impression of cold is made on the face or general surface. These nerves—the trifacial and the spinal—may act as excitors of inspiration, when the pneumo-gastric nerves, the *principal* excitors of this function, are divided, and the cerebrum is removed. It was therefore very far from my intention to conclude, as Prof. Volkmann states it—"dass die unwillkürlichen Athembewegungen ausschliesslichvon vagus ausgehen." (p. 337). I may especially refer to § 309 of my late work† on this subject, in which I quote the experiments of Prof. J. Reid, which are precisely similar to those of Prof. Volkmann. The real facts are, that, in many cases, on removing the brain and dividing the pneumogastric nerves, the respiration ceases; in others, it still continues, but the inspirations are rare. In the latter case, as in the case in which rare acts of inspiration occur after the total

* See the Ed. Med. and Surg. Journ. No. 139, p. 15.

† Diseases and Derangements of the Nervous System; 1841.

removal of the lungs, these acts may be excited through the medium of the trifacial or spinal nerves. Gasping and other acts of the muscles of respiration are also frequently caused, under similar or other circumstances of experiments, by the abnormal condition of the circulation within the medulla oblongata.

Professor Volkmann adverts, in the next place, to the respiratory movements observed in the case of the embryo protruded still involved in the amnion, and in the experiment in which the fœtus has been born under blood-warm water. Both cases illustrate the subject under discussion, and present no difficulty to any one who properly distinguishes between the physiological and pathological conditions of the respiration. The fœtus, separated from the maternal influence, and not introduced into that of the atmospheric air, *is asphyxiated.* The respiratory movements observed are pathological, the consequence of asphyxia ; that is, of the circulation of venous blood within the medulla oblongata.

Though *not* the *exciting cause,* the contact of the arterial blood is the *essential concomitant,* of the physiological movements of respiration. In asphyxia, the true excito-motory principle in the medulla oblongata ceases to respond to the proper influences, whilst it is morbidly and excessively excited by the venous blood circulating within its tissues, and the physiological and rhythmic actions of respiration yield to convulsive and pathological movements. A similar effect is induced by other irritations of the medulla oblongata. Legallois induced such an effect by irritating the lower end of the medulla oblongata in the separated head of the young rabbit (" Expérinces," p. 154); I have repeatedly seen a similar phenomenon in the separated head of the turtle. In the latter case, the maxillæ separate, and are then brought together with great force and a grinding movement—both movements being obviously convulsive.

The difference in the fœtus before and after birth, if it do not breathe, is then no less than the state of asphyxia.

In hibernation, in which venous blood is circulated through the tissues physiologically, we must conclude that it is to the *gradual* institution of the phenomenon and to some change of structure or function gradually induced that the peculiar effect is to be ascribed.

It will be readily deduced from these remarks, that physiological respiration is a reflex action, whilst the pathological affections of this function arise frequently from the various morbid impressions made by the blood upon the medulla oblongata, the central organ of respiration. I do not think we advance the explanation of these phenomena by referring them to a necessity for respiration (" Athemnoth"). To do so is to argue from final causes. Our great Hunter has exposed himself to a similar reproach in using the term " stimulus of necessity." But if we shew that a morbid irritation in the medulla oblongata; that, in a word, the irritation of a pointed instrument, the experiment of Sir A. Cooper, the state of anemia, of asphyxia, all act on the same principle, we do indeed take a step in physiology; and all these conditions do, in fact, induce the peculiar and pathological acts of gasping, of violent inspiration and expiration, and of the spasmodic flexure of the trunk and limbs in question.

Secondary Asphyxia.

There is another interesting view of this important subject. The danger is not altogether over when the patient appears to be restored from the state of asphyxia. The respiration and the other functions may proceed nearly naturally—for some time—for some hours even—and suddenly convulsions may seize the patient, and death may ensue.

The blood apparently remains poisoned. Time, as in so many other cases, is an important element in the perfect restoration to health.

On one occasion I had placed a mouse and a sparrow in the same limited quantity of atmospheric air, until both began to *pant* from the want of a purer air. I removed them to their respective cages. To my surprise the bird was found dead on the succeeding day, and the mouse on the second day.

It will be remembered that Sir Humphry Davy was seized with alarming symptoms on the evening of the day on which he had breathed the carburetted hydrogen gas.

A soldier was taken out of the Thames in a state of

asphyxia. Animation was restored. But many hours afterwards he was seized with convulsions and expired.

From these and other similar facts we must deduce the conclusion—that our watchful care, and our remedies, must be continued after apparent danger is over. There is a more hidden danger,—the consequence of the venous condition of the blood, still ill arterialized—secondary asphyxia!

The patient should be *kept* in a free, cool atmosphere, and be made to take free and deep inspirations, and active exercises should be enjoined, in order that the blood may be both freely circulated and respired.

In still-born infants, similar precautions are most essential.

After gradual and partial asphyxia especially, every means of resuscitation should be long continued.

Secondary asphyxia is, I am persuaded, the source of danger in laryngitis, cynanche tonsillaris, and other diseases in which the respiration has been defective. Sudden death has been an unexpected and unexplained result in such cases. But I need not and must not say more on this subject, however interesting. I trust I have, in discussing it even thus briefly, sufficiently illustrated the necessary and important connection between physiology and pathology.

II. *The Higher Vital Functions.*

The Circulation.

From asphyxia, the principal pathological condition of respiration, I must now proceed to the circulation. I have already treated of this function physiologically, in its diplo-cardiac, general, systemic and pulmonic forms. It is now my object to shew the application of these views to pathology. And first, in regard to the single, though diplo-cardiac circulation.

The 'Arrière' Circulation.

The first of the series of morbid conditions affecting the circulation is that which arises out of a morbid condition, vital or physical, of the heart itself. The force of the heart

may be preternaturally great, as in hypertrophy; or it may be morbidly feeble, as in dilatation. Or, the force of the heart being natural or morbid, the valves may be deficient and not duly closed at the proper moment, and there may be a reflux of the blood; or these may be indurated and their orifices firmly contracted, a condition which calls forth undue action and eventual hypertrophy.

Such conditions of the central organ of the circulation must have their influence on the distant part of the system to which it sends, and from which it receives, blood. And, in discussing this subject, we shall see the force of the remark which I made a short time ago,—that the circulation of the blood is not double, as it is frequently described to be, but that it is, in fact, one and single; any derangement in one part of the blood's motion, in its circular career, affecting all the rest.

I will suppose that we are witness to a disease inducing interruption in the circulation *in one point*, and I will trace the effects of such interruption in the other portions of the circle. Or rather, I will describe the interesting case which I place before you in this preparation and this drawing. Plate II, fig. 3 ,4—7.

Mr. C——, aged 63, a barrister, called on me on the 10th of September, 1835. He had returned from the circuit, during which his friends had observed his altered appearance. I was struck with his *breathlessness*, small indistinct pulse, pallor, thinness, &c. I appointed to see him at home.

On the next day I saw Mr. C—— at his own house. There were breathlessness on the slightest exertion, augmented impulse of the heart, without either distinct second sound or *bruit de scie*, slight *anasarca*, and slight *icterus*.

The progress of the case was rapid. The breathlessness became urgent; there was a distinct rattle over the posterior right side of the thorax; the left ventricle beat rapidly, with considerable impulse, and without distinct second sound, or bruit; there were some cough, distinct icterus, and augmented anasarca; the jugular veins were turgid; the pulse was small, irregular, indistinct.

To these symptoms hæmoptysis succeeded. The only position which could be sustained was the erect. The cough

became troublesome. The breathlessness, the rattle on the right posterior side of the thorax, the rapid forcible beat of the heart, without second sound or bruit, the small, indistinct pulse, the icterus, the anasarca, continued, with occasional sickness.

Gradually the cheeks became cool, the beat of the heart less forcible, the pulse less indistinct, the posture less raised; the extremities cold and clammy, and the patient sank very slowly during several days.

Examination.—The organs were examined thirty-six hours after death, on September 29th, 1835.

There were slight icterus and anasarca.

The head was not examined.

The thorax.—The *left* cavity of the pleura contained one pint of sero-sanguineous fluid.

The costal pleura was very vascular; there were no adhesions, except between two contiguous portions of the lung, and of this to the pericardium. The *right* cavity of the pleura was obliterated by adhesions.

The *trachea* and bronchia were filled by frothy bloody mucus. The bronchial tubes were dilated, and their lining membrane redder than natural.

Both lungs, but especially the right, were gorged with bloody fluid, so that only the upper portion gave the healthy crepitus on pressure between the fingers. A portion of the lower lobe of the *right* lung presented a circumscribed apoplexy, of the size of an egg; similar but smaller apoplexies were found in the middle lobe, and in the upper lobe of the *left* lung.

The two layers of pericardium adhered by means of coagulable lymph, which admitted of being readily torn and stripped off. This membrane was very vascular within; and, on its exterior surface, it was loaded with adeps and serum. The *heart* was considerably enlarged; the *right auricle* and ventricle were dilated and thickened; the auriculo-ventricular and pulmonary valves free from disease; the pulmonary arteries and their branches appeared enlarged; the *left auricle* was much dilated and hypertrophied; the auriculo-ventricular valve was very much thickened, of the firmness of cartilage, and admitted one finger only; the *left ventricle* was

slightly enlarged and hypertrophied; the *aortic* valves were ossified, and rigidly immoveable, and their orifice so contracted as not to admit the little finger.

The abdomen.—The peritoneal cavity contained no fluid. The *liver* was small, and its surface granulated. It was shown to Mr. Kiernan, who stated that it was in the second stage of hepatic-venous congestion. The gall-bladder was full of dark-coloured bile; its ducts free.

The peritoneum covering the intestines was deeply congested. The intestines themselves, from the middle of the jejunum to the rectum, were highly congested—the valvulæ conniventes being of a deep purple hue, and presenting numerous small patches of ecchymosis. The spleen, pancreas, kidney, &c. were healthy.

