Inaugural Dissertation

on

The Physiology of Death

embracing
an Enquiry into the Vital Functions, and
the Laws which regulate their mutual dependence

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Introduction

The changes and phenomena which fall to be considered under the name of Physical Death are to be looked upon as affecting the body and certain of the functions pertaining to it; and, accordingly, the various forms of being, material and immaterial, come within the scope of this inquiry, only in so far as they are connected with the changes of organized and living matter. Thus we exclude on the one hand, all speculation as to the existence and properties of Spirit apart from its manifestations; and on the other, the consideration of changes in the organism itself after its functions have been annihilated. It is necessary to lay down this limitation from the beginning, in order to avoid inconsistency: but its conditions and consequences will be entered into more fully in the sequel

Certain circumstances in the nature of the subject appear to render this limitation peculiarly desirable; for it is natural to suppose

as indeed we find to be the case, that a topic of such high and universal interest should have been examined from all possible points of view, and with the most various special objects, by persons not principally or even at all concerned with the physiological questions implicated in it. Hence it becomes necessary to separate those parts of the subject which come within the limits of the present inquiry, and which bear upon the purely scientific question of the physiological nature of death, from other departments of it, whose individual interest and importance are nevertheless not easily over-rated. In order to make accurately this separation, and further, to present a connected account of the different aspects under which the subject of death has been viewed by the human intellect, the following remarks may not be out of place:

1st. The essential nature or cause of the phenomena which accompany physical death, and more particularly the description and classification of these phenomena as seen under different circumstances have received much attention. The extreme importance of

this subject as a branch of the study of diseases, and also in relation to obscure cases of homicide and suicide appears to have drawn attention to it in the first instance; but it first acquired an independent scientific interest in the hands of Bichat, who, as will afterwards be seen, by throwing aside all particular applications of the inquiry, and confining to view his knowledge respecting death from the simplest and most illustrative cases, succeeded in effecting a generalization of the greatest importance in science, and thus gave a new impulse to questions of the highest interest in many departments of human knowledge.

2d The nature of the psychological changes occurring in connection with physical death has been the subject of much earnest investigation in relation to theology, and is, moreover, of vital importance on purely metaphysical and ethical grounds.

3d The consideration of the chemical and other changes occurring in the body after death, through which it resumes the characters of unorganized matter, has devised

interest chiefly from its connection with various important inquiries in Medical Jurisprudence.

As the first point of view is the one which I wish to follow out on the present occasion it will be admitted that all partial objects must be set aside; and by considering the question in the light of a general scientific inquiry, not devoted to ends of special and immediate utility, but resting on the basis of its own inherent interest, it will become of a much less complicated nature, and probably afford much more satisfactory results than by any other method. Moreover the psychological and medico-legal aspects of the subject are manifestly only incidentally connected with that to which this essay is devoted; and if it shall be considered that I have too rigidly excluded these and other collateral themes, I can but answer that I believe this is the only way in which the obscurity and confusion, generally considered as attaching to elementary questions in medical science, can ever be removed.

The death of the body is therefore to be considered apart from all extraneous subjects.

But as soon as we begin to grasp the idea of death in an abstract and isolated form, we find it inseparably associated with the prior conception of life. The death of the body cannot be conceived of otherwise than as the destruction of certain pre-existing conditions. The entire and primary absence of these conditions gives merely the idea of inanimate matter; it is necessary to suppose them to have been present in order to have the idea of their removal. Without establishing, therefore, the conditions of life, we can obtain no adequate conception of the facts and phenomena which essentially constitute death.

This remark opens up a very wide field of inquiry, and one which lies at the very threshold of all physiological science. But it is to be observed that it is only the essential phenomena of life which have to be determined; with the absolute nature and detailed working of its laws we have little or nothing to do; and these we may advantageously leave to be separate subjects of inquiry, except in so far as the investigation of them may be incidentally necessary. By thus

ascertaining, in the first instance, the essential facts on which the inquiry is based, we shall be enabled to pass, from a clear and definite point of view, to a consideration of the rest of the subject

The method which I propose to myself, in these pages, is therefore the following; first, to consider the conditions which taken together constitute life; secondly, to regard death as consisting in the cessation or removal of these conditions; and, lastly, to investigate the mode in which this change is accomplished.

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Chapter I

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It is proposed, in this chapter, to consider in general, what are the phenomena which appear to be essentially included in the idea of Life, with a view to the subsequent investigation of the suspension of these phenomena in Death.

In the outset of the inquiry it is proper to observe, that the term Life, as applied to organized beings, has been recognized, both popu-

lerly and philosophically, in two very different
significations; first as applied to a state or
condition of the organism in connexion with
which certain phenomena are manifested;
and, secondly, in the sense of the aggregate of
these phenomena themselves, or rather, perhaps,
the act of their manifestation. It is not dif-
ficult to see that this double employment
of the term has arisen from the indissoluble
connexion which exists in the mind between
the idea of life in the abstract, and the phe-
nomena by which it is manifested; a connex-
ion which is perhaps on the whole best under-
stood, by considering the term Life as merely
the expression of a number of particular
facts or phenomena, which have, however, this
mutual relation that they are observed in con-
nexion with an individual organism. The idea
of Life is, therefore, in its origin, extremely
complex, being deduced from a consideration
of the entire phenomena of the existence of
organized bodies; and it only becomes a sim-
ple idea in virtue of the generalization by
which the whole of these phenomena are
classed together under a single term.

If it be now inquired upon what principle this generalisation is effected, it must frankly be admitted that we are led directly to a question at once the most important, and the most controverted in physiological science. But although a solution of this question, in some form or other, must form the basis of every rational system of physiology, I do not consider it to be necessary or advisable to enter into it here; because I conceive that the very general use, in all ages, and by all classes of reasoners, of terms corresponding to those of Life, Vitality, &c., justifies the supposition that there is some common ground on which all may join in the use of these terms in the prosecution of an inquiry like the present, without the necessity of previously discussing the question whether, as some suppose, the peculiar properties and phenomena of organized bodies are due merely to the circumstance of organization; or whether both organization and its phenomena involve the existence of certain laws peculiar to this form of being.

In carrying out this plan, however, it is to be observed, that we have to deal, not with

the intimate nature, but with the external phenomena of Life; and the main question which we have to settle is which of these phenomena are to be considered as essential, and, in particular, with which of them is the permanence of the organism especially connected? In order to treat of this question, it will be necessary to enter into some details as to these phenomena, and more particularly as to the facts of their mutual dependence

Further, it is important to observe that all the phenomena which we are accustomed to observe as peculiar to organized bodies are the results of changes or actions occurring in the organism, for the production of which it is fitted in virtue of its mechanical and other endowments: and that in so far as we can ascertain the elements of these changes, they are conveniently designated by the term <u>function</u> A description of the functions of the living body therefore, will necessarily, if complete, include the description of all its phenomena. For the same reason the persistence of function may be taken as the test of life; for as long as any of the changes to which the organism is ad-

apted are produced so long will the phenomena which are characteristic of life be witnessed.

These things being premised I shall proceed to lay down the following three propositions, which will form the basis of the test of the chapter:

1st The phenomena and changes peculiar to organised matter are capable of being recognized and defined, and are extremely different, in many respects, from the phenomena of unorganised matter, as well as from the changes which tend to the destruction of the organism:

2d. A degree of harmony and mutual relation of the functions or changes of living bodies is observable in the normal state:

3d. A careful consideration of the functions shows that they are to a certain degree dependant upon each other, and also that the persistence of the organism itself is essentially dependent, in consequence of known laws, on the integrity of certain of its functions.

It has been already stated that life is essentially connected with the manifestation of phenomena, and therefore with the performance of the functions which are peculiar to the organism; and that therefore the investigation of

the mutual relations of these functions, and the degree of their mutual dependence, forms the principal object of inquiry in relation to this subject. In pursuance of this object it is necessary in the first place to consider these functions individually as developed in the different classes of organized beings; and afterwards to arrange, with reference to our subject, the entire sum of the functions in the most complex class of organisms. The advantage of this arrangement will be clear when it is pointed out how much confusion has resulted from the older methods in which the functions of Man have been systematized without reference to these simpler forms of being from which the best and clearest ideas may be derived

Proceeding therefore from the simpler elements to the more complex. the inquiry presents itself what remarkable phenomena are presented by living bodies in general as distinguishing them from unorganized matter? For the solution of this question it will be necessary to review shortly the mode of existence of the latter. We may remark especially the following facts:

Organized masses come into existence and

increase in virtue of the mere juxta-position of their constituents by the mechanical aggregation and chemical combination of these. The mass is capable of being changed indefinitely by the accession of new matter, and the result is dependant on the nature of the external addition But such changes are by no means necessary to the existence and permanence of the mass already formed: on the contrary, the forces which brought it into existence in its present form tend to preserve it in that form for an indefinite period, were it not for the influence of accidental external causes of change in the operation of which the mass itself is entirely passive.

The only specific tendency which is observed in the aggregation of unorganized matter is that upon which is founded the beautiful law of Crystallization. This law, which determines particular kinds of unorganized matter to assume a definite form in the process of aggregation of its particles, may be considered as the highest law of the being of such forms of matter. For the form thus attained is susceptible of no further development or change; it is perfect in

itself from the first, and has no adaptation to any further purpose. It is not fitted for the performance of function. The subsequent growth if any is merely a repetition of the same formative process, and the permanence of the body is not due to any power within itself but merely to the absence of all destructive agencies external to it. The difference in these respects between the phenomena of Crystallization and those of Organization we shall presently consider.

Further, as a consequence of the law already stated that the changes occurring in an unorganized mass are accidental and not necessary to the permanence of its form and qualities, it follows that the destruction of such bodies must also be due to accidental causes; and that therefore their existence can have no definite or normal termination. Thus we see that inorganic bodies are subject to the following conditions; they are formed and increased by aggregation of matter from accidental juxta-position; they are subject to accidental change which does not in any respect add to their perfection; they are incapable of

progressive development and their existence is not subject to a normal course and termination; lastly, the highest law of their being is the attainment of definite form, a form invariably simple, not composed of dissimilar and mutually dependent parts and above all not subservient to the performance of function

If we review now the most general and universally diffused phenomena of organized ~~beings~~ bodies, we shall find that the laws of the manifestation of these phenomena present a most remarkable contrast to those just enumerated as characteristic of unorganized matter. Thus we find organized beings subject to the following conditions

1st The law of the first formation of the organism is peculiar and characteristic in this respect, that it appears in all instances, which are well understood, to demand the existence of a parent being, from which the new organism is developed according to a uniform type of structure. This law may be said with certainty to include the vast majority of cases in which the primary origin of the organism has been made the subject of careful investigation, and among the rest, all

those cases of fissiparous and gemmiparous generation which are known to exist in the lower animals and in plants. It may therefore be pronounced from analogy, that many of the instances in which the mode of generation has not been brought directly under observation are still to be referred to the same law; the process, as a considerable number of the cases, to explain which the theory of spontaneous or equivocal generation was proposed, have been satisfactorily accounted for by more recent observers, particularly by Redi in the 17th Century Needham in the 18th and Ehrenberg more lately. The universality of parental generation is opposed in the present day only by negative evidence; and whatever modification of our ideas on the subject future discovery may require, there seems no reason to suppose that we shall ever be deprived of the means of establishing a very uniform law of origin for the whole range of organized being

2d. The mode of development of the organism is distinctive. When the crystal acquires form, its development is complete; no future addition of substance can add to its perfection. The organism, on the contrary, has a definite form from the beginning, when it lies within the body of the parent,

a simple unchanged cell; but so soon as the fructifying influence has reached it, a change begins, the result of which is its gradual development, that is, its acquisition of a compound structure and approximation to the perfect type of its race; and this development is not the result of forces acting on it from without, but of powers, which we must conceive of as innate, inasmuch as they are exercised without reference to the surrounding structures of the mother. Thus its changes are not arbitrary and accidental, but are necessary to its existence, and follow a normal course, and the result is a ~~expand~~ compound organization, adapted to the great distinctive character of living beings, the performance of function, and composed of many dissimilar parts acting harmoniously for the preservation of the whole.