These morbid structures are preserved in this bottle. They form a beautiful *series*, and they pourtray the true *pathology of the disease*—unlike the usual scraps of morbid anatomy which we find in our museums.

The whole explains too, what I would venture to designate the living pathology as distinguished from the mere morbid anatomy. It is impossible, in effect, that morbid appearances should follow in a more distinct order, or account more lucidly for the symptoms during life. I know of no case on record so illustrative of the effect of obstruction of the circulation, upon the *arrière* part of that circulation.

The breathlessness is accounted for by the condition of the valves of the aorta and the left auriculo-ventricular valve. The smallness and indistinctness of the pulse by the former. The turgid jugulars by the impeded circulation, propagated from the lungs to the right side of the heart.

The impeded flow of the blood through the aortic and mitral valves, led to *congestion* in the lungs, and this amounted to such a degree as became true '*apoplexie pulmonaire*;' in consequence of this impeded circulation in the lungs, we have congestion of the hepatic vein in its second stage; as a further consequence of hepatic-venous congestion, we have congestion of the veins of the intestine, so remarkable on the post-mortem examination.

The congested state of the liver led to the icterus, and to

the hæmorrhagic state of the intestine. That of the vena cava to the anasarca.

It is impossible to imagine a *series* of phenomena more distinctly connected; the smallness of the pulse, with the contracted aortic valve; the congested lung, with impeded circulation through the left side of the heart generally; the impeded flow of blood through the right side of the heart and the turgid jugulars, with the congested lung; the congested hepatic vein, with the impeded flow of blood through the right side of the heart; the progressive, though *arrière* congestion of the hepatic veins, with icterus, and of the *roots* of the vena portæ, in the intestine, with that of the hepatic vein.

The subject is still further illustrated by plate I, figure 3.

It must be remembered that the whole of these phenomena take place in the minute and capillary vessels, situated between the venous roots and the larger arterial branches. Hence congestion, 'apoplexie,' hæmorrhagy occur. Hence effusion of serum,—œdema, anasarca, and other dropsies take place. The minute arteries and the capillary vessels are the immediate vascular source of every morbid effusion, whether this be blood or serum, and of every morbid deposit, whether tubercle or the encephaloid matter.

Of all these, *the blood* is the immediate material source.

But to return to the subject before us: you will observe, by the direction of the arrows, that if the aortic or mitral valve be diseased, there must be an impeded flow of blood through the corresponding ventricle or auricle; then in the lungs, with hæmoptysis, or *apoplexie pulmonaire;* then in the right side of the heart; then in the hepatic vein and liver—hepatic venous congestion; then in the intestine, with the purple hæmorrhagic state; lastly, in all the exterior parts of the body. This is a subject for us to reflect upon. Words cannot convey all the interest which attaches to it: we must think of it, and feel it.

The *circulation* of the blood is usually described as being *double*, systemic and pulmonic. You will observe that it is, in reality, only *single*, the systemic and pulmonic circulations being only *one*. The blood flows from the left ventricle

through the system, and through the lungs, before it arrives at the *same* ventricle again.

This is not an idle remark, of no practical or pathological value. It is *only* by viewing the circulation in its true light, that we can trace, as we have done, the influence of an impeded flow of blood in *one* part of its course, upon *every* part comprised in *both* portions of the whole circulation.

It is only in this manner that we can find the rationale of all the symptoms in disease of the heart,—of the congestion of the lungs and of the liver,—of the face, and of the extremities.

These effects of an impeded flow of blood in one part of its double course should be borne in mind, if ever the aorta should be again tied. Unfortunately, in Sir A. Cooper's case, the condition of the lungs, the liver, the intestine, are not given. During life, the patient "appeared to have an uneasiness of the heart, as he kept his hand upon the left breast." In a case of contracted aorta, opposite the *canalis arteriosus*, which occurred to Mr. Whinstone, the right ventricle was ruptured.

It is obvious that if the *flow* of blood be impeded through the *left* heart, it must *overflow*—in the lungs, then in the right heart, and then in the head and extremities;—in the liver, and then in the intestines. Hence, congestion, hæmorrhagy, dropsy.

In the same manner we might trace the effects of extensive disease of the lungs, and of the liver, on the circulation *arrière* to these organs.

Here again I trust I have shewn the necessity of studying physiology in order that we may understand pathology.

The Dropsies.

As further effects of impeded 'arrière' circulation, I may notice hydrops pericardii and hydrothorax, as especially resulting from impeded circulation through the left heart and the lungs; ascites as arising from impeded circulation through the liver; and anasarca as the effect of impeded circulation along the vena cava.

All these forms of dropsy may result from disease of the heart.

Ascites is the frequent effect of original disease of the liver.

Ascites may, in its turn, compress the vena cava and induce anasarca.

In these two cases, the anasarca may be second in the order of development. In disease of the heart it is frequently the first.

What is the rationale of the dropsy which accompanies albuminaria?

The Capillary Circulation.

I now revert to the *capillary* circulation. And I do so to make a few brief observations on the important subject of *inflammation*, of *congestion*, and of morbid structure generally.

That these morbid conditions are all primarily seated in the minute and capillary vessels, there can be little doubt, and our efforts are principally directed to explain their forms and origin.

Inflammation appears to originate in a changed physical condition of the minute and capillary vessels. Every *cause* of inflammation produces this effect; and then follows congestion and enlargement of the adjacent arteries, with augmented sensibility, pain, sense of throbbing, &c. In congestion, on the contrary, there is an interruption to the flow of blood along the capillary vessels, from an impediment to its flow along the veins, or through the heart itself. It is an effect on the *arrière* circulation.

The difference between inflammation and congestion, is the difference between physical alteration of structure and mechanical impediment to function.

Morbid structures sometimes arise from morbid conditions of the blood itself, and of the tissues into which they are deposited; and sometimes probably from morbid or deficient action of the nervous system.

The mode of action of the *causes* of inflammation may be seen on applying alcohol to the web of a frog. The blood globules soon cohere to the internal lining membrane of the iso-metric and minute vessels. In plate II, fig. 1 and 2, this effect is seen most distinctly. When the alcohol is applied to the lower surface of the web only, the lower layer of capillaries is affected, as in figure 1. The effect of this interrup-

tion to the capillary circulation is soon seen in the other vessels, constituting true inflammation.

The Coronary Circulation; Sudden Death.

It is well known that diseases of the heart are apt to terminate in sudden death; excessive disease of the lungs, as pneumonia; or of the brain, as apoplexy; also terminate in speedy, not to say sudden, death. But the question *why and how* disease of the heart induces sudden death, has not, I think, been investigated so fully as it deserves. Disease of an organ is not, until it becomes extreme, incompatible with its functions. Great disease of the brain, and great disease of the lungs, nay, great disease of the heart itself, may subsist with life. And yet the slightest disease of the last-named organ is *apt* to terminate in sudden dissolution! How is this terrific event to be explained?

Many facts induce me to believe, that the cases of *sudden death* arise chiefly from interruption of the coronary circulation! These facts I must beg to be allowed to lay before you.

An interruption to the due supply of the coronary circulation induces the cessation of the action of the heart which occurs in syncope from hæmorrhagy, and the more permanent cessation of that function in cases of sudden death. That form of disease of the heart which consists of ossification of the coronary arteries is attended, in turns, by both of these phenomena; the appearance of the countenance and the condition of the pulse, in some of its attacks, and the very designation of syncope, prove that the more transient cessation of the heart's action takes place during its course; and the awful cases of sudden death, the expected event in this disease, too well proves the fact of the sudden and entire cessation of this function as its termination. Ossification of the coronary arteries, then, by impeding the flow of the coronary blood, produces the transient or the permanent cessation of the heart's action, and its consequences—syncope or death. Ossification of the crural artery, in like manner, induces death or gangrene of the limb.

But ossification of the coronary arteries is not the only disease of the heart which arrests the coronary circulation. In a case presenting most accurately the symptoms of angina

pectoris, and terminating by a predicted sudden dissolution, a fatty condition of the organ was the only circumstance which presented itself, on a post-mortem examination, to explain the phenomena. The adeps probably compressed the coronary arteries in their course. It is probable that syncope and sudden dissolution occur in other diseases of the heart, especially dilatation, from interruption of the coronary circulation.

Hæmorrhagy not only induces syncope, as an immediate effect, but, in some instances, both as an immediate and as a remote effect, sudden death. The state of anæmia from any cause has this effect; and in this manner chlorosis itself has in several instances, in my experience, issued in sudden dissolution.

That an arrested coronary circulation really paralyzes the heart is proved by the effect of certain substances which, when injected into the jugular vein, arrest the action of the heart by arresting the circulation in its coronary vessels.

I have proposed to myself the investigation of this question by a series of experiments on the effects of interruption of the coronary circulation by ligature, and by the actual injection of substances into the coronary arteries.

The cerebrum being removed, or the spinal marrow divided, in a young animal, the heart must be laid bare, and artificial respiration maintained; ligatures are to be put round the coronary arteries loosely, and the heart is to be covered and protected from the action of the atmospheric air; the ligatures are now to be tied, or the coronary arteries injected, and the effect upon the action of the heart observed.

The coronary circulation will participate in all those morbid conditions of the general circulation which have been formerly described. In contracted aortal valve, in deficient mitral valve, in feeble ventricular impulse, the coronary circulation will be impeded. In certain circumstances it may even be arrested. But, in such a case, the heart being suddenly paralyzed, it *may be* arrested for ever!

That this view of the case is true, is proved by an occurrence by no means unfrequent in similar circumstances: the coronary veins are frequently found dilated and enlarged by the action of regurgitated blood.

But sudden death is most apt to occur in that form of dis-

ease of the heart in which the coronary arteries themselves become ossified, or converted into a substance resembling cartilage—one form of *angina pectoris*. The calibre of the artery is diminished, its elastic power impaired, its lining membrane in a morbid condition; the circulation is impaired or arrested; the heart, the main-spring of life, is paralyzed!

In some instances, this paralysis is not complete or permanent; and a peculiar, transient, but fearful state of syncope occurs. Hence the designation of *syncope angens* for this disease. In other instances, the paralysis is absolute, and the most sudden death occurs. I need not recall to your mind the melancholy circumstances attending the death of Hunter.

That an impaired coronary circulation, whether arising from the impeded flow of blood through arteries contracted by ossification, or impeded by adipose substance, or from a dilated and feeble condition of the left ventricle, or any source of obstruction in the left auricle, or ventricle, or from an insufficient condition of the blood itself, in cases of hæmorrhagy, anæmia, and chlorosis, or from other morbid conditions of the blood—should induce *the same* fatal effect, is what we should expect a priori.

The well-known effect of mental emotion, or muscular effort, or of the assumption of the erect position, in inducing the sad event, in all these cases, whilst it confirms the justice of our views, should lead us urgently to enjoin quiet and repose.

Other Causes of Sudden Death.

Bichat designates the heart, the lungs, and the brain, the 'trépied de la vie,' in some part of his celebrated work; and considers sudden death as originating in one or other of these organs. It is rarely, however, that *disease*, seated either in the lungs or brain, induces *sudden* death. Asphyxia is promptly fatal. And some diseases within the cranium are still more promptly so. But, in the latter case, the disease has extended its influence beyond the cerebrum, and affected the *medulla oblongata*. Sudden hæmorrhagy within, or adjacent to, the medulla oblongata, or so situated or in such abundance as to compress this organ, may induce death as

prompt as that of asphyxia itself, with which it is indeed identical.

Instead of referring *sudden* death, therefore, with Bichat, to the heart, lungs, and brain, I am disposed to refer that fearful event, in every case, to arrested coronary circulation, or to lesion of the medulla oblongata. The former may arise, as I have stated, from various circumstances; the latter may be the effect of disease within its structure, of pressure, or of counter-pressure.

Less sudden death may be induced in the manner described by Bichat. The heart, the lungs, and the brain may, in this sense, be the 'trépied de la vie;' and the blood may be said to be borne upon that tripod.

Less sudden death still is induced, if the stomach and intestines, the brain, the kidney, be morbidly affected. These organs are only less essential to life *in degree*. Rupture of the intestine is immediately marked by the sinking or slowly dying state.

Blood-letting; Hæmorrhagy.

A thousand other questions relative to the circulation crowd upon us, and none of greater interest than those which relate to the morbid and curative effects of loss of blood. In a complete treatise on the subject of these lectures, these questions must occupy a considerable space. But in the present instance I must dismiss them with a very few remarks, and a reference to my work on this subject*.

Certain diseases give a peculiar *tone* to the circulatory system, enabling it *to bear*, and causing it *to require*, great loss of blood in their treatment. They are inflammations of the serous membranes and parenchymatous substance of organs. Other diseases induce this effect in a much slighter degree; such are the inflammations of the mucous membranes. Lastly, other diseases render the system unduly susceptible to the effects of loss of blood: these are the class of irritations, as gastric and intestinal disorders and irritations.

This fact is of the utmost moment in practice, in guiding us in the use of that most powerful and either beneficial or in-

* Observations on Blood-letting, &c.; 1836.

jurious remedy, the lancet. In this point of view, it belongs to my next lecture; but in another, it has a reference to pathology. The morbid effects of loss of blood are so insidious, so apt to be induced in certain cases by our very treatment, so similar to the symptoms of certain diseases, so deceptive, therefore, that no question in pathology or in daily practice is so important.

The Nervous System.

In treating of the pathology of the nervous system, I must again refer to its subdivisions into the *cerebral*, the *true-spinal*, and the *ganglionic*.

The True-Spinal System.

The physiology of the true-spinal system embraces the proper function of the true spinal marrow, with its system of incident and reflex nerves, and the functions of ingestion and egestion, which are *all* excited and reflex in their nature and forms.

The pathology of this system wears a different aspect. The morbid condition may exist either at the *origin* or in the *course* of the incident nerves, in the *true spinal marrow* itself, their centre, or in the *course* of the reflex nerves.

The causes which act on the true spinal marrow may be very various. First, a disease of this organ; secondly, an adjacent tumor irritating or compressing it; thirdly, disease of the cerebrum, or in the upper part of the cranium, affecting it by counter-pressure.

Besides these sources of a pathological condition of the true spinal marrow, we have another and most prolific source of derangement in the condition of its own *circulation*, of the *quantity* and *quality* of the *blood* sent to it, and of the *force* with which it is sent. I have already alluded to this subject in treating of asphyxia. It is one full of the deepest interest. It presents a new and ample field for the future cultivator of pathology. Whoever engages in it must trace the effects of morbid ingesta, of retained excernenda, &c. &c.

There is still another fact to be briefly noticed. I have ascertained, by experiment, that, although irritations of the cerebrum and cerebellum induce no effect on the muscular

system, yet irritations of the dura mater excite singular muscular actions. I have noticed this subject in the last volume of the Transactions of the Royal Medical and Chirurgical Society, and intend to prosecute the subject by experiment and observation.

How much of light will be thrown upon the subject of epilepsy, and other forms of convulsion, in adults and children, and indeed upon the whole of the *Class* of diseases of the nervous system, by the investigation of these various points, it is impossible, I believe, at present to conceive. Every such case now involves a variety of questions scarcely agitated until very recently.

The Ganglionic System.

After the true spinal, comes the ganglionic system. The effects of various agents which impress the heart with adynamia, as violent shocks or accidents, certain poisons, &c. are obviously exerted through the medium of this part of the nervous system.

During the half-lethargic condition of the frog in winter, the entire cerebrum and spinal marrow may be removed by slow degrees, at considerable intervals, and then it is obvious that nothing but the ganglionic system remains. The circulation is, nevertheless, good In a frog so prepared, we may perform experiments on the ganglionic system. One such experiment is of great interest; a blow on the stomach, or on a limb, immediately enfeebles the action of the heart, and arrests the capillary circulation.

My object being, throughout these lectures, only to throw out hints, I need not occupy your time further with the bearing of a proceeding already sufficiently obvious.

III. *The Mental Faculties and the Passions.*

I need scarcely observe that the condition of the intellect is linked with that of the circulation within the cerebrum. If the arterial pressure be not duly sustained, there are syncope, insensibility, delirium; or if the return of the venous blood be impeded, there is coma. These facts are admirably illustrated in my experiments on the effects of loss of blood, and in the effects of blood-letting in practice, on observing the

effects of posture. In the human subject, I have known syncope sustained and delirium induced by unduly preserving the erect position. The opposite effect of impeded return of blood from the head is seen in various diseases of the heart.

Mania; Puerperal Mania.

But there is another morbid affection of a deeply interesting character, which sometimes undoubtedly depends on a morbid condition of the *cerebral circulation*, only longer concontinued. It is that of *mania*, and especially of *puerperal mania*. I have known mania induced by blood-letting in a chlorotic patient: the case was pneumonia; and this disease was subdued by the remedy; but, when the protective influence of the disease was removed, mania occurred as a remote effect of loss of blood.

Mania, too, is frequently the result of imperfect excernent processes. The fæces unduly retained; the bile inadequately secreted or excreted; are constant sources of insanity; and the facts suggest the proper medicinal treatment. In two cases of the very deepest interest, I have recently seen insanity removed by following out the suggestion just made.

Apoplexy; Paralysis.

The prevention of apoplexy and paralysis proceeds upon the same principles. The circulation within the head and in the general system must be kept in a state of just *equilibrium*. Plethora is a frequent cause of these maladies; but the opposite state, or that of anæmia or inanition, has its danger. The late Dr. Denman published a case of protracted hæmorrhagy from encephaloid polypus of the uterus, in the midst of which the patient was attacked with hemiplegia, a coagulum of blood being formed in the opposite lobe of the cerebrum; and I have seen many cases of *threatening* of an apoplectic or paralytic attack distinctly warded off by acting upon the principle enforced by such facts.

But, if a state of equilibrium of the circulation be important, the strict regulation, both of the ingesta and egesta, is still more so. The fæces and the bile must be excreted; and the condition of the urine must not be overlooked. The

gouty diathesis especially requires the utmost attention in this latter respect. I need scarcely remind you, too, of the disposition to apoplexy and hemiplegia, as well as epilepsy, in the disease recently so well illustrated by Dr. Bright.

The Hydrencephaloid Disease.

Another subject, and the last which I may mention, connected with the condition of the circulation within the cerebrum, is that of the hydrocephaloid disease in children. Its designation announces its *similarity* to hydrocephalus. But its nature, origin, and treatment are opposite. Arising from sources of exhaustion, it is connected with a deficient supply of blood; and its cure depends upon a just diagnosis, and the judicious administration of stimuli and nourishment.

This subject is discussed in my recent volume on the Nervous System.

Living Pathology.

In this lecture I have endeavoured to give a sketch of what I have ventured to designate *living pathology*—the *physiology* of disease, as distinguished from what is termed *morbid anatomy*. This living pathology must be our guide in our prescriptions, which must be directed to correct what is wrong in function—morbid actions, and remove what is the result of those actions. But this is the proper subject of my next lecture.

The *causes* of this pathology act principally through the *nervous* and through the *vascular* systems. As the simplest examples, I may adduce improper food: a dinner of pork annoys the *incident nerves* of the stomach, and induces epilepsy; the poison of bad saussages passes into *the blood*, and induces a morbid condition of the general system. Similar effects are induced by retained fæces. *But the same two-fold principle obtains, I believe, most extensively in pathology.*

LECTURE III.—ON THERAPEUTICS.