3d. The mode of existence of the inorganic body is, as we have stated, quite passive - its preservation is not provided for, and the preserving and destroying powers of Nature act on it indifferently. With the organism it is different. The law of change, which is one of the conditions of its existence, is made subservient to its preservation. The exercise of function begins early; so soon as impregnation

has taken place, the germinal vesicle begins to assimilate nourishment from the surrounding parts; it swells, bursts its investment, and is carried down the Fallopian tube into the uterus, where it becomes connected with the parent again by means of the chorion, and where a circulation and placental respiration afterwards replace the former simple mode of nourishment. But in some of the lowest grades both of animals and vegetables, as in the Protococcus and Monas and Volvox on the one hand, and the Protococcus on the other, there is never any material advance beyond the most rudimentary form of structure. Accordingly the simple cellular nutrition remains throughout their existence; and although in these organisms there is so complexity of structure to distinguish them from inorganic substances, they are marked out as belonging to the living kingdoms of Nature, by their exercise of function. Thus we see that the assimilation of nourishment, and the constant renewing of material, constitute one of the most invariable and necessary concomitants of life.

4th Again, the mode of disappearance and decay of the organism is widely different from that of inorganic matter. The powers which compose the

crystal continue ever in action: their activity has no natural limit and cannot be observed to be subject to variation; they resist the decomposition of the body so long as they are not opposed by extraneous powers stronger than themselves; but, whenever these come into action, the destruction of the crystal begins and proceeds. In the organized system, on the other hand, we have manifestly a normal period of existence; the powers which called it into being are subject to weaker or stronger action; they are at last subject to decay and annihilation; and in all classes of such beings, especially the simpler kinds, and in these with great uniformity, we can observe and establish a rule or law of decay, just as we can observe a normal origin and development. If the best illustrations of this law are to be found in the simpler organisms, it is because the conditions of their existence, being less complex, are also less apt to be interfered with by deleterious principles without; which in the higher classes are very apt to introduce irregularity into an order otherwise most definite and uniform.* The decay and death

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* The most general fact that we can ascertain in regard to the law of decay, is, that in all organisms it seems to have some unexplained connexion with the reproductive power. So

of the organism is therefore a necessary law of organization which acts in a perfectly definite manner except where its operation is superseded by other destructive agencies acting accidentally on the organism from without

As a general conclusion it may be stated, – that organized bodies are possessed of definite form and structure, simple, or composed of dissimilar parts; that the type of their structure bears a definite relation to that of a parent organism, with whose prior exist-

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ence as the animal or vegetable has the power of performing the functions of reproduction, its other functions retain their vigour; but so soon as these disappear, the general decay is established; changes in nutrition follow, and thus the whole of the functions become impeded. In the simplest forms of being, however, the connexion is much more intimate; for, in those composed of a single cell, the reproductive function is only performed at the expense of the parent. Many vegetables and animals are only capable of one act of reproduction: and it is well known that, by a timely removal of the flower-buds, the lives of many vegetables may be prolonged beyond their natural term of existence

once they are essentially connected; that its parts are related to each other by functional changes which have a mutual adaptation and by which the life of the organism is manifested and its structure maintained; that the termination of its existence is evidenced by the total cessation of function*; and lastly, that it is subject to this termination or death, not as an accidental result of foreign interference, but as one of its own unalterable laws

From the above a general view of the conditions of organized existence, and of its relation to the continual exercise of function, it will be now sufficiently evident, that, in all our inquiries into the subject of death, we must make these

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* It should, however, be stated that in the case of vegetables there is a period of embryonic development in which the organism is capable of existing a long time without change or further progress, while it still retains the power of going through the normal course of its existence at any future period. This period of repose in the seed at the commencement of the separate existence of the vegetable has no analogue in the animal kingdom; and with this exception the law, that functional change is necessary to the persistence of vitality, is invariable.

functions the basis of our investigation, considering them as the test or criterion of the possessed of life. The classification of the functions, accordingly, with a view to the observation of their mutual harmony and dependence, demands attention before closing the present chapter.

The functions of all organisms concern in part the individual, in part the species. The necessity of both of these orders of function has been sufficiently explained. The assimilation of new matter, and maintenance of structure demand, as already pointed out, the constant exercise of the former class of functions; while the law of origin which prevails throughout living nature requires that every individual in turn shall become possessed of the power of performing a part in the reproduction of the species. But the exercise of this latter class of functions is no way necessary to the well-being or life of the individual; on the contrary, the functions belonging to this class are only capable of being exercised at intervals; they act only during a certain period in the life of the organism, and are capable of being entirely removed without detriment to the rest of the system. The connexion,

therefore, between the reproductive system and the rest of the functions, and, as a consequence, the relation of this system to life, is one of a very distant and accidental nature; and we are accordingly justified in laying aside the consideration of it as having no direct bearing on the present subject. In what follows, it is accordingly proposed to treat almost exclusively of the functions relating to the individual.

The most universally distributed and the most indispensable class of all the functions relating to the individual is that one whose especial office is the maintenance of structure. This class of functions is most intimately connected with life; inasmuch as the action of all others depends on the integrity of the structures assigned to them. The development and growth of the organism is intimately dependant upon their perfect action, and the failure of that action is the cause of the final decay. The consideration of them, therefore, is highly necessary in reference to death

These functions were distinguished and described by Bichat; and, in consequence of their relation to the organism, which they preserve and

maintain, were appropriately designated by him the Organic functions. From their very nature it follows that they belong to all organized beings; but they have been made an important instrument of classification in natural history, from the circumstance that of all the functions relating to the individual some organisms exercise only the organic functions, while others possess in addition a class of powers not primarily connected with the preservation of structure, although exercising a certain influence over the organic processes. These latter functions, or powers, being in their nature quite distinct from the former and resulting in acts quite peculiar to the organisms thus endowed, have been called for want of a better or more expressive term, the Animal Functions. The distinction between animal and vegetable, founded on the possession or non-possession of this latter class of functions, will now be apparent. In passing this distinction we may remark that in the vegetable in which all the functions are directed to the preservation, either of the individual organic structure, or of the species, these functions are called into action whenever the organism comes into its normal relations with the

external world; and that as these functions constitute the whole life of the organism, their action is unmodified by any other powers whatsoever. Thus the absorbents in the plant perform their function, subject only to the condition that the roots be in contact with an appropriate soil; again the opening and closing of the flowers, the exhalations of the leaves, and the rising of sap in the stem, take place according to the presence or absence of the external stimuli with which those actions are connected. In the animal, on the contrary, although these external stimuli are equally necessary, and although they are the invariable excitors of the organic forces, yet these forces are in all instances liable to modification and control from the functions to which the name of <u>Animal</u> has been given. These latter functions, in virtue of the special gratification of receiving and transmitting impressions, become the regulators of the organic functions, and occasional excitors and controllers of their action: and thus the animal functions, although unquestionably not essential to the idea of an organism, become, <u>in the animal</u>, quite necessary to life; a condition important to be kept

in view in reference to subsequent inquiries. For this reason the animal functions might aptly be called central, communicating, or regulating.

Here it is worth while to state clearly, that, in this view of the functions, the strictly mental acts are not included; and this for the reason, that they are conceived to be embraced in a totally different category from all the actions of which we have been treating. The detailed proof of the correctness of this view requires the investigation of a species of evidence of a peculiar kind not admissible in physical science, and the argument founded on this evidence is therefore not entered upon at present. The best idea of the connexion between the mental powers and the bodily functions implied in this method of classification may be obtained by considering the organism as the instrument whereby the mutual transmission of impressions between mind and mind, or (according to another metaphysical hypothesis) the action and re-action of mind and matter on each other, is accomplished. To the establishment of this intercommunication the animal functions are subservient; and all

the special manifestations of these functions in the organism (apart from their influence on the organic functions) are directed by this subserviency to the purposes of mind. But the results of mental action, on the contrary are related only to mind itself and have no necessary connexion whatever with the demands of the organism ;. so that, without pursuing the metaphysical argument, it may be asserted, that, on physiological grounds alone, it is proper in an inquiry like the present, to separate the consideration of mind from that of the bodily functions, except in so far as the former may accidentally re-act upon the latter. To make the justice of this separation more plain, we may refer to the case of the temporary abolition of mental action under the influence of narcotics, in which case it is well ascertained that so long as the mind only is affected the bodily functions are not at all implicated, and will be as well performed, (if subjected to the necessary conditions) as when the mind is entire; or we may advert to the more permanent, although not so complete destruction of the mental faculties in some of the most abject cases of dementia, as

a proof that the vigour of the body is by no means commensurate with the state of perfection of the mental faculties, or even of sensation and volition. The bearing of this argument upon the question of death is evident, and leads to the conclusion, that, except in the case where mental phenomena are taken as the index of the persistence of the bodily functions, or where these functions are interfered with by mental operations, the question of physical death does not involve the consideration of psychological questions at all. In fact, according to the case just supposed, as to the connexion of mind with organization, the disappearance of mental manifestations at the moment of death is only one in the chain of phenomena resulting from the incapacity of the body to perform its functions; and with respect to the mind, it is clear that, the instrument being destroyed, the power which presided over it must either remain inactive, or act in another direction.

We now proceed to the analysis of the two great classes of functions above adverted to.

§ I Organic functions (Bichat) Nutritive functions (Cuvier) Functions of vegetative life.

In pursuing the history of these functions it is advisable to carry back our ideas to the simplest forms of organized structure, in order that the most essential and least complicated varieties of function may be brought first under our notice; and as the class now under consideration has for object the constant renewal of the structures of the organism, it is natural to expect that all the actions belonging to this class shall be subservient to the actual process by which this molecular change is effected; in other words, that they shall be a series of nutritive processes, involving a more or less complex mechanism according to the nature of the organism.