I. *The Functions of Ingestion and Egestion.*

The mode of action of remedies and of poisons still presents one of the most interesting subjects of inquiry with which we can be engaged. In discussing it, I shall pursue the plan adopted in my two preceding lectures, and given in the table of classification.

Sufficient has been stated to demonstrate the importance of attention to the ingesta and egesta. But the full effects of abstinence, of a strict regimen, and of free action of the bowels and liver, are scarcely yet known.

The influence of entire abstinence from wine, and occasional abstinence from food, is exceedingly great in cases in which the stomach and bowels, with the liver and kidney, are disordered.

The influence of the simplest of remedies, 'the lavement,' or κλυστηρ, literally a *washer*, used daily in ample quantity, is also exceedingly great. A friend brought his little boy to me, saying that, in spite of every mercurial and purgative, the alvine evacuation was still as pale as the palest clay. I recommended a full enema of warm soft water, to be used twice daily, and to omit all medicine. In five days, my friend, who had been sceptical as to the efficacy of the remedy, returned to express his satisfaction and surprise at the result. I believe a loaded state of the stomach and intestine, and drastic medicines, equally arrest the flow of bile along the biliary ducts in some cases; and that in such cases the full enema of warm water is the specific and efficacious remedy. Acting mildly and mechanically, it removes the material cause of obstruction, and the bile flows naturally and freely.

The influence of change of air, of the country-air, of the sea-breezes, is sometimes so great as only, I think, to be accounted for by supposing the respiration of the blood itself to be improved. We certainly see chlorosis cured, and other changes in the blood itself induced, by this measure.

Then the importance of attending to the urinary secretion and excretion can only be duly appreciated by perusing the incomparable works of Dr. Prout and Dr. Bright. In the *prevention* of apoplexy and hemiplegia, no point is more important, after the diet and the alvine evacuation, than the just secretion and excretion of the urine. In the *gouty* subject this is especially essential.

II. *The Higher Vital Functions.*

In looking over that part of the arrangement which relates to the higher vital functions, we are at once struck with their importance, whilst we find it difficult to apply other than *general* remedies to their disorders.

Through the medium of these functions, however, our most important remedies act, and upon these organs the class of poisons exert their frightful power. On these two points, and especially the latter, I shall here make a few remarks.

The Nervous and Vascular Systems; Action of Poisons.

Those authors who have treated this question have, I think, generally taken too limited a view of the subject. Dr. Addison and Mr. Morgan have advocated the theory of nervous agency, Mr. Blake that of vascular agency, too exclusively. Indeed, the two former eminent physiologists have "assumed" it "to be unphilosophical to admit of a two-fold operation of poisonous agents on the living body*."

Dr. Addison and Mr. Morgan observe (p. 60)—

"The conclusion at which we have arrived is simply this: that all poisonous agents produce their specific effects upon the brain (?) and general system through the sentient (?) extremities of nerves, and through the sentient extremities of nerves only; and that, when introduced into the current of the circulation in any way, their effects may result from the impression made upon the sensible structure of the blood-vessels, and not from their direct application to the brain itself."

Mr. Morgan, in a subsequent most interesting "Lecture on Tetanus," observes (p. 28)—

"Tetanus is, by common consent, allowed to be a truly

* An Essay on Poisonous Agents, &c. p. 59.

nervous disease. I mean, by a *nervous* disease, a disturbance in the functions of the brain and general system, caused by their connection and sympathy with the *nerves* of the injured part, *and by that only*. Now whether all diseases, and all morbid phenomena, do or do not owe their origin to sympathy *alone*, is a question which will never be settled in our time (?). So far, however, as my own opinions go, I firmly believe that *every* disturbance in the system may be fairly traced to the sympathy in the brain with a local impression, and not *necessarily* to absorption or to any other agent. Let me not be misunderstood: I do not dispute the well-known fact of the absorption of morbid matter by the veins and absorbents, nor of the necessary subsequent conveyance of this matter (whether it be gaseous, fluid, or solid) through the whole circulating system; but what I contend for is this—that neither its *contact with the brain*, nor its entrance into absorbent vessels, is *essentially necessary* to its operation on the living body. I believe that the sentient extremities of nerves are the parts upon which an impression is first made; and that the different degrees of morbid susceptibility observed in different structures may be more satisfactorily accounted for" "by the theory of nervous communication, upon the hypothesis of the *necessity* for absorption and the *contact* of the morbid agent with the brain."

Mr. Blake, in his able paper, observes—

"Of the many opinions that have been entertained on the manner in which poisons produce their effects, there are only two which it is now necessary to notice, as they express the views of by far the greater number of physiologists of the present day.

"According to one of these opinions, before a poison can produce any general effects, it is essential that it should be mixed with the blood circulating over the body, and thus brought into contact with the nervous tissue, or, at least, that the poison should, in some manner, be strictly applied to the nervous centres.

"The other opinion to which I have alluded is, that these poisons modify or destroy the functions of the nervous system, by an impression made on the nerves of the part to which they are directly applied, and which, being transmitted

to the nervous centres, may destroy these functions, independently of any contact of the substance with the nervous tissue generally."

"As the opinion which would ascribe the general effects of a poison to an impression made on the part to which it is directly applied, is in opposition to the conclusions to which a careful investigation has led me, I shall take a short review of the evidence adduced in support of this opinion."

"In regard to tetanus" (itself) "I would observe, that we are not justified in concluding that the whole of the morbid phenomena are the result of the mere local irritation of a nerve. It is highly probable that some pathological state has been propagated from the injured nerve to the nervous centres, before the violent symptoms which characterize this disease manifest themselves. Were the symptoms the mere result of the local irritation of a nerve, we might expect to produce them at pleasure, by merely irritating the nerve; but it is well known that this is not the case. (?) In every instance it is necessary that a certain time shall elapse between the local inquiry and the appearance of the disease, which time is probably required in order that the pathological condition above alluded to may be produced. It would thus appear that we have no pathological facts which lead to the conclusion, that poisons act by an impression made on the nerves of the part to which they are directly applied*."

Now it appears to me that it is precisely an exclusive doctrine, which is the erroneous one, and that, whilst *either*, *alone*, is inadequate to the explanation of the whole series of phenomena, *both* are absolutely required for this purpose.

I think, then, that *all* external agents may be divided into two classes:—

I. *Those which act* PHYSICALLY, *and on the Nervous System; and*

II. *Those which are* ABSORBED, *and act through the Vascular System.*

The former act on the peripheral origin of the incident nerves of the true spinal and ganglionic systems: such as mechanical violence; chemical violence; the sudden im-

* Edin. Med. and Surg. Journal, No. 142.

pulse of light; heat; cold; galvanism; &c. The latter constitute the class of remedies and of poisons properly so called: these must pass into the state of solution, be absorbed, be carried along with the blood; &c. In both cases, the force of the agent may be finally exerted in the nervous centres, as in the tetanoid affections arising from the mechanical irritation of a nerve, and the application of strychnine; the former is the result of the physical lesion of a nerve with *reflex* action; the latter, of the absorption of the poison, its application to the nervous *centre*, and the *direct* action of this. Traumatic tetanus and hydrophobia in the human subject have this character respectively. The act of vomiting, induced by tickling the fauces, or by injecting an emetic substance into the circulation, possesses the same essential character.

But I have said that the physical agents may act through the ganglionic system; they then, as it appears to me, induce their effects on the principle of shock, and affect the heart principally. In this manner the corrosive poisons act when administered internally. The phenomena may be compared to the effects of sudden rupture of the stomach, intestine, gall-bladder, &c., and to the effects of excessive violence done to a limb in accidents or experiments, on the action of the *heart*.

But the same principle prevails throughout the animal œconomy, whether physiologically or pathologically considered. *All* the acts of *ingestion* are excited by physical impressions made on the system of incident nerves; *all* the acts of *assimilation* are performed through the vascular system. Morbid agents act through the medium of either of these systems. Poisons most generally act through the vascular: they may be *absorbed* into the œconomy; or they may be *retained* in it; for nothing can be more deleterious than the retention of what ought to be evacuated and expelled; a fact, as we have already observed, illustrated in the cases of the retention of the carbonic acid, which ought to be extricated in respiration, and of the urine in cases of suppression.

Of remedial agents, many indubitably act on the origin of the incident nerves: the douche of cold water applied to the

face induces an act of inspiration on this principle; the same remedy applied to the hypogastric region induces contraction of the uterus in the same manner; the feather applied to the fauces induces vomiting by an impression made on the fibrillæ of the trifacial nerve. Other remedies are as indubitably absorbed into the circulation, and act on the spinal marrow and other internal organs. We have proofs of this mode of action in the vomiting induced by the external application of the tartrate of antimony and in the stranguary induced by a blister of cantharides.

Of poisons, the corrosive doubtless act on the nervous system, and induce the effects of shock and of physical violence, effects which resemble the death-blow given by rupture of the stomach or intestine, or by the mechanical violence of tremendous accidents.

The very same poisons much diluted, and other poisons, are absorbed, and act on the internal structures, the spinal marrow, the heart, &c.

Experiments.

The subject of the action of remedies and of poisons is still open to further experiments. These may be best instituted on the frog. If in this animal the cerebrum be destroyed by a needle, which may be accomplished in an instant, we have sensation destroyed, whilst all the vital functions are still carried on in the most perfect manner. We may then pursue our experiments with the conviction that we are inflicting no pain or suffering of any kind.

Our first experiments may be made in reference to those agents which act *physically* (see p. 66). In this manner we may produce various tetanoid and convulsive affections, acting through the medium of the incident nerves, the true spinal marrow, and the reflex nerves. These experiments it does not seem necessary to detail.

Our next series of experiments may be more varied. Those agents which, as I have stated (p. 66), act by being absorbed and carried along the circulation, must be employed. A few such experiments I shall proceed to detail:—

1. On the 16th of July, 1841, Mr. H. Smith and I ap-

plied a solution of strychnine to the expanded web of a frog: in fifteen minutes it became tetanic, the first symptom being a singular croaking respiration.

2. In a second frog, we divided the spinal marrow *below* the origin of the trachial plexus, and applied the strychnine as before.

We concluded that, if the strychnine act through the medium of the incident nerves, the lower extremities would become tetanic, whilst the anterior extremities would remain free from the influence of the poison. I need scarcely observe, that it is absolutely impossible that the anterior extremities can be made tetanic, in this case, through the medium of the incident and reflex nerves, of which the former originate in the lower extremities. And it is proved that tetanus cannot be induced through the medium of the ganglionic system.

The anterior extremities became tetanic first, after an interval of twenty minutes, and the posterior extremities became tetanic after an interval of fifty minutes.

There was none of the peculiar noise in the inspiration observed in the former experiment; and the tetanus, though quite decided, was less violent.

3. We tied a ligature round the large vessels proceeding to and from the heart. The circulation was completely arrested. We applied strychnine; but no tetanus occurred.

4. We now tied a ligature round the thigh of a frog, *excluding the sciatic nerve*, but so as not to arrest the circulation, as seen under the microscope; and we applied the strychnine as before. In this case the spinal marrow was not divided; and sensation remained in the web. Nevertheless, no tetanus took place in the space of a whole hour.

We now removed the ligature; the circulation was speedily restored; and in five minutes the frog became tetanic.

5. We now divided the spinal marrow just below the cerebrum, so as to annihilate sensation, and we then divided all the tissues of the thigh, *excluding the femoral arteries and veins*, keeping these asunder at the distance of a line. The circulation was very perfect in the web. We applied the strychnine. In thirty minutes the animal became strongly tetanic?

6. We applied strychnine in two instances to a wound in the middle part of *the snake*.

We concluded that if this poison act through the incident nerves, it would, like physical agents, produce phenomena, more or less limited in their extent, about the poisoned part; but that if it acted through the circulation, the whole animal would become simultaneously tetanic.

In a moderate space of time the whole animal became tetanic.

It is impossible not to conclude, from these experiments, that certain poisons are absorbed, and carried along the circulating blood. In the case of strychnine, it is equally obvious that the immediate action of the poisoned blood is upon the true spinal marrow.

There is still ample scope for further experiment; it is a question whether any poison act specially on other parts of the nervous system, as the cerebral, the ganglionic, or on other of the viscera, as the heart, the stomach and intestines, the kidney, &c.

Tetanus traumaticus is an example of a purely nervous action, through the incident nerves of the true spinal system. A *similar* effect is actually induced in the decapitated turtle, by irritation of its incident nerves.

Hydrophobia, apparently so similar to tetanus, acts through the medium of the vascular system, its virus being absorbed and conveyed to the *central* organ of the true spinal system, resembling the action of strychnine.

As a general example and conclusion, I think it must be admitted, that *all physical* agents (whether poisonous or remedial) acting on the nervous centres, do so through the medium of the *incident nerves;* whilst *all chemical* agents, acting on the same nervous centres, act through the medium of the circulating system.

Tolerance and Intolerance of Remedies.

There are conditions of the vascular and nervous systems which lead, respectively, to *tolerance* and *intolerance* in regard to remedies of various kinds—a principle of the utmost moment in practice, and presenting a field of inquiry not hitherto explored.

Inflammation of the encephalon, especially, and of the serous membranes and parenchymatous substance generally,

induces such a degree of *tone* in the system, if I may so express myself, such a degree of tolerance in regard to the detraction of blood, that it is difficult to impress the system by blood-letting.

The same, and other morbid conditions, also induce tolerance in regard to the tartrate of antimony, and mercury; so that the former is sometimes given in large and repeated doses without inducing vomiting, and the latter, long-continued in its most efficient forms, without inducing ptyalism.

In *all* these cases the undue tolerance ceases—perhaps yields to the opposite condition of the system,—as the disease subsides, and the remote, as well as the immediate, effects of the remedy present themselves.

An opposite condition of the system, or that of intolerance, is seen in certain diseases of a different character. In cases of *irritation*, as gastric or intestinal irritation, from indigestible substances taken, or the excernenda retained;—of *accident*, as fractured ribs, *before* inflammation is set up;—of the delirium tremens, or the delirium traumaticum;—of exhaustion from loss of blood;—of the different forms of *erethismus*, especially that from mercury; &c.—there is, compared with a state of health, and still more, with the case of inflammation of the serous membranes, great intolerance of loss of blood.

The first case, or that of great tolerance of loss of blood, and some other remedies, arises out of the condition of the *vascular* system. But there are conditions of the *cerebral* and *nervous* systems which lead to *similar* effects. They are *mania* and *tetanus*. In these affections there is a degree of intolerance of certain remedies, as purgative medicines, opium, mercury, &c., which is quite extraordinary.

But, in a *therapeutic* point of view, the degree of tolerance or intolerance of blood-letting is the most important. It is determined by placing the patient perfectly upright, looking towards the ceiling, and allowing the blood to flow until incipient syncope be induced.

This plan can, of course, be adopted only in the cases in which it has previously been determined to bleed *fully*. It is, therefore, expressly limited to those cases. But in these it affords a rectification or confirmation of the diagnosis, and a criterion of the powers of the patient, of the utmost mo-

ment. It frequently induces us to take *more* or *less* blood than we should otherwise have *guessed* to be necessary; and in both cases it *guides* us aright. It therefore affords a *guard* at once against inefficient and undue blood-letting.

I have said that this *rule* applies to such cases as appear, after the fullest investigation, to demand full blood-letting. If the plan be then adopted, of raising the patient into the perfectly erect position, and of allowing the blood to flow until the first dawn of syncope, I believe that full blood-letting will be accomplished, and neither more nor less; and that we have, in the quantity of blood which has flowed, a measure of the violence of the disorder and of the strength of the patient; and, in doubtful cases, a corrective of our diagnosis. We have also an intimation that we ought to recur to, or desist from, further blood-letting. If *much* blood has been taken, the disease is inflammatory and severe, and the powers of the patient good; and we may and ought, if the symptoms continue, to bleed again speedily and freely. On the contrary, if early syncope take place, we must be wary in regard to further blood-letting.

I am so impressed, by long experience, with the importance of this view of the subject, that I have earnestly wished that we had some such guide for the use of blood-letting in cases not requiring or bearing full blood-letting, and for that of our other powerful remedies. But in *both* these instances we are compelled to trust to the *symptoms*, and these frequently only appear when the remedy has already been carried somewhat too far. Blood-letting, digitalis, mercury, &c. are of this class. I have known the patient overwhelmed with exhaustion, with sickness, and faintness, and with ptyalism, which had not been detected until they had become extreme.

The Treatment of Asphyxia.

The treatment of asphyxia involves an attention both to the functions of respiration, and to that of the true spinal marrow.

The object, doubtless, is to effect a restoration of the respiratory and circulatory functions, the former of which has been arrested by the external conditions of the patient; the latter, by the contact of morbidly carbonized blood with the capillary vessels of the lungs.

The *first* thing to be attempted is the restoration of warmth by active friction with warm hands, &c.; the *second*, the imitation of artificial respiration by any means at hand, of which none is better, usually, than the action of alternate pressure and its relaxation, applied to the thorax and abdomen so as to induce expiration first, and inspiration immediately, by the play of the elasticity of the ribs.

The *third* effort is made by suddenly dashing cold water on the face and general surface, previously warmed by the frictions, in the hope of inducing a more decided inspiration.

Artificial respiration must be attended to, if these measures, very promptly enforced, fail; and unless the proper apparatus be present, the mouth of another person of robust make, is to be applied to that of the asphyxiated person, covered with a handkerchief, the nostrils being closed.

Then follow *electricity*, &c.

But my present object is not to detail the practice in asphyxia, which would detain you too long, but to bring before you once more the subject of

Secondary Asphyxia.

This I cannot do better than by adducing the following interesting police report from the "Globe," which has been published since the first part of these lectures was sent to the press! The case has occurred most opportunely, however sadly, to illustrate the *insidious* character and painful consequences of this hitherto undetected form of asphyxia.

"UNION HALL.—A few days ago, several jurymen, who sat on the body of Margaret Story, a young woman in the service of Mr. Stevens, a solicitor at Brixton, waited on Mr. Cottingham, and represented that, since the inquest was held, rumours had been circulated about the neighbourhood, that very gross negligence had been exhibited towards the deceased by the family in which she lived. They (the jurors) proceeded to state, that the deceased was taken out of a pond at the bottom of her master's garden, into which she had thrown herself, and that subsequently to the act she was conveyed into the house still living, but that a report prevailed

that she was not attended to in the way her situation required. When the inquest was held on the body, no fact prejudicial to the family in whose service the deceased lived came out, and a verdict was returned.

"Mr. Cottingham said, that, if any additional facts had transpired, he (the magistrate) had no objection to enter fully into the investigation of all the circumstances.

"The magistrate then gave direction that Mr. Stevens should be apprised of what had taken place; and that gentleman and Mrs. Stevens, together with their domestics, attended, when the whole of the circumstances attending the death of Mary Story were fully entered into, and of which the following are the brief facts:

"Mr. Drew, the solicitor, attended to watch the proceedings on the part of Mr. Stevens.

"The deceased had been a fortnight in Mr. Stevens's service, at the expiration of which time, one night, between ten and eleven o'clock, after eating a hearty supper with her fellow-servants, she left the kitchen, and, in a short time afterwards a loud shriek was heard at the bottom of the garden, when the gardener immediately ran to the spot, quickly followed by Mr. Stevens, who was going to bed at the time, and also by the cook and lady's maid. The gardener succeeded in dragging the deceased out of the pond, and, with the assistance of two policemen, who were attracted on hearing the shrieks, carried her into the house, where she was soon divested of her wet clothes, and laid before the kitchen fire. Mr. Stevens lost no time in despatching a messenger for Dr. Keys, the family physician, and by the usual applications in such cases, the deceased soon recovered sufficiently to be enabled to express herself, and said she was a foolish girl for attempting to put a period to her existence. Another medical gentleman also attended on deceased; but she grew worse in the course of the same night, and expired the following morning at eight. Her friends not allowing a *post-mortem* examinations, which would satisfactorily explain the cause which produced death. In consequence of the reaction which took place soon after the deceased was taken out of the water, it was anticipated that she would ultimately have recovered; and, in accounting for her death under such cir-

cumstances, the medical gentlemen were of opinion that it was in consequence of the shock to the nervous system, produced by the sudden immersion in the water.