The most essential act of nutrition, in the case of the simplest animals and vegetables, is found to be two-fold, and to consist - 1st. of the selection and appropriation, by the organism, of a portion of the fluids external to it, and of the solid matters dissolved in those fluids; and 2d. of the contemporaneous rejection and extrusion of the effete matters, or those which have played their part in the composition of the organism. For the accomplishment of these two most necessary

conditions, it is obviously required, that the external nourishing fluid shall come closely in contact with every part of the tissues on which it is to act. This is easily accomplished in those simple monads which have been formerly referred to (p.17.) in which the whole organization is a single minute cell, in immediate connexion with the fluid from which its nourishment is derived; the transudation of the external wall of the cell being all that is necessary, in order to secure that the materials of organization shall permeate every part of the organism. Nearly equal in simplicity is the function in some more complex structures, as in the sponges and algae, where the mode of organization permits of the access of external fluids to every part of the tissues by the ordinary laws of capillary attraction; the solids composing them being highly porous, and the supply of fluids to the free surfaces sufficiently ample. Thus the simple cellular nutrition, apart from any other processes whatever, serves for the maintenance of structure in many of the lower classes of beings.

But in by far the larger share of vegetables as well as animals, the contact of the nutritive fluids with the textures to be acted on is accomplished by a different process; viz by the motion of the fluids in regularly formed vessels which convey them to every part of the body, and place them directly in connexion with the textures. The function of Circulation, as thus defined, is highly necessary to the immediate act of nutrition, in all those more complex organisms whose mode of organization does not admit of the porous structure essential to simple cellular nutrition, or to which that structure would be of no use, from their destined existence not permitting a sufficiently extensive contact of fluids with their surface. But the two ultimate processes of nutrition already pointed out remain unaffected by this superadded function; except that the necessary elements of structure are withdrawn, not from the accidental fluids external to the body, but from this internal reservoir of nutritive fluid; and that the products of the decomposition of the tissues are thrown into the same reservoir, either directly, or, as occurs in many animals, but not in plants, partly through the agency of another

set of vessels, the lymphatics, whose special uses, in the economy, cannot, however be considered as well understood.

The existence, in any organism, of this mode of nutrition (by a fluid circulating within vessels) demands, further, two other conditions; firstly, that the effete matters which are derived from the decomposition of the tissues be expelled from the circulation; and, secondly, that the waste thus caused in the nutritive fluid be constantly replenished, according to fixed principles of selection, from without. From these conditions arises the obvious necessity for two other classes of functions, which are accordingly found invariably to accompany a circulation, throughout the kingdoms of living natures: on the one hand the functions of elimination, comprehending Secretion and Excretion; on the other those of Assimilation, which include Absorption, and in the higher animals Digestion and the accessory processes. It is not necessary to describe these processes in detail; the object of their mention at present is merely to place in a clear point of view their relation to the other organic functions, and especially to

the ultimate function of nutrition. And here a remark of some importance presents itself; that while it is true on the one hand that the function of circulation cannot be interrupted for a moment, in those organisms in which it exists, without the nutrition of the textures being similarly affected, the two orders of function last mentioned may be and frequently are subjected to temporary intermissions without any such result to the nutritive process, which continues to be kept up independently of them for a time. This observation is important, not only in reference to the present essay, but as showing the physiological basis for the distinction, so much insisted on by the older physiologists, between the Vital and Natural Functions; which, in their hands, led to so much confusion and laxity of expression, and also to so much doubt and difficulty of arrangement, that Bichat was induced, with much propriety, to avoid making this distinction a ground for a scientific arrangement. But the consideration of this subject belongs more properly to the next Chapter.

In regard to the functions thus <u>immediately</u>

subservient to the purposes of nutrition, it only remains further to be observed, that all the processes by which the materials of organization are prepared and afterwards removed from the blood, have been very much elucidated of late years by the very beautiful investigations of Müller, Schwann, Henle, and Sodsir: the general result of which seems to be, that secretion, absorption, and nutrition, to which may be added growth and development (whether of the individual texture, or originally of the ovum itself) are processes essentially similar, and only differing in accessory circumstances; and that their fundamental analogy may be expressed by saying that they are all modifications of the development of a single structure, viz the simple primary cell, which has been shewn by Schwann and others to be the basis of all organized tissues. This simple but very remarkable generalization has led, and will probably still lead, to the recognition of much less complex laws of these various organic processes than had before been guessed at. It is not my intention to attempt to indicate these laws; but considerations connected with subjects afterwards to be treated of,

demand the notice of one circumstance, which is both very important in itself, and may be considered as a very legitimate result of the latest observations on this subject; viz, that the power, or powers, concerned in the transformations of the simple cell, as exemplified in the processes of nutrition, secretion, &c, are not communicated to it from any other tissue, and certainly not the result of nervous action; but are properly to be regarded as of the nature of *vires insitæ*, that is, acting independently within the tissues where their effects are manifested, and confined to them.

Before leaving the subject of the organic processes, two other functions require notice, and have, I think, an equal claim to be included in the list of the organic functions, because, although not directly concerned in the repair of the tissues, they subserve important purposes in the organism closely connected with Nutrition. The first of these is Respiration, which, in its widest sense, includes all the merely chemical changes which ensue from the exposure of the nutritive fluid within

the body to the influence either of the gases of the atmosphere or of some fluid which acts the part of conveying the necessary gas, in the state of solution, to the fluids within the organism. The changes here indicated are properly defined as chemical, because they go on when the nutritive fluid is exposed to the air under other circumstances, and out of the body

The end of Respiration, in relation to the organic processes, has been the subject of much discussion; and perhaps no explanation of it has yet been offered, at all corresponding to the idea of its importance derived from the consideration of the universality of its occurrence in the Animal and vegetable Kingdoms. But whatever be the law of organized existence which determines the necessity of this communication between the nutritive fluid and the atmosphere, it is certain that the important part played by the respiratory process in regard to two of the principal elements of the living tissues, oxygen and carbon, entitles it to be considered as most especially and essentially an organic process connected, at least in animals, with the excretion

of the carbon of the organism, of which it is by far the most important eliminator.* Further, the recent researches of Liebig seem to establish the fact that the function of respiration in plants performs a part precisely opposite to that assigned to it in animals; that whereas in the latter the diffusion of oxygen through the blood, and the removal of carbon in the form of carbonic acid, constitute its office, in the former that office consists in imparting to the tissues the necessary carbon and removing the superfluous oxygen. If this be admitted it is clear that the combined action of these antagonist processes must be the establishment of a cycle of chemical changes, through the intervention of the atmosphere, between the two great kingdoms of organized nature; that plants give to animals as food, an element which these excrete by the respiratory process in the form of carbonic

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* Berzelius, Liebig, and others have proved that the liver, which was formerly considered to have a somewhat similar office, eliminates, in the normal state, very little carbon; and that the quantity of bile destined for the excretion is much less than was formerly supposed.

acid, and which by the respiratory process of vegetables is again taken into their system to form the basis of their structure. And if it be also recollected that carbon is, of all the four essential elements of organized tissue the only one which is naturally both fixed and insoluble, and that therefore it could only be equally diffused by being cast into the atmosphere in the form of carbonic acid, it will become plain, that, in this point of view, if in no other the end of the respiratory process in the economy of nature is one equally vast and important. Accordingly we find this function to be at least coextensive with circulation, if not even more widely ~~diffused~~ prevalent; and related to it by a connexion so close, as to have obtained for it, among the older physiologists, a place among the vital functions, or those which "ne quidem per exiguum tempus suspendi aut interrumpi queant." The nature of this dependence of the functions on respiration, is reserved, however for a future chapter.

The only other function which remains to be noticed in connexion with the organic functions is one, which in systems of Physio-

logy has generally been accorded a different place - the function of Motion. I do not stop to consider the question how many sources of motion may be admitted in organized bodies; it is sufficient to state in general the grounds on which I conceive the motive powers to belong strictly to the organic series They are as follows;

1st It is known that motive powers exist in all organisms; and that even vital contractility the one most especially connected with the ends of animal existence, is not peculiar to the animal kingdom;

2d Motion whether existing in animals or vegetables is invariably subservient to most important ends in connexion with the nutritive processes; and its connexion with these processes is necessary ~~and~~ absolute and inseparable from the very nature of the processes in question;

3d The motive power, even in animals, is exactly on a par with others already adverted to, in respect that it is of the nature of a vis insita, originating in the textures where its effects are produced, and

therefore not immediately dependent on the nervous system, which, as will be seen in what follows is the seat and centre of the animal powers. This fact of independence, which, as far as concerns muscular irritability, was maintained by Haller*, and demonstrated by Bowman† is a general property of contractile textures, and by no means confined to a particular class of these or to an individual muscle; and the only real difference between the muscles of the animal and organic systems therefore lies in the different mode and extent of their subjection to the accidental nervous stimulus. Accordingly, the distinction between voluntary and involuntary animal and organic muscles, although exceedingly convenient for many purposes, does not necessarily imply, according to this view, any corresponding difference in the laws of vital contractility, but only differences in the circumstances under which these laws act, and in the nature of the stimulus acting upon them

On these three grounds, as well as on considerations which will present themselves when

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* Elementa Physiolog. Lib XI Sect II, 11 † Philos. Transact. 1840

we consider the animal functions, I incline to arrange the motive powers in the organic series. It is not to be supposed, however, that in so doing I overlook the great distinction between animals and vegetables as to the character of their motions; a distinction which will be again referred to before closing this chapter

In regard to the organic functions in general there is only one remark further to be made, that several of them, especially secretion and motion, are made subservient to various purposes in particular organisms not in any way connected with life. Instances of this are found in all special secretions, and in the ordinary phenomena of locomotion in animals, and the curious instances of irritability in the Mimosa and other vegetables. With the mere mention of these instances, which of course have no connexion with the subject of this essay, we may now pass on to the animal functions

§ II Animal Functions (Bichat) functions of centralization and communication Nervous Functions

It is proposed to include under this head

all those functions whose office in regard to the organism consists essentially in the transmission of impressions between remote parts; and which therefore demand consideration, not only in themselves, but also in reference to the way in which they modify the action and effective performance of those functions already considered.