"In the course of the enquiry, Mr. and Mrs. Stevens, together with all the servants of the family, were examined, and also the two medical gentlemen who were in attendance, and all agreed that every possible attention was paid to deceased.

"The jurymen put some questions to the witnesses with a view to ascertain whether there were any grounds for the reports which had spread abroad in the neighbourhood relative to the alleged negligence and want of attention exhibited by Mr. Stevens's family towards the deceased; but the answers given showed that they were wholly destitute of foundation, and that the most prompt attention and kind feeling were exhibited throughout.

"Mr. Cottingham, on hearing the whole of the evidence produced, said that it must be evident to every person that there was not the slightest degree of blame attributable to Mr. Stevens, or any member of his family; but that, on the contrary, they had all evinced every disposition to do all in their power to save the life of the deceased after she was taken out of the water."—*January* 13, 1842.

Treatment of Paraplegia.

Perhaps there cannot be a more glaring application of *anatomy* and *physiology* to therapeutics, than that which guides us in the treatment of paraplegia. The issues or setons employed in this disease have proved less efficacious than they would have done, because they have been applied *below* the real seat of the morbid affection.

I was consulted some time ago by a gentleman affected with paraplegia; there was loss of sensation from the feet to the region of the sacrum inclusive. Issues had been applied on each side of this bone! They might, with equal efficacy, have been applied to the foot itself! Guided by the symptoms, we have forgotten the anatomy and physiology.

Our success with issues has been more marked in cases of paraplegia with caries. For in this case the external tumor

has distinctly denoted the real seat of the disease, to which our remedies have been accordingly applied.

A few days ago I saw a paraplegic patient, in whom the muscles of the eye, the hand, and the feet, were affected. It was plain that the disease was seated as high as the base of the brain. There was no guide to the extent to which it had descended to the spinal canal.

On the other hand, I recently saw a case in which the hands were spared, but there were reflex spasmodic actions on voiding the bladder. The seat of the disease was, therefore, *below* the origin of the brachial plexus, and *above* the central organ of the reflex actions of the bladder and extremities—*therefore, between* the second and last dorsal vertebræ. To this spinal region, therefore, the local counter-irritation prescribed was specially applied.

III. *The Mental Faculties and the Passions.*

I have little to say upon this subject. And yet there is no question that, as the violent exercise of the former, and subjection to the latter, are the sources of many maladies, and especially those of the cerebrum, and of the true spinal system, in their relation to the mental, sexual, and muscular powers, so a due regulation and strict repose and quietude in regard to them, form a considerable part of the treatment of insanity and of certain forms of spinal affection.

Treatment of Insanity.

Much has been recently published on what has been designated the 'non-restraint' system of treating the insane. If by this expression is meant the abandonment of every useless and needless restraint, no one can applaud the project more than myself. But if it means that the physician of the insane is to be deprived of a necessary resource, and of a most important remedy, under peculiar circumstances, I can only aver that he might as properly be deprived of the use of opium and of the lancet. I have seen patients quieted, lulled, composed to a state of 'balmy sleep,' by the strait-waistcoat, who would have been not only wakeful, but furious, all the night, and exhausted in the morning, but for this gentle restraint.

It is therefore as an opiate, as a remedy, that I would use this measure.

But I expressly disapprove of the agitation of the question in the *public mind*. Is the physician no longer to have the free use of his own judgment? Is he no longer fit to be trusted with his own remedies?

The public are not wise judges in medical matters. How many a patient has been bled after a fit, or an accident, very injudiciously, in self-defence on the part of the medical practitioner! And now the physician is to be deprived of the use of what he may deem an important *remedy* in insanity, out of a similar forced deference to a prejudice induced in the public mind! Fortunately, in this latter case, the responsibility may be placed, where it will assuredly sit very uneasily, in that very public mind.

If abuses have been committed, let *these* be brought before the light of day. But let the discussion of a subject on which eminent physicians *may* differ, be carried on *amongst themselves*. They are virtuous enough and wise enough, without the aid of laymen, magistrates, and others, to discuss this, as well as other most weighty questions.

The important questions in regard to the *cure* of the insane, are those which relate to diet, to the secretions and the excretions, to exercise, to moral and mental treatment.

The diet should, in every case, be of the simplest, lightest, and most digestible kind, in moderate and regulated quantity. In few, very few, cases, should beer or wine be allowed. All the excretions should be continued in the most perfectly free and healthy state. Exercise in the full open air should be taken daily, so as to complete the digestive process, and infuse tone into the general system.

Great attention should be paid to warmth and dryness of the *feet*, and to every comfort in clothing.

If the patient should be furious, or dangerous to himself or others, he is to be gently, but effectually, restrained, and all struggling and contention, *the worst form of restraint*, should be avoided.

Gentleness and firmness in moral treatment should be happily combined.

My views on this subject are embodied in the following

tribute paid by me some time ago to the late Mr. Stilwell, of Hillingdon, near Uxbridge :—

The late Mr. Stilwell.

'Of all that has been done within the last quarter of a century, for the amelioration of the sad condition of the insane, by far the greatest part was accomplished, though within a narrow circle, by one now no more—one whose modesty kept him and his achievements hidden from the busy world, but to whose merits I have great pleasure in doing this act of justice.

Mr. Stilwell was a person of singular originality of mind and benevolence of heart. No less qualities could have suggested the possibility of realising for the insane a peaceful English fireside, with all its associations, in exchange for the dungeon and the prison.

More than thirty years ago, when the low and cruel despotism of the ignorant *keepers* of the insane was at its height, and when the clang of *chains* was loudest, this gentleman projected an asylum for the insane, which should be conducted *without keepers and without chains*, in which all possible liberty, compatible with the safety and good of the patients, should be permitted, and every comfort should prevail which could make it worthy of the designation even of an Englishman's home.

Mr. Stilwell actually conducted this institution for the third part of a century, on this plan, without one single accident! And when I state that, during that period, the patients constituted, *bonâ fide*, one family, with himself, Mrs. Stilwell, and their five sons and one daughter, from their very infancy upwards—that they played together in the same garden, and took their meals together at the same table— I imagine you will think with me, that the plan was one requiring no little courage, and its successful execution one requiring a watchful eye of no little steadiness. I confess, that to me, its history at first presented the idea of a romance rather than of a reality; but its reality far exceeds any thing imagined or accomplished by Pinel, or by Esquirol.

Every thing which Mr. Stilwell did was judicious too; there was no rejection of important means of safety and be-

nefit to the patient, though for eighteen months together the strait-waistcoat, for example, was never used; there was nothing pretended; all was real—all was English.

I regard the late Mr. Stilwell as the English Pinel, or the English Esquirol; and more, for these gentlemen are left behind by an infinite distance, in the accomplishment of all that may and can be done for the insane.

I would that our pauper lunatics, instead of being crowded in a gallery which presents a picture of misery, not to say of horror, were so placed, few in number, together, in what I will designate farm-house establishments.

The project which I have sketched is the truly humane project for the care and treatment of the insane, as far above the propositions of some recent noisy advocates of non-restraint, as *real* and *substantial* comfort is above its mere and empty *name;* and this project was designed and successfully executed by the late Mr. Stilwell, whose memory should be associated with that of Howard, for his active benevolence towards another class of prisoners.'

Summary.

The formation and the purification of the blood, it is now obvious, are not only amongst the most important questions in physiology, but amongst the most important topics which can occupy the practical physician.

If the sources from which sanguification proceeds be not sufficient, if they be impure, the whole stream becomes inadequate or inapt to sustain the functions of life. If after being formed, and after having performed its office in the animal œconomy,—if after having received into its channel the matters which ought to be removed from the œconomy, its purification from these be not duly accomplished, it carries itself the poison into the innermost recesses of the frame!

Sanguification must, therefore, be duly instituted, and the purification of the blood must be continually, adequately, and unceasingly maintained.

The due regulation of the diet and the air, and the due performance of egestion, are to be insured, as perfectly as may be by the physician. Sometimes a chalybeate is re-

quired; sometimes the respiration of a freer atmosphere, of the country-air, and of the sea-breezes, must be enjoined.

In the gouty diathesis, especially, and in other morbid conditions of the œconomy, the ingesta must be strictly regulated; and the excretions, and especially that of the urine, must be corrected if erroneous, and augmented, if, as they frequently are, they be too scanty.

In the treatment of the *dropsies*, our attention must be continually fixed on their *cause*,—the original disease; (see p. 53.) Without this, we may give *diuretics*, in all their empirical forms, in vain. The pressure of the fluid in ascites may prove a mechanical impediment to the action of the liver, the kidnies, &c. Paracentesis may therefore exert a really curative influence. Sometimes the ascites, though previously undiminished, does not return.

The condition of the *higher vital functions* must be carefully watched and regulated. The circulatory system and the nervous system have been shewn to be, in a great measure, the media of the operation of external morbid agents. The *blood* frequently circulates the morbid poison; the *vis nervosa* is frequently under the impression of a morbid physical agent. Through both, our remedies are constantly applied. The ready way into the mass of blood is afforded by the absorbents of the stomach and alimentary canal in general, and of the lungs; the nervous system is beneficially affected by cold applied in various forms, as the 'douche,' the breeze, &c. By these the respiration, the action of the intestine, and of the uterus, is promoted.

It is in a state of equilibrium in regard to the circulation within the brain, that the danger of apoplexy, of hemiplegia, of some forms of mania and epilepsy, are avoided.

Besides these general facts, other principles guiding us in the application of remedies have been pointed out, and I trust it has been shewn that the truly able practitioner must be continually drawing upon his store of anatomical and physiological knowledge.

I must conclude this lecture by a few words on a series of functions not hitherto noticed, viz.—

IV. *The Functions of Reproduction.*

The immediate functions of reproduction, in both sexes, are properly functions of the true spinal marrow and the system of incident and reflex nerves; conception and parturition are equally acts of this system. The science of *Obstetrics* must, therefore, be greatly dependent on our knowledge of this subject.

The acts of ingestion and of egestion, in reference to reproduction, being left out of further question, we have still some important topics to consider. They are presented to your view in the table.

Sanguification.

Sanguification is maternal or placental, and it is plain that there can be no process of purification except through the same medium. The placenta must be the important medium both of all absorption and of all excretion.

Respiration.

The respiration is placental. And if the placenta be detached, or the circulation through the cord be interrupted, a true *asphyxia* takes place, from which nothing can restore the little patient but the institution of pulmonary respiration.

The Circulation.

The circulation in the fœtus is aplo-cardiac and systemic only, *within* the animal frame. What afterwards becomes two auricles and two ventricles, and pulmonary artery and aorta, communicate freely. There is then but one heart—but one exit from that heart. It is from a distant arterial branch that the blood is carried to a sort of *exterior* and distant branchiæ, the placenta, to be bathed, as it were, by the arterialized maternal blood, and to become itself arterialized, in the same manner as the blood of fishes is arterialized, by

its contact in the branchiæ with the water in which they swim.

The adult is diplo-cardiac, because the circulation is so too. In the fœtus the circulation is at once aplo-cardiac and single.

The amazing *power* of the heart is particularly shewn in the case of the acardiac fœtus to which I have adverted (p. 27). The ventricle forces the blood, not only along the whole arterial system, and the umbilical cord of the perfect fœtus, but through the placenta, the umbilical cord, and all the viscera of the acardiac fœtus, not omitting the portal system, until the blood flow to it again!

Referring you to the remarks made, p. 28, I may observe that the rule adopted in midwifery, of applying a ligature on the maternal, as well as the fœtal side of the point of division of the umbilical cord, is unnecessary, except in the case of twins with united placentæ.

In cases of a single fœtus there could be no hæmorrhagy from the maternal portion of the divided cord, except to empty the vessels of the cord and placenta, unless there be a direct communication between the maternal and placental blood-vessels. Of such communication, the experiment would afford a *test* more certain than any injections. An empty condition of the placenta might, in certain instances, render its expulsion more easy. The obstetric *rule* has doubtless been founded on the occasional *accident*.

I have often wondered whether the pulsatory movement of the blood be discernible after it has passed through a *secondary* circulation, and it has occurred to me that the fact might be ascertained by properly placing the fin or tail of the *fish* under the microscope, the pulsatory movement being made evident, if possible, as in the web of a frog, by a slightly applied ligature. (I have performed this experiment on the eel, since this paragraph was in print, and could observe no pulsation.)

In construction, and, not less, in function, the fœtus resembles the lower tribes of animals. Its circulation is that of the batrachia. One heart supplies the general frame, and drives the blood to the placental lung or branchia. The relative *quantity* of respiration and *degree* of irritability are

analagous to those of the lowest orders of animals, the former being small, the latter considerable.

It is on this principle that we may explain the low number of the fœtal pulse (p. 15), compared with that of the breathing infant. It is on the same principle, I believe, that we may explain the celebrated problem of Harvey, which Legallois attempted, I think, to solve in vain,—that the fœtus, which, being separated from the maternal influence, has not yet respired, will bear the privation of air much longer than the infant which has once respired. In this respect it resembles the reptile form and the hibernant condition of animals.

The Nervous System.

The play of the nervous influence in the fœtus is confined principally to the ganglionic system. The senses are scarcely impressed; and there are no acts of ingestion or of egestion to be performed. The fœtus may, therefore, be perfectly developed though amyelencephalic. Does it ever attain maturity?

In the fœtus from which *these* drawings were taken, the cerebrum and spinal marrow were entirely wanting; the ganglionic system and the development of the limbs and of the internal viscera were, however, complete—a beautiful confirmation of all our views.

What shall I say of the pathology and therapeutics of the fœtus? It has doubtless been affected with syphilis in utero. Has not this syphilis been cured by mercury in the same circumstances?

Variola has also affected the fœtus, and tubercles have been formed, during intra-uterine life.

But this is altogether too extensive a subject to occupy us further on this occasion.

I have now, Gentlemen, brought to a conclusion these hasty sketches, and it only remains for me to express my sense of the honor which has been conferred on me by the nomination which has thus enabled me to bring these different topics before you, and to state, that if I have not done justice to that nomination, as I greatly fear, it has not been for want of the desire to do so, but of the power.

POSTSCRIPT.

I may here insert a note of a case of insufficient power in the *right* heart and its consequences, for which I am indebted to Mr. Barlow. In this case the *lung* was, of course, not involved in the effects of the cardiac disease. 'I have,' says Mr. Barlow, 'recently attended a very interesting case of heart disease, producing, in their turns, hemiplegia, ascites (relieved by tapping, and only recurring afterwards to a slight extent), and finally hæmatemesis, accompanied by melæna, producing such profuse discharges of blood that the patient sank from exhaustion. The left side of the heart was found, upon examination, healthy; but the cavities of the right division were dilated and attenuated,—and the auriculo-ventricular opening was so much enlarged as to admit readily the points of the four fingers and thumb. There must have been an imperfect closure of the opening, regurgitation of blood, and obstruction to the return of blood through the vena cava, which satisfactorily explains the entire train of symptoms, the hemiplegia, the ascites, the hæmatemesis, &c.'

POSTSCRIPT SECOND.

Having omitted several illustrations of the subject of these Lectures in the text, I beg to add them in this place.

TABLE. (See p. 5.)

Of Masses.
1. *Acts of Ingestion.*
2. *Acts of Egestion.*

Of Atoms.
1. *Endosmosis in the Lungs, &c.*
2. *Absorption by the Lacteals.*
3. *Assimilation, Nutrition.*
4. *Reabsorption by the Lymphatics.*
5. *Exosmosis in the Lungs, &c.*
6. *Secretion.*

Experiments. (*See p.* 9—.)

I propose to ascertain the limit of the exhalation of carbonic acid, by the respiration of the same portion of atmospheric air repeatedly. I propose to ascertain whether the cessation of the exhalation of carbonic acid coincides with the cessation of the absorption of oxygen, when this exists in different proportions in the air respired. I propose further to ascertain whether, when there is a great excess of carbonic acid, this gas is absorbed. These and other researches will illustrate the remark made, p. 12, l. 34—37, and determine whether the absorption of oxygen and the exhalation of carbonic acid are *equivalent,* or *independent,* processes.

Experiments. (*See p.* 64.)

I propose to repeat the experiment of Dr. Addison and Mr. Morgan, of crossing the carotids of two dogs, and inoculating one with the woorara, interposing between the carotids of the poisoned and the other dog Reid's syringe, which will secure the transmission of the blood from the former into the latter animal, and remove the objection made to the original experiment, on the ground of the enfeebled action of the heart in the poisoned dog, and the consequent failure of the supposed flow of blood from this to the other dog.

I may here observe that a similar experiment is mentioned in Birch's History of the Royal Society, and by Bichât, in his work, Sur la Vie et la Mort, (ed. 3, Paris, 1805, p. 227).

(*See p.* 66—.)

It is remarkable that some of the actions formerly termed *sympathetic*, are *only* induced through incident nerves, such as *sneezing;* others have not only a centripetal, but a central origin, as *vomiting*, which is equally induced by irritation of the fauces, disease within the head, and emetic tartar injected into the blood; a third are induced by an action on the central organ of the nervous system exclusively, as *gasping*.

Experiment. (*See p.* 68.)

I have succeeded, by removing, or rather destroying, the spinal marrow, by small portions at distant intervals, in retaining the circulation after the total destruction of the central organs of the nervous system in the frog. In such a case, we may observe the effect of agents acting *physically*, and by *absorption*, on the ganglionic system, and the viscera, exclusively.

Remedies. (*See p.* 70.)

Doubtless our remedies act on the same principles as poisons. The douche of cold water on the face excites inspiration; and the same remedy applied to the hypogastric region, induces contraction of the uterus and restrains uterine hæmorrhagy, on the same principle of a physical action through incident nerves. Other remedies are absorbed and act through the vascular system, as the secale cornutum.

It will be readily admitted that there is ample scope, in the subjects which have been so rapidly sketched, for much further investigation; and I trust it has been clearly shewn that such an investigation would have an immediate application to *practice*.

FINIS.

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EXPLANATION

OF THE

PLATES.

EXPLANATION OF PLATE II.

This plate portrays the disease described pp. 49— .

Figure 1 shews the diseased *aortic* valve.

Figure 2, the apoplexied condition of the *lungs*.

Figure 3, the congested condition of the *liver;* and

Figure 4, the congested and hæmorrhagic state of the *intestine*.

Figure 5 represents the *one* entire circulation of the blood in mammalia, effected by means of the pulmonic and systemic hearts.

Fig. 1

Fig. 2.