The idea attached by Bichat to the term Animal functions was somewhat different from this. He considered these functions as endowed with the office of bringing the organism into relation with the external world; or rather, (as this description would apply equally to the organic powers) he regarded the animal functions as those by which the consciousness of the organism was enabled to act upon and receive impressions from the world without.* In this point of view sensation and voluntary motion of course held the most prominent place among these functions, which were thus assumed to be essentially connected with the presence of mind and consciousness; and although

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* Bichat Anatomie Generale Introduction VIII

this assumption has repeatedly been made since it manifestly does not correspond with the discoveries of a more modern physiology, in which it is shewn that almost all the acts characteristic of the animal life are capable of being excited independently of either consciousness or volition. Something like a foreshadowing of this conclusion is indeed to be observed in Bichat's division of the sensibility into animal and organic; but the discovery of the reflex function of the spinal cord renders it certain, that although the mind, in its connexion with the organism, undoubtedly acts by and through the animal functions, yet it cannot be considered as constituting a part of these, much less as giving them their distinguishing character; and that therefore, although the animal functions subserve important ends in connexion with mind, yet, as this is not their invariable law of action, it is necessary to distinguish them apart altogether from this connexion. This conclusion corresponds very closely with the view given in a former part of this chapter from other considerations of the relation of mind to the organism.

Proceeding, therefore, upon the view, that the

most essential part of the animal functions is that indicated above viz the transmission of impressions between remote parts, and confining for the most part, our view to the higher animals in which these functions are best understood, we may observe the following conditions

1 The communication of one part of the organism with another may be accomplished by means of the direct transmission of impressions from the part where these are excited by an external stimulus, to that on which they act, thus constituting the phenomenon called sympathy; the peculiarity of which is that the communication thus established between the individual parts exists in every instance in virtue of a special law of transmission, altogether unconnected with any other similar acts or with any general function of the organism. Such a power of nervous sympathy was much insisted on by the older physiologists, who saw no other way of explaining the connexion observed to exist between distant organs; and the sympathies of the stomach with the pharynx, of the respiratory organs with irritation of the glottis, and

of the external with the internal urinary organs, with many other phenomena which were matters of daily observation, were explained entirely upon this theory. But modern science has shewn that the greater part of these supposed isolated facts are to be referred to a general law of the utmost importance in the animal economy, and that the direct or sympathetical transmission of nervous influence is an inadmissible hypothesis as regards most, if not all of the facts which it was brought forward to explain

2 By far the most important law, accordingly, which regulates the communication of impressions from part to part, is not that of direct or sympathetic transmission, but the law of centralization of impressions. The most essential fact on which this law is founded is the existence, in the organism, of one or more centres of transmission, which collect and combine the impressions from various parts, and transmit them according to fixed laws either separately or in the form of associated and combined actions to the structures on which they are destined to act. The order of action

is therefore as follows; the impressions originated by external stimulus are conveyed to the centres of transmission, where they are reflected towards the tissues to which they are directed, and in this texture are manifested, according to the function of the part in the form of a stimulus again. Thus it is well known that in an animal dead to all impressions upon the consciousness, irritation of the skin of a limb may produce all the effects of a stimulus applied to the muscular system directly; and if the susceptibility of the nervous system be heightened by placing the animal under the influence of strychnia, the effect may amount to tetanic convulsions over the whole body, thus proving distinctly the communication of the impression through a centre of transmission, by which it is diffused over a very wide field of action. Thus, too, we must explain many of the alledged sympathetic phenomena; as, for instance, the spasm of the glottis from foreign bodies in contact with the bronchial membrane, or from inflammation of the same part; to which might probably be added, without too great stretching of the analogy,

the excitement which the action of the heart undergoes from the presence of stimuli in the stomach, or even from the application of warmth to the epigastrium* externally.

The instances now given correspond pretty nearly with the law announced by Marshall Hall and supposed by him to reside especially in the spinal cord, giving rise there to the excitomotory function: but I do not see how we can escape from the conclusion, That the law of centralization has a much wider application in reference to the organic functions than any indicated in this doctrine; and that secretion, nutrition, and probably all the organic powers, are subject, in the animal body, to be excited by stimuli applied at a distance, and transmitted in all probability through some central portion of the nervous system, although the precise locality of this central portion cannot be defined with such exactness as in the cases referred to reflex action. The case of the stimulation of the heart, just alluded to, seems to derive additional illustration from the contrasted

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* See Currie Medical reports on the effects of water Appendix II p. 27 et passim

effect of opium applied to the external and internal serous surfaces of the organ*; where, although indisputably the mechanical conditions of its application are very similar, and the proximity to the seat of action nearly the same, the application is in the former instances attended with little or no effect, and in the latter produces an instant impression upon the contractile power of the organ, a difference which appears to be only explicable upon the theory of nervous transmission, and which, if so explained, implies centralization of the impression, and its diffusion to the entire muscular substance. In like manner the facility with which the entire liver is excited to the secretion of bile by an irritation of the stomach or duodenum is an instance (valuable by its complete independence of consciousness) not of a vague sympathy, but of the centralization of a nervous impression, which is thus made to act diffusively upon the glandular tissue; and the analogous instances

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* See experiments by Henry, Ed. Med & Surg Journal Vol XXXVII p 19 Haller (Elem Physiol V. I LIV Sect 5) long ago pointed out the different effects of stimuli applied to the external and internal surfaces

of the secretion of the lachrymal, seminal, and salivary fluids by irritations applied to more or less remote parts seem to me to demand the extension of a "reflex function" of the nerves to others of the organic functions besides that of muscular motion. It is in this general sense that I distinguish it by the name of "centralization"

It is further to be observed that the reflex function, however manifested, whether in motion, secretion, or any other organic function, has no necessary connexion with consciousness or sensation; and is in fact quite identical in its characters, whether the nervous impression be transmitted through the sensorium or not. Thus the secretion of bile takes place under stimuli no way different, or differently applied, from those which influence the lachrymal secretion although the former only is apart from consciousness; and the contractions induced by pinching or irritating the skin of an animal, are, we have reason to believe, as strictly instances of reflex motor action, and are certainly entirely identical, whether or not the communication between the centre of transmission and the sensorium be interrupted. We are therefore authorized in saying

that the function of centralization, certainly the most universal and important of the nervous or animal endowments, by no means necessarily implies the existence of mind in the organism.

As we descend in the animal scale, the centres of transmission, which in the higher Vertebrata are for the most part in the form of one organ, whose different portions are closely connected and dependent the one on the other, become more numerous, more isolated, and less capable of consentaneous action. Each centre has its own field of action, and its own set of organs; and if these organs are in their nature adequate to the support of an independent life, the organism is, in virtue of this fact, susceptible of becoming two perfect organisms, and of being divided without injury; a phenomenon observed in many of the lower classes of animals, and in fact forming the regular mode of reproduction in a large class of the Radiata. Further, the field of action may become indefinitely small, and the centres indefinitely numerous; but we have anatomically none but negative reasons for, and, physiologically, every reason against the admission of the existence, in animals, of what

is described by naturalists as the "diffused" form of nervous system, and supposed to be characteristic of the extensive group of the Acrita*, that, namely, in which the centres of transmission lose altogether their character of centres, becoming identified with, and diffused over, the tissues of the animal It is evident that, by this arrangement, not only would all consentaneous action be destroyed but the essential character of distinction between animals and vegetables would be lost; that distinction consisting, as we have already shewn, essentially in this, that whereas in the latter it is necessary to stimulation that the stimulus come in contact either with the tissues a organ acted upon, or some part mechanically connected with it; in the former there exists a power of transmission according to fixed laws, by means of which a stimulus may act at a part remote from that to which it is applied

3. The essential organs of the animal functions, or those structures included under the

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* Vide Carpenter's inaugural dissertation on the Comparative Physiology of the Nervous System page 3

name of the Nervous System, must, according to the views now given, be of two primary orders; first, a series of peripheral organs adapted for the transmission, from part to part, of impressions which act on the animal organism; and secondly a series of central organs, destined to collect and, by combining or diffusing, to regulate, the nervous impressions transmitted by the peripheral organs. And as it is clear that these impressions, in their passage from the point of excitation to that of action, must first tend towards the centre, and afterwards be reflected from it to the tissues, it follows that this double series of transmissions must be represented in the transmitting organs, or nerves; and hence arises the functional distinction, now so well understood, between the afferent and efferent nervous fibres, the separate localization of which, in regard to the cerebro-spinal System of nerves, constitutes perhaps the most brilliant train of discovery in modern physiology. The combination in one act of the afferent and efferent transmission, by the simultaneous operation of the central and transmitting organs, constitutes a true reflex act in its most general sense as has been

already explained*. The nature of the reflex act is

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* The view here given of the reflex function appears to me to be necessary as an explanation of many most important sympathetic actions, such as those of which instances have already been given. It is very probable that the next important contribution to the physiology of the nervous system will be a further localization of the reflex function; and as the special connexion of the cerebro-spinal system is indispensably with the organs of motion, it seems not unreasonable to look to the great sympathetic nerve, as a series of centres of simply reflex action connected with the function of motion and others of the organic functions, and so far isolated from the central masses as to be removed from direct voluntary influence. This application of the reflex function would free us from much of the embarrassment and inconsistency attending the theories of Winslow Prochaska and Bichat regarding the "organic system of nerves"; the objections urged against such theories by Valentin and others in later times being mainly directed against the supposition that the sympathetic is endued with a separate and independent power of originating, as well as transmitting the nervous influence. It is right, however, to state that the theory of a reflex function in the sympathetic nerve is opposed by Longet in his late work on the nervous system.

the same in all parts of the body, and in all animals, and its organs have accordingly the same essential parts; but the appreciable result of the impression differs according to the function acted upon. Thus a reflex nervous impression conducted by the efferent nerves to a secreting tissue will of necessity result in the excitement of secretion; while a similar impression conveyed to a motor organ will result in a manifestation of contractility. It is scarcely necessary to mention that in this last case the act of transmission belongs to the class of actions called excito-motor, the principal seat of which is, as Marshall Hall has shewn, in the spinal cord.

It is very possible that, in some animals, the whole series of nervous phenomena may receive sufficient explanation from the functions just described; and in some, as for instance the Polypi and some of the Radiata, in which the nervous structure is either not known or consists of a filamentous ring with ganglionic enlargements and diverging fibres, it must be admitted that neither anatomical nor physiological considerations appear necessarily to suggest any other modes of

nervous action than a reflex transmission of impressions. But in Man and all the higher animals, in which we have indisputable evidence of the existence of mind and consciousness, the animal functions, with which these qualities are most closely connected, derive from them an important modification which must not be overlooked. It is well ascertained that the acts implying the existence of consciousness are especially connected with one portion of the nervous centres, called the sensorium; and that only those nervous acts which stand in a more or less direct relation with the sensorium by anatomical connections, are liable to be influenced by, or to influence, the operations of mind. Thus if the nervous filaments concerned in any act have for their centre the spinal marrow such an act is essentially reflex; but if these filaments, in addition to their spinal connexions communicate directly with the sensorial or cerebral portion of the nervous matter, such a communication implies, in the healthy state of the system, the participation of consciousness in the act referred to. The functions of transmission and centralization when placed by

their organs in connexion with a sensorium, are therefore subject to modifications from consciousness which may be defined as follows; either the impression conveyed by an afferent nerve to the sensorium, is arrested there, and reaches the consciousness, producing the phenomenon called sensation; or the process is reversed, and an impression originated by mind in the sensorium, is conveyed along an efferent nerve to its distribution. The most intelligible example of the latter process is in the case of those muscles termed voluntary, which, having a direct and uninterrupted nervous connexion with the sensorial centre, are immediately under the influence of the mental faculty of the will; but although this direct interference of the mind with the organic functions is limited to one of these functions, viz motion; yet we have sufficient evidence in physiology of an influence of a different, but not less evident description exerted by mental acts, or other impressions on the central organs, over all the organic functions indiscriminately, through the medium of the nervous system. This class of facts in physiology deserves the most attentive consideration; and

we shall have occasion hereafter to refer to circumstances by which it is shewn that nutrition, secretion, and many motions whose connexion with the sensorium is not sufficiently uninterrupted to place them under the influence of volition, can yet be affected, and that materially, by impressions upon the nervous centres. In illustration of this reference may simply be made to the effects of emotions of mind upon the circulation, the digestion, and on various secretions, as examples of the class of actions now alluded to.

It is not necessary to enter at greater length into the connexion between mind and the organism; because, as has already been maintained, the life of the animal is found to depend on this connexion only in a very indirect manner; and therefore it was thought proper, in the first place, to consider the nervous system, or animal functions as apart from the manifestations of mind, and thus avoid the error which in the systems of the older vitalists caused so much confusion, the identification of the thinking with the living principle, the recognition of the soul as the source and centre of the bodily life.

Chapter II.

We have now to approach a subject of the highest importance in reference to a scientific theory of death; the question, namely, in how far the general sum of the vital powers is dependant on the integrity of individual functions; in other words, the inquiry as to the conditions under which general death necessarily takes place, and as to the order in which the arrest of the functions may occur.

In proceeding to the consideration of this subject, it is necessary, for the sake of clearness to make the following remark; that as we have all along denoted by the term life the sum of vital actions present in the individual, it is clear, that the persistance of <u>any</u> of the functions of the organism, however isolated from the rest, is an evidence of life so far as these functions are concerned; and it is therefore not physiologically correct to speak of death as being total and complete, until <u>all</u> the evidences of vital power have ceased,

and the body has become entirely passive, subject only to the chemical affinities, and mechanical forces which operate upon inanimate matter. Inasmuch, therefore, as the cessation of life is not an isolated phenomenon, but a number of phenomena following one another in a certain definite course, so it is obviously improper to demand, that any precise moment should be fixed upon as the moment of death, or any single fact as its most essential phenomenon. Life in a physiological sense is not to be tested by the continuance of the pulse and breathing, or of the connexion between mind and body; so long as a muscle is susceptible of contraction, it contracts in virtue of its inherent vitality; and death is not complete until this and all other vital phenomena have disappeared.

On the other hand, we are informed by constant experience, that the want of certain of the external signs of life, particularly of the respiration and beat of the heart, is habitually followed by real and complete death, as shewn by the putrefaction of the body; and to the state recognized by this empirical method of observation, the name of apparent

death has with propriety been given. Nor is the condition thus distinguished by any means to be overlooked by the physiological inquirer; for although numerous instances of recorded experience show, that the empirical mode of judging of death is liable to occasional fallacy, yet it is not the less true, that the phenomenon of apparent death is connected with a fact of great importance in this inquiry, namely, that when a certain amount of interference with the functions has occurred, a condition is induced incompatible with the persistance of the rest, and therefore with the life of the organism. Hence, while it is necessary to account for the termination of every vital action, it is obvious that great assistance in this inquiry is to be gained by a previous determination of the general conditions which are absolutely inconsistent with the continuance of life. This will therefore form the first step in the inquiry.

It is further necessary to state, as the phenomena of death in the higher animals must differ essentially from the corresponding phenomena lower in the scale of organized

existence, that the investigation is now limited to the former, except in so far as illustration may be derived from a comparison of different grades in the scale of being.

In the view of the functions given in last chapter, it was argued, that the reproductive functions might with safety be dismissed from consideration with reference to the present subject; and this on the ground, that they are in action only at inconstant and irregular periods, and are not connected with the welfare of the organism, nor necessary to its individual existence. On this ground, their suspension can neither be directly a cause, nor a sign, of general death.

The organic functions are the preservers of the organism from decay, the maintainers of its structure and textural peculiarities. The animal functions are the excitors and regulators of the organic powers, which last, however, are essentially inherent in the tissues, and not dependant on the animal powers for their capability of action. The organic functions are in repe-

able from the idea of an organism; on the contrary, it is quite possible to conceive of organic existence apart from the functions of transmission which, with their organ the nervous system, are in fact absent in the entire vegetable kingdom.

From such considerations it might be natural to come to the conclusion that the connexion of the animal functions with life is almost as slight and indirect as in the case of the reproductive functions. Nevertheless it is well known that this conclusion is unwarranted by facts, and it is equally inconsistent with the views already given of the general connexion of the functions. It is very important to understand this connexion, and the mode in which these functions operate on one another.

In the vegetable, the organic powers inherent in the tissues act in consequence of stimuli directly applied; the harmony of their action is the direct result of a structural adaptation which provides that the necessary stimulus shall always be present when wanted, and shall be brought into direct relation with the organ to be acted upon. Thus the absorbents

of the roots are in contact with the soil from which they derive the nourishment of the plant, and the leaves are so arranged, that the minute vessels of the sap may be continually brought into sufficiently close relation with the air which is to act on the fluids within. In the animal, on the contrary, where the presence of a nervous system admits of a remote communication of impressions, no such structural provision is made; either the stimulus acts at a distance from the seat of function, or it is conveyed thither by processes demanding the intervention of the nervous function. The air is not naturally in contact with the vessels, but it is brought in contact with them by a series of actions, in which the nervous system plays a prominent part. The nutriment also, remote from the vessels which are to absorb it, requires the intervention of the nervous function in the accomplishment of the processes by which bring it into relation with these vessels. Thus a nervous system becomes necessary to the life of animals, in consequence of peculiarities in their structural adaptation.

But there is another mode in which the action of the nervous system on the organic

processes may influence the life of the animal. This is in consequence of the law adverted to in last Chapter, (Page 55) by which it appears that the organic functions, although essentially independent, are subject to influence of various kinds from the nervous centres, by which their action may be either favoured or retarded. The effect of such influences in deranging the equilibrium of the functions, will be fully discussed hereafter.

The observation of facts, therefore, and the elementary principles of physiological science tend equally to the conclusion, that the animal or nervous functions are, in the animal, as essentially, though not so directly, necessary to the general life as the organic; although it is also quite clear, that in the suspension of the vital actions, the animal functions can only have a mediate operation, arising out of their connexion with the organic processes. The root and origin of death in all its forms must accordingly be looked for in these latter functions. The particular modes in which the suspension of the animal functions influences the organic, will form an import-

not subject for consideration; but it must first be determined, in what way the organic functions are capable of being suspended by circumstances acting directly upon themselves.

In the investigation into which we are about to enter, as to the dependance of the organic functions upon one another, it is proper to keep in view the remarks already made in the first Chapter on the mutual relation of these functions. It was there maintained that textural nutrition is the basis, and fundamental type of the organic functions, from its immediate connexion with the repair of the tissues. It was further shewn, that the other processes of organic life owe their principal importance to their connexion with the nutritive process, the most essential, and universally distributed of them all. This process must therefore be expected to be very intimately concerned in the phenomena of death, and claims, among all the functions, the priority of consideration.

1. The suspension of the function of nutrition (by which is meant the direct and primary arrestment of the molecular changes which are contin-

nally effected in the vicinity of the capillaries) may be expected to affect the other functions differently according as it may be partial or general in its effects upon the tissues. As the activity of every tissue and organ is dependant on the due repair of its molecules, it is evident that the general arrest of the nutritive process involves the general extinction of function and vital action; but the sequence of phenomena which in such a case would manifest the failure of the vital powers, would depend on the comparative liability of the different functions to be rapidly affected by the non-nutrition of their tissues. As the mode in which the functions are affected by imperfect nourishment of their tissues will necessarily come under consideration in another part of this essay, it would be superfluous to dwell on it at present; it is sufficient to attend to the fact, that the ultimate act of nutrition is most essentially a "vital function," in that it contains within itself the elements of destruction and renovation for all the other powers.

2. The cessation of the functions of absorption is not attended with immediate peril to the rest of the

powers; but the ultimate effects, slowly and gradually induced, correspond in many respects to the effects which might be anticipated from a gradually diminished activity of the nutritive process, as is seen in the death by fasting, hereafter to be considered.

3. The arrest of the functions of Elimination and Secretion likewise produces no immediate effect on the life; and death, when due to this cause, invariably occurs in consequence of a poisonous action exerted on the nervous system, by the retention in the blood of some animal principle destined to excretion.

4. The suspension of the motor function will produce effects according to the organs specially involved; it is never general, unless in consequence of some affection of the nervous centres.

5. The suspension of the circulatory function, however produced, is invariably attended with rapid abolition of the whole vital actions, animal and organic. The nature of the speedy effect thus produced will be presently enquired into; but as it is evident, that all the changes within the capillary vessels are simultaneously involved, part of the effect must be due to

the arrest of the nutritive procss in the lectures. The circulation is therefore, like the ultimate nutritive procss, a truly vital function. Further the sudden and uncomplicated arrest of the nutritive function all over the body may be regarded as invariably occurring, in the higher animals in connexion with arrested circulation; as we have no evidence of any other causes which operate in the organism whereby such a general effect could be produced on this function, nor has actual observation revealed the existence of any such cause.

In this point of view the circulation becomes by far the most important of the organic procsses; inasmuch as in those animals which possess this function its arrestment in one way or other may be considered as not only the most important sign of commencing death, but actually as the cause whereby all the other organic functions are brought to a stand. When we descend lower in the scale of being, it is necessary to look for the causes of death apart from the existence of a circulation; and when we come to the simplest forms, we find that the suspension of nutrition

constitutes in itself, the sole phenomenon of death. But this does not prevent us when we come to speak of the animals possessing a circulation, from considering that function as the centre of the organic life, and looking on all the others as dependant upon it. And since causes acting on the animal functions can only (as we have already pointed out) influence the organism through the medium of the organic powers we are justified in looking to the effect of such influence in suspending the circulation as the solution of its action upon the body.

The principles now laid down appear to be sufficiently comprehensive to form the foundation of a method which shall be applicable to all particular cases of death. In the following chapters it is proposed to follow out this method; - in the first place by the consideration of the phenomena attendant upon arrested circulation, according to the particular mode in which the suspension takes place; and, secondly, by investigating the mode of suspension of the animal functions, whether produced by causes directly affecting these functions themselves, or acting on their organs indirectly

through the circulation. It is only after thus unravelling the phenomena of death in their simplest forms in which they can possibly occur, that the other questions connected with this inquiry will present themselves in a tangible form; only thus can the complex issues of disease and injury be brought into apparent harmony with the known laws of organic and animal life.

Chapter III.

The circulation may be arrested in two ways; firstly in consequence of deficiency in the propelling power; - secondly, from some general obstruction acting in the course of the vessels as a complete obstacle to the passage of blood. In either of these ways, death may be caused, according to the principles laid down in last Chapter.

All causes acting at or near the heart, so as greatly to diminish the force, or interfere with the efficiency, of its contractions, may be referred to the first head, - and are classed together, because they are known to give rise to a very uniform series of phenomena. To the second head are referred such causes as act on the peripheral extremity of the circulation, so as to cause complete obstruction. Of this last kind ~~one of all those~~ the most remarkable example is undoubtedly that arrest of the circulating function which takes place from the non-arterialization of the blood; and as the phenomena of this are also very constant, and yet very different

from those of the former series, they are usually distinguished from it by a different name. To the effects which result from direct impediment to the heart's action the physiologist gives the name of Syncope; and to the series of phenomena which result from obstructed Respiration, that of Asphyxia.

The causes and essential nature of the phenomena thus designated will receive consideration in this and the succeeding chapter. In the meantime it may be stated, that the connexion of these states with different kinds of death, especially sudden death, has of late years received much attention, and with the result, that a large number of such cases have been shewn, when well understood, to present some of the phenomena, and take more or less of the forms about to be described, of which pure syncope and asphyxia are the type. It is therefore upon merely empirical, as well as scientific grounds, of importance to be acquainted with these phenomena, which seem to be so generally misapplied, and which present such remarkable characteristics.

The true amount of the obligation which in this matter we owe to the investigations of Bichat, is not easily overrated. Before his time

the question of death can hardly be said to have been entertained as part of a scientific physiology; insomuch that in the very profound and completely systematic mind of Haller it seems only to have found place as a species of ultimate fact and to have been disposed of as such. Many cases which have been since considered as demanding a definite explanation, were, in the systems of the older authors got rid of by referring them to a failure of the powers of life, or some other form of words to which no definite meaning could be attached. To this uncertain state of scientific opinion on this point, the arbitrary division of the functions into vital, natural, and animal, very much conduced; for although this division was certainly founded on empirical, rather than on rational distinctions, yet it was a very ready mode of accounting for individual cases, which found a simple explanation by ascribing their phenomena to an aberration of, or interference with, the so-called vital functions. By the dismission of these functions from his system of classification, Bichat introduced an incalculable improvement; he thus refused to

found his system upon arbitrary rules, and attempted to place it within the domain of true science. But in so doing, he could not fail to see that he had thrown away the explanations given in former years of the phenomena of death; lesion of a vital organ, or of its function was now no more to him than that of any other; and the event of all such lesions had equally to be explained upon general scientific principles. He could not admit the connexion of a function with life as an ultimate fact, but thought it necessary to attempt an explanation.

From the attempt to remodel the theory of death, arose the "Recherches Physiologiques sur la Vie et la Mort." In this work Bichat assumes that all known modes of death affect the functions in one of three modes; two of which involve first the organic system, one the animal. Hence the death of the heart, the lungs, of the brain are Bichat's three primary destructions; and the line of argument he adopts is to prove the "vital" nature of these organs in showing their mutual influence and dependance, by arguments of which it is sufficient to say, that they have been the basis of all the investigations

since his time. He illustrates his position by a reference to cases of sudden death, which he rightly considers as affording the purest results, both because they are the simplest and also the most accessible as subjects of experiment.

It has become evident, however, that mainly from not recognizing certain principles now well known as regulating the connexion of the animal with the organic functions, the theory of Bichat is defective in several important particulars. That he was also in error in some of his experimental results, has been proved by various subsequent investigations; and although the imperfections alluded to scarcely detract at all from the value and merit of his beautiful investigations, they suffice to shew, that the science of Bichat's time was not adequate to the explanation of many points which are now sufficiently clear; and give ample reason for the revision which the subject has lately received in the hands of several systematic authors, but more particularly of Dr Alison, to whose writings and public instructions on this and many other subjects I have to acknowledge the largest debt of gratitude.

So far as I am aware, however the subject has been of late merely accidentally treated; and on this account it appeared to me well suited for the purposes of a monograph. If in pursuance of this object I have withdrawn myself somewhat from the more brilliant, and perhaps, more ambitious field of original research and discovery, I hope that my judges will accept as a sufficient reason, that to the young student, during his term of probation, it appears of infinitely greater consequence to re-assure himself in his knowledge of existing science, than to wander with uncertain and perhaps devious steps in a path which has often a tendency to withdraw him far from the subjects of his every-day labours.

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§ I. Of the phenomena of death beginning at the heart. Syncope or Fainting.

Of the two modes, already mentioned, in which the circulation may be brought to a stand, the first is that in which the arrestment proceeds from insufficiency of the central organ to propel the blood into the vessels. This state of the circulating system, if sufficiently protracted, leads to the mode of death by syncope; and the phenomena attending

this condition demand our attention, as connected with the theory of the fatal event in such a case.

The symptoms, or externally apparent phenomena of syncope differ to a certain extent according to the circumstances under which it is produced. When brought on by causes acting gradually on the system, it is well ascertained that all the functions may continue to be exercised with tolerable regularity, although with diminished energy for a considerable period of time, during which the senses may be clear, and the intellect undisturbed, and in this state the slightest causes co-operating with those already in action may have the effect of at once inducing all the phenomena of the most sudden syncope, with immediate, and perhaps, permanent depression of the heart's action. But the fainting fit, as usually observed, is ushered in by certain precursory symptoms, the intensity and duration of which appear to be very much dependent on the circumstances of the case, as well as on the idiosyncrasy of the individual. These symptoms are principally weakness and languor, more or less sudden, with a distressing sensation at the epigastrium

Virginia — This should be expanded

termed anxiety or sinking, sometimes with a feeling as if death were imminent;— followed almost immediately by deafness and obscuration of sight, tinnitus aurium, flashes of colour before the eyes, confusion of intellect, and vertigo. The complete state of syncope succeeding to these symptoms is attended by disappearance or sudden sinking of the pulse, slow sighing respiration which is sometimes almost imperceptible, and suspension of the sense and motion. The heart is, however, generally to be felt beating at first, and the stethoscope will detect its first sound, although the second is usually inaudible. In the meantime the animal heat falls both in the internal cavities and the external parts,† the skin becomes pale and clammy, and the forehead is covered with a cold sweat. Sometimes the beginning of a paroxysm is attended with considerable nausea, or even vomiting, but this is by no means general.

These symptoms may spontaneously give way at the end of a short time, or they may proceed to complete stoppage of the heart's action, and apparent death, a con-

† Dr. Currie found the heat in the palm as low as 63° F.

dition which is usually soon followed by entire declension of the internal heat, cadaveric rigidity, and all the signs of real death.

In many instances the syncope is instantaneous, and the depression of the heart's action and respiration take place simultaneously with the loss of consciousness and voluntary power, and without any premonitory symptoms, as when the conditions necessary to the circulation are ~~mechanically~~ interfered with, either mechanically by a rupture of the heart or aorta, or by certain substances, which when introduced into the veins, have the power of paralysing the muscular fibres of the heart itself. Such cases may be taken as the simplest form, and true physiological type of death by syncope.

The characteristic phenomena of death by syncope may be enumerated as follows:

1. The heart, after a few fluttering beats, sometimes slower, oftener much more rapid than usual, but almost always intermitting, suddenly stops. If its power be not completely gone it may recover partially in a short time, but remains intermitting and feeble and soon

ceases again. The pulse ceases along with the heart or before it, being last felt in the large vessels nearest to the centre of the circulation. The characters of the pulse – frequent or slow – intermittent &c &c – Demand some careful discrimination

2. The respiration ceases altogether after a few convulsive gasps, or from the first, if the syncope be sudden and irremediable. Where the heart's action remains perceptible, however slightly, the respiration continues, although very slowly and feebly performed, and at very long intervals.

3. The functions of the nervous system are rapidly prostrated. Consciousness and sensation are lost, voluntary motion is suspended, and the muscles generally remain flaccid; reflex action is only excited when strong stimuli recall the action of the heart; the pupils are often dilated and insensible to light. When the syncope is sudden and complete, these functions are abolished simultaneously with the disappearance of the pulse and the other symptoms already noticed; although the attack may be preceded in many instances by symptoms, which are indicative, that the organic or animal functions, according to cir-

cumstances, are primarily involved.

The mode in which this sudden action on the nervous system takes place, is reserved for consideration in next chapter; at present the fact is merely stated.

4. The contractility of the muscular tissue is not necessarily immediately involved in syncope; although it may be exhausted in the general convulsions which sometimes accompany the beginning of the attack. In consequence of this circumstance it may be remarked, that if the cause of syncope cease to act, the depression of the heart is not necessarily permanent. Hence the spontaneous recovery in the majority of cases; hence also the possibility of re-exciting the heart by attention to the proper methods of stimulation. Nevertheless it may occur that the cause of the symptoms is such as to destroy muscular contractility more or less generally over the body (a mode in which many poisons exert their deleterious influence on the system); and if this condition affect in the first instance the heart,†

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† See the experiments of Mr Blake on the effects of cer-

it is easy to see that the fatal effect must necessarily be permanent.

It is often stated that the effect of death by syncope is to prevent the cadaveric rigidity from taking place; but this does not appear to be by any means uniformly the case. The same may be said of the similar assertion with regard to the coagulation of the blood.

5. The actions of secretion, nutrition and absorption appear to be arrested principally in consequence of the arrest of circulation; although it is pretty evident from certain experiments by Chossat (quoted by Dr Alison—Practice of Physic and Path. page 6) that in some instances these functions may be affected by a direct action on the extremity of the circulation, at the same time that the heart suffers more or less of the usual depression. But in either case, the effect of syncope on the extreme capillaries becomes evident in the various symptoms already enumerated, particularly in the declension of animal heat and the condensation of moisture

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tain salts injected into the veins. Edinb. Med. & Surg. J. 1841. page 104
See also Brodie's experiments with tobacco in Phil. Trans. 1811.

on the surface, giving rise to clammy coldness of the skin.

In the most characteristic cases of syncope, all the phenomena above enumerated are observed to take place abruptly and simultaneously; and when the depression of the circulation is complete, it is scarcely possible to say whether the animal or organic functions are first affected. Indeed we shall see reason to believe, from a consideration of the various cases in which syncope occurs that some degree of suddenness in its mode of attack is a distinguishing feature of that physiological condition, especially when seen in its purest and most unmixed form. At the same time it is no doubt true, that the fits of syncope may be preceded for hours, or even days by progressive symptoms, indicative of a grave amount of impression on the system, and the ultimately fatal attack may take place under circumstances which very much diminish the apparent suddenness of its accession. Such cases however, being of a complex nature, cannot be properly understood, until the investigation

proposed in the next Chapter shall have prepared the way for their consideration.

It may, however, be at present stated, as a fact well known to medical men, that the occurrence of repeated attacks of syncope within a short space of time, uniformly leads to a state of the system in which such attacks are more easily provoked, and come on from slighter causes, and with fewer premonitory symptoms, than in the natural state; and that the fit induced under these circumstances is apt to last much longer, and be attended with much greater and more alarming depression of the circulation, than could be at all expected from the nature of the cause which induced it. This is one form of the condition referred to by Cullen as "mobility of the nervous system"; but into the pathology of which we do not enter at present.

There are also minor grades of depression of the heart's action, affecting the system with very various degrees of intensity, and producing feelings of faintness, but without the same complete abolition of the functions which takes place in syncope, properly so called; yet the tendency of the affection

is sufficiently indicated by the frequent, irregular, soft pulse, and the feeling of nausea or sinking, some degree of coldness, perhaps shivering and muscular debility. Such symptoms may appear and pass away again without the suspension of sense and voluntary motion which occurs when the heart's action is more decidedly depressed.

The external causes which act upon the system so as to produce syncope are so numerous and various, that it would be wholly inconsistent with the purposes of this Chapter to enumerate and treat of them separately, more especially as the mode of action of several of them will be adverted to in another part of this Essay. But these causes may be all classified with reference to their evident mode of action under one of two heads, viz; 1st such as act by destroying the equilibrium which naturally exists between the power of the heart and the resistance to be overcome; or 2nd such as interfere with the mechanical conditions necessary to the propulsion of the blood through the great vessels.

To the first kind may be referred all influences which act directly or indirectly so as to weaken the force of the heart. That the

majority of such influences act upon the heart through the medium of the nervous system, there can be no doubt; and the principle of this action will be discussed in reference to the animal functions. There is besides, however, much reason to believe, from a consideration of cases already alluded to (p 80) that a certain proportion of these causes may act directly upon the heart itself, although to what extent this is true it may perhaps be difficult to decide. Of this latter set of causes an excellent example is to be found in that pathological condition where from disease of the coronary arteries, the circulation in the substance of the heart itself is primarily obstructed†; a condition leading to a variety of symptoms, among which a tendency to syncope is one of the most marked, and certainly fatal, if the coronary circulation continue to be much obstructed. The few cases which have been accurately observed‡ of inflammation in the mus-

Degeneration of Heart should be mentioned

† Parry, Elements of Pathology and Therapeutics - p 325 - DCCCXXX. Mr. Erichsen also produced the same result experimentally - See Med. Gazette 1842.

‡ Vide Heim in Rust's Magazin. Band VI - p 343; also Medico-Chirurgical Transactions of Edinburgh Vol II. - p 237.

cular substance of the heart; shew that here also a great part of the danger proceeds from the same cause; and it is well established that certain substances have the power† when introduced into the circulation, of affecting the heart in a way which is best explained by supposing them to have a primary influence on its muscular fibre, the heart being found after death insensible even to the stimulus of galvanism. On the other hand, the most characteristic examples of the diminution of the heart's power from an influence communicated by the nervous system, are to be found in those cases where syncope is due to mental emotion, to intense pain, or, as often happens, to the sudden transition from a state of suffering to one of ease.

The balance between the circulating power and the resistance of the blood may also be modified by circumstances affecting the latter. In this way syncope may be caused by obstruction, as that of an aneurism or other tumour to the flow of blood through the great vessels; or by simple dilatation of the cavities of the heart,

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† As Blake's experiments quoted supra page 80.

and ~~consequent~~ increase of quantity of blood to be propelled at each stroke; if that dilatation be not accompanied by hypertrophy, and consequent increased power of the organ. A similar effect may be produced by valvular disease, and contracted valvular orifices, or any other condition which increases materially the demand upon the power of the circulating organ.

In the second place the influences which interfere with the most important mechanical conditions necessary to the action of the heart and the efficiency of its contractions, are worthy of notice. The movements of the heart may be embarrassed either by the presence of a polypus within its cavities or by extensive adhesions to the pericardium without; and in either case, the termination of the disorder in fatal syncope is probable. Rupture of the heart also, or such wounds of the great vessels as lead directly to the emptying of its cavities, are conditions manifestly mechanically inconsistent with the carrying on of the circulation, and therefore entailing fatal syncope. We must be careful, however, not to suppose that all hemorrhage proves fatal in this way alone; the above remark applies to

Not applicable in the latter case.

the case where the heart is directly emptied by the rupture of the great vessels nearest to it; the fatal result of hemorrhage in other cases being much more complicated.

All this upto § II will bear Condensation

It remains in this place to consider in what mode syncope affects the amount of blood found in the cavities of the heart and in the great vessels after death. It is not possible to enter here upon the consideration of the greater number of the cases where death is apparently caused in this mode, because I believe, and shall afterwards adduce evidence to shew, that the most of these are complicated as regards this circumstance in a way which prevents their being adduced as instances of the pure physiological condition of syncope. But there are nevertheless cases sufficient to shew, that where this condition can be effectually observed, and the result has not been marred by circumstances tending to derange the circulation in other ways, it is quite possible to establish a criterion derived from a consideration of the distribution of the blood, which shall distinguish this condition from that of asphyxia, next to be adverted to.

It is indeed to be expected, that all

conditions which suspend the circulation by directly influencing the motions of the heart, will leave the distribution of blood unaffected: and that therefore unless the cause of syncope acts by emptying one side or other of the heart, or unless there has been some previous or subsequent condition leading to an unusual distribution of the blood, we may expect to find the heart, as regards this circumstance, in its normal condition, that is to say with no decided preponderances in the amount of blood in one side over the other; and this accordingly I believe to be the only trust worthy post-mortem appearance indicating the pure uncomplicated death by syncope. That this assumption tallies with the results of observation and experiment, is proved by an examination of all those cases which have been adverted to as presenting the pure physiological type of this condition, those namely where the action of the heart is arrested instantaneously or nearly so, and where that organ is found after death to have its contractility destroyed, so as to be insensible even to the stimulus of galvanism. In Sir B. Brodie's experiments

he found this condition fulfilled when an animal was killed by tobacco; and in these cases the heart is found with the two sides equally distended, and the left containing florid blood; a circumstance which is inevitable if the function of respiration shall have continued efficient up to the moment of final cessation of the heart's action. In the experiments of Mr Blake the same condition of the heart was frequently observed; and a similar result was obtained in experiments which I shall afterwards have occasion to narrate in which death was induced by syncope in animals in whose artificial respiration was kept up by carefully inflating the lungs. We are thus warranted in considering that where the circulation stops from simple want of power in the heart, that organ will be found uniformly distended with blood, which will maintain the line natural to either side.

On the other hand, it is conceivable, that where the heart has not lost its power, but is the subject of a kind of tonic spasm, the opposite condition might have place, that is, the emptiness of both sides of the heart, but still with the similarity in state of both sides

of the organ, which has been shewn to be characteristic of true syncope. I have repeatedly seen this state of the circulation in animals in which the heart had been directly emptied by puncturing the auricles; the effect of which is, that successive portions of blood are thrown out at the openings, and the heart finally becomes inactive by contracting upon itself, remaining for many hours after death hard and rigid, with its cavities empty and contracted. I am not aware of any instances in which this tonic spasm of the heart exists as an idiopathic condition, producing the effects here mentioned; but the empty and bloodless state of the heart has been noticed under very opposite circumstances, in certain very obscure cases described by Mr Chevalier,† and afterwards by Mr Worthington,‡ in which death was apparently produced by sudden idiopathic syncope, and dissection shewed the heart extremely flaccid, and all the cavities completely empty. Of these cases no adequate explanation has yet been given.

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† London Med. Chir. Trans. Vol I p 167. ‡ Lond. Med. Repos. Vol 17. p 361

Finally, the state of syncope may be attended in certain cases by a condition of the heart intermediate between repletion and emptiness; both cavities having in them a certain amount of blood, but not being distended or full. This is most likely to occur when blood has been removed from the body in such a way and at such a distance from the heart, as neither to empty it completely, nor to give rise to death without affecting the quantity of blood in the heart, as we shall see to be the effect of hemorrhage in some cases. In fact this state of semidepletion is found to be a frequent morbid appearance in cases suddenly fatal by hemorrhage from a large arterial trunk†, as well as in those where death is due to a long and gradual draining of blood; and has also been found in some instances in conjunction with a bloodless state of the whole body⊖. Such cases are not, however always fatal from pure syncope, and accordingly the equal distribution of blood proper to this condition is not always found.

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† See experiments by Seeds, in London Med. Gazette Vol V - p 433

⊖ Lieutaud, Precis de la Medecine Pratique - p 72 (1761)

First 4 paragraphs almost superfluous W. J. G.

§ II. Of the phenomena of death from interrupted Respiration. Asphyxia

The order of cessation of the functions in asphyxia has been the subject of more attentive consideration, and especially of more direct experimental investigation than any other mode of death. This arises partly from the importance of the subject to the medical jurist, partly from its intricacy and the remarkable facility with which conflicting theories may be submitted to the test of experiment. On this account the subject of asphyxia is, much more than that of syncope, complicated with details of physiological evidence collected at different periods, and by different individuals, who have in turn attempted to generalize the results of their own investigations, and to complete the theory of its phenomena.

In attempting to analyse what is known upon this topic, it has been usual among later writers to proceed to a certain extent historically, by shewing the successive rise and overthrow of opinions in the order in which the new facts that gave rise to them were ascertained. But I believe that a view of the actual information on this subject may be very much simplified by

dropping the historic method; and instead of detailing in succession the views of Haller, Goodwyn, Bichat &c, by simply stating what is actually ascertained as to the order of the phenomena. When this is to a certain extent determined, a short process of induction will enable us to set aside all that was indubitably false in the older theories, and reduce the questions at issue into the smallest possible compass.

Of the external causes of asphyxia it is only necessary to say here, that they are all comprehended under the following heads, being the only modes in which the function of respiration can be interrupted. These are entirely chemical and mechanical, and we may set aside all more strictly vital causes from a knowledge of the fact, which seems however, not to have been properly appreciated by Bichat, that the necessary changes in the venous blood go on quite well under any circumstances where that fluid is exposed to the influence of the atmospheric air, with or without the intervention of a membrane. Thus the causes of asphyxia are all

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† Sur la Vie et la Mort art VI – sect 2.

such circumstances as interfere with the necessary contact of air or oxygen with the pulmonary vesicles, on which the capillaries, charged with venous blood, are distributed. Such causes act in one of the following ways; 1st by the absence of oxygen in the air inspired; 2nd by mechanically obstructing the access of air through the air-passages; 3rd by impeding or interfering with the movements of respiration, or the other mechanical conditions by which air is drawn into the chest; and 4th by lesions of the structure of the lung itself, entailing obliteration of the air-vesicles, or thickening of their parietes. Perhaps another cause may also be admissible;— the obstruction of the pulmonary capillaries by the introduction of some saline substances into the circulation (shewn by Mr Blake to take place with salts of soda, silver &c)†; but this is somewhat of a peculiar condition, and not primarily a case of obstructed respiration, although presenting many analogies to that condition which will be considered in the sequel.

When any of these causes acts merely by

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† In the article quoted ant. p. 101

the suspension of respiration without producing any other deleterious effect on the system, a series of phenomena follow, in themselves ~~remarkably~~ uniform and constant, but differing very remarkably from those observed in Syncope. It will be convenient to describe first those which are externally apparent in a case of pure uncomplicated asphyxia such as is produced in an animal by ligature of the trachea

The commencement of asphyxia is marked by an increase, amounting to distress, of the peculiar sensation which in the natural condition, prompts to inspiration (besoin de respirer); and the whole of the motions proper to this act, which are usually partly voluntary and partly reflex, are simultaneously excited in unusual intensity, with the help of all the accessory muscles, thus producing a series of convulsive efforts, partly no doubt independent of the will, but of which the individual is at first quite conscious. The heart at this time pulsates with regularity and force. The respiratory efforts continue incubated till about 1½ minutes from the beginning of the obstruction; at which time they

slacken in frequency and regularity, and become more of an automatic character. At the same time the sensation is abolished, the pupils become dilated and the frame relaxed, the respiratory movements being continued chiefly by the diaphragm and intercostal muscles. The pulse is now feeble, and the heart, though still regular in its action, is beating more slowly and languidly. The venous system becomes congested, and the superficial veins turgid, as is peculiarly evident in the conjunctivae, which are injected. The altered state of the blood in the capillaries becomes apparent in the progressively increasing lividity of the lips and face, and soon after of the general surface. Very soon all motion of respiration is suspended, and the impulses of the heart, having first become very slow and then irregular, cease to be felt.

If at this stage the chest be opened, the ventricles of the heart are found motionless, with the exception of slight occasional twitchings; the auricles, however, still contract for a short time, and the right auricle is the last to cease. The right cavities are found

with blood, and the venous system in the internal parts, particularly in the liver, spleen, mesentery, and venae cavae, remarkably congested; the left ventricle is nearly empty, but the corresponding auricle contains a little black blood. The lungs are much congested, as also the pulmonary artery and its branches; while the pulmonary veins contain but little blood.

This inequality in the distribution of the blood in the heart and great vessels is a very distinguishing feature in the pure death by asphyxia; but the phenomena now described are worthy of remark, as presenting several important peculiarities, in which this mode of death differs essentially from syncope. In the latter we have the sudden disappearance of the pulse and the immediate abolition of the nervous function as the first functional lesions; the respiration disappears from the want of muscular effort, and total abolition of the reflex function; and the circulation, arrested from stoppage of the heart's action, is found in the normal state, the blood being equally distributed on either side of the heart. In asphyxia, on

the contrary, the heat of the heart continues till almost every other sign of life has been exhausted; and the violence of the respiratory efforts, gradually declining, attests the continuance of the cerebral functions for some time after the changes have begun, and step by step, first volition, and then reflex action, have ceased. It is unnecessary to enter further into the external differences of these two states; which when uncomplicated can easily be distinguished by the characters now given.

In addition to the apparent phenomena of asphyxia already described, there are various physiological facts in regard to it, which bear an important relation to the theory of this form of death. These be arranged in reference to two orders of functions, the circulation and the nervous powers:

1st. In regard to the circulation.

If the carotid artery be laid bare in an animal of which the trachea is tied, the blood will be observed through the coats of the vessel to become gradually darker; but there

is in the first instance no diminution of its velocity or force. The alteration of colour begins, according to Bichat in about 30 seconds and is completed at the end of ½ or 2 minutes, at which time the blood in the arteries and veins is exactly similar.† About this time or soon after, as Dr Reid has shewn, the hemadynamometer begins to indicate a diminished pressure in the arteries, and at the same time the frequency of the pulse becomes less. If the artery be now opened, the blood will flow out, but in a smaller stream than natural; and hence it is clear, that some cause has come into operation preventing the free circulation of the blood. What this cause is we do not now stop to inquire; but its close connexion with the respiratory process is shewn by the fact, that the admission of air into the lungs will instantly restore the flow of blood, which will also rapidly resume its natural line

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† Sur la Vie et la Mort. Art VIII. §. Corroborated by Reid and Erichsen, whose experiments certainly outweigh the statement of Dr Kay that the effect is incomplete at 3 minutes. Ed. Med. & Surg Journ. Vol 55 - p 444

This experiment may be repeated several times successively.

Whatever the cause of obstruction may be, it affects the heart in the following manner; the blood accumulates in the right cavities, while the left receive less and less blood, which is for some time vigorously expelled into the arteries; but as the supply of the left ventricle becomes gradually smaller its cavity diminishes in size, until at length although spontaneous contractions still occur in its fibres, no blood issues from a divided artery; and the ventricle, by contraction, has obliterated its cavity.† After this the blood slowly accumulates in the auricle from the large vessels of the lungs, and its contractility continues for a very considerable period."o
In the meantime the right cavities have become more and more distended, till at last they also cease to contract, being in a precisely opposite condition from the cavities on

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† A limitation of this statement to a slight extent, will be found below.

o Kay on Asphyxia. Or in Edinr. Med. and Surg. Journal Vol XXIX-42

the left side.

The contractions of the ventricles cease generally about the 10th minute, or from this to the 14th. That of the auricles continues some time longer; on the right side (the "ultimum moriens") as long as the 20th minute. How it has been proved by the late very careful experiments of Mr Erichsen and Dr Sharpey (Edin. Med. and Surg. Journal Jan 1845 page 46), that if artificial respiration be applied at any period before the final ceasing of the contractions, these contractions, however feeble, may be revived; and that long after this period, even so late as the 45th minute the inflation of the lungs will rapidly relieve the distention of the right side of the heart by the flow of the superfluous blood through the pulmonary veins into the left auricle, and thence into the ventricle although the latter will not, at this late period contract efficiently upon it. Further it appears from numerous observations,† that even the mechanical relief of the distended vein,

† See Dr John Reid. Edinburgh Journal Vol 45 page 387

by puncturing the auricle or venae cavae, will when the right ventricle has become enfeebled, re-excite it to contraction

It is therefore to be observed:— 1st. that the left ventricle of the heart continues to contract almost as long as any blood is thrown into it; 2nd that the right ventricle continues to contract until mechanical distension prevents it from expelling its contents, and that its contractions, when enfeebled, may be renewed by relieving this distension; and 3rd, that the heart continues vigorously in action at a period when the circulation is so far obstructed that the distribution of blood in the venous and arterial systems is materially altered.

Hence it is evident, from a consideration of the phenomena of asphyxia, that the cessation of the heart's action occurs after, and not before, the primary obstruction to the circulation has begun to act, and therefore, that however it may be a consequence, it cannot be a cause, of this obstruction in the first instance. Accordingly, we are enabled to set aside, as these former

alone, all the theories of asphyxia proposed by Bichat and Goodwyn, in so far as these propositions involves the proposition here refuted by the simple test of experimental observation.

But we may go farther, and assert what is also capable of demonstration from the phenomena of asphyxia; viz, that the primary cause of the obstruction to the circulation, at least in adult animals, acts in the smaller vessels of the Lungs. This is evident from the following facts: 1st from the distinct limitation of the space within which the obstruction is proved to occur (by the experiments of Dr Kay, already referred to, in which it is shewn, that the opposite condition of the two sides of the heart is occasioned by the blood accumulating in the pulmonary arteries and keeping in gradually diminished quantity into the pulmonary veins); 2nd by the experiment of Mr Ericksen[+], in which by tying in an animal the branches going to

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[+] See Ed. M. & S. Journal Jan 1. 1845 - page 22

one lung, while artificial respiration was performed in the other, he found that the obstruction to the circulation was limited to the lung in which the bronchus was tied*; 3rd from the observation of the same physiologist†, that the difference described as affecting the condition of the two sides of the heart does not occur in very young animals, in which, from the open state of the foramen ovale and ductus arteriosus the suspension of the pulmonary, does not involve the general, circulation; and 4th from the fact, that the admission of air into the pulmonary vesicles even after the circulation has ceased is followed by an immediate increase in the quantity of blood on the left side of the heart§, a fact only explicable by considering the cause of obstruction to exist at the point where the blood is exposed to the contact of the air. Taking these observations, therefore, in connexion with the negative fact, that the heart is certainly not the primary cause of interruption to the circulation, we can have little difficulty in admitting, that the site of that obstruction is in the capillaries or smaller vessels of the lungs, without any further

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* Edin. Med. and Surg. Journal Jan.y 1845 p. 22. † Loc. cit. p 11 § Idem, p 46

examination of the rival theories of Bichat and Goodwyn on this subject.

2nd The order of suspension of the nervous functions demands attention.

It has been noticed in comparing the phenomena of syncope with those of asphyxia, that the nervous functions, in the latter, as in the former case, are not suddenly and instantaneously abolished, but that a certain sequence is observed, - indicating, it may fairly be assumed, that particular portions of the central and transmitting organs, are, with their functions, first insulated, while others remain still free; and that the whole of these organs are affected in a definite, and, to a certain extent, regularly progressive manner. The facts which have been ascertained as to this succession may be here stated apart from all theory.

The external phenomena of asphyxia reveal to us that the sensorial functions are arrested some time before the reflex acts have suffered any considerable diminution. The indication of this fact is taken from the character of the movements, which are at first manifestly to a certain extent under the control of the will,

but afterwards become of a purely convulsive, and involuntary character. Thus the respiratory efforts of the animal are at first attended with violent struggling, and with motions of the trunk and extremities, which are evidently the consequence of impressions on the sensorium; but afterwards these movements become much more limited, and at last the inspiratory acts take place at longer intervals, and through a series of associated movements of the reflex kind. The cessation of all arbitrary exertion of muscular power in this case, while the habitually associated acts are still excited by the nisus respiratorius, leaves us in no doubt that the part of the nervous system connected with the manifestations of mind is the first to be involved in the general death of these organs which takes place in asphyxia.

Taking as the criterion of insensibility the cessation of the voluntary and locomotive efforts, Dr Reid gives as the result of his observations, that in dogs the sensorial functions are arrested from 2 to 2½ minutes after ligature of the trachea. Mr Erichsen gives about 1¾ minutes. At the time of the complete arrest=

ment of the sensorial functions the respiratory movements are enfeebled, but they do not entirely cease till a short time after. The complete abolition of the automatic movements is fixed by Mr Erichsen at 2½ minutes on an average[+]. A comparison of these results with those given in regard to the arrest of the circulation suggests some interesting relations of time which are important in reference to the theory of asphyxia, and will be afterwards referred to.

Such being the ~~indisputable~~ series of phenomena in asphyxia, as ascertained by the united results of observation and experiment