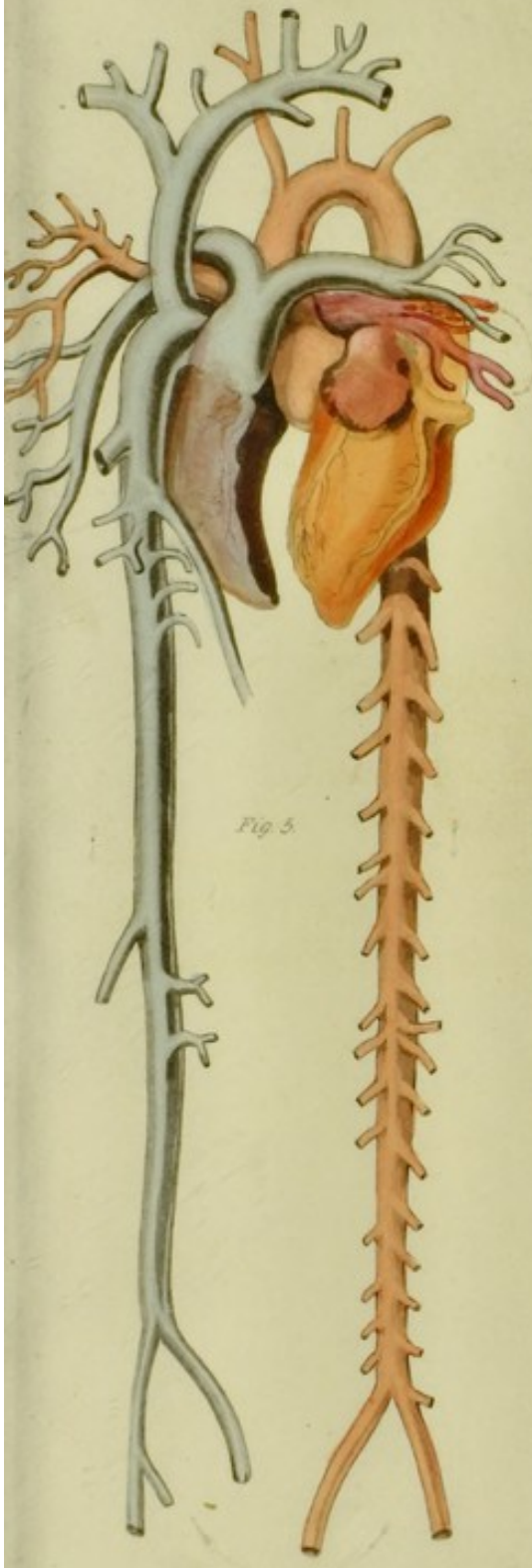


Fig. 3.

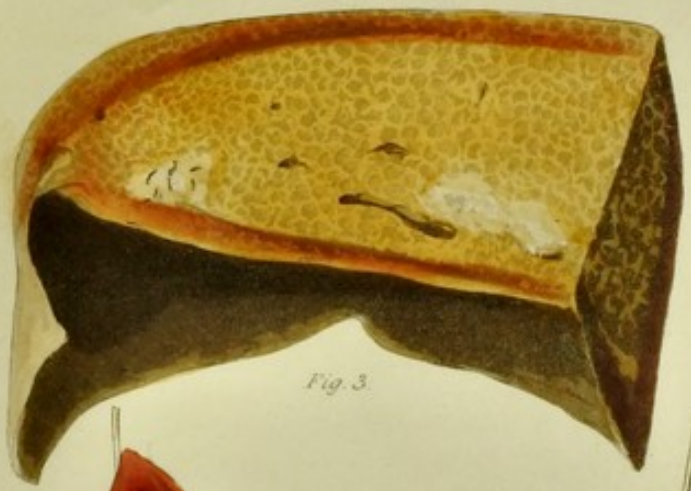
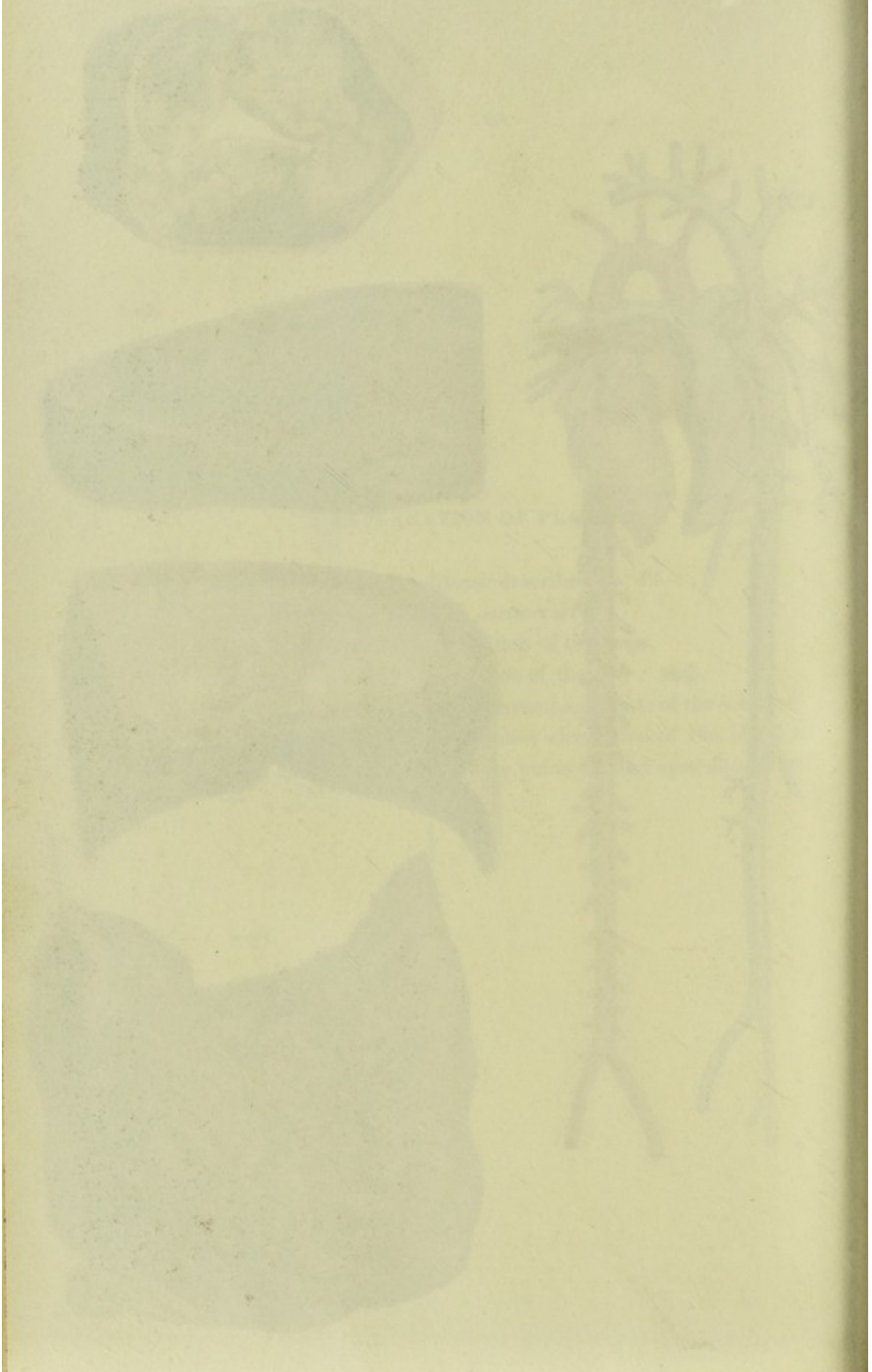


Fig. 3.

Fig. 4.



EXPLANATION OF PLATE III.

Figures 1 and 2 represent the upper and under layer of capillaries respectively, with their circulation arrested by the external application of alcohol.

Figure 3 shews the contiguous distribution of the *arteries* and *nerves* in the *cutaneous* tissue of the frog.

Figure 4 portrays the similar contiguous distribution of the *arteries* and *nerves* in the *muscular* tissue of the same animal.

Fig. 1.

Fig. 2.

Fig. 3.

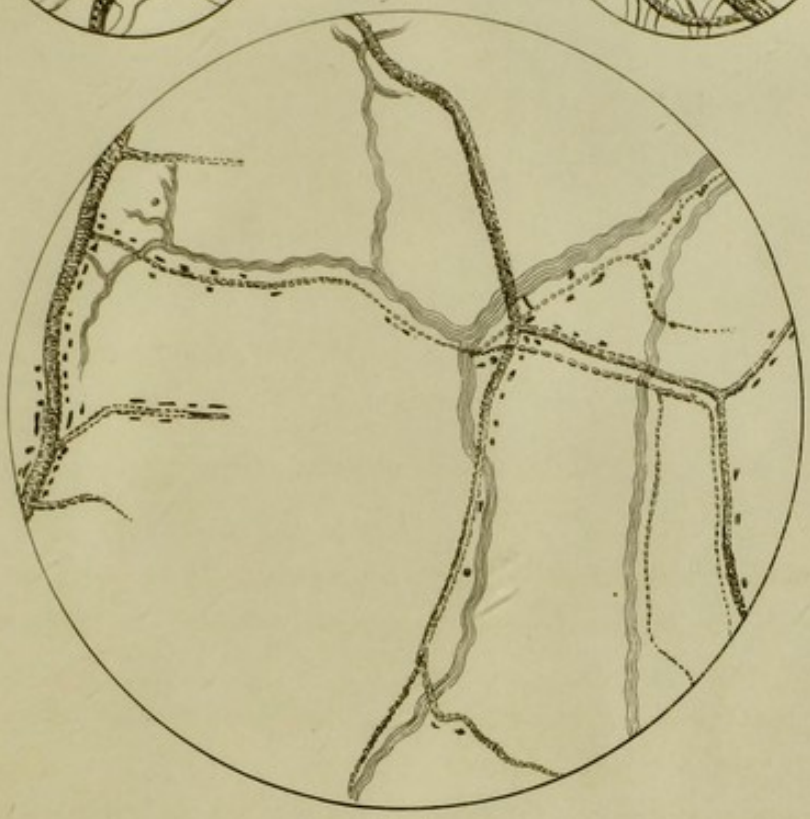


Fig. 4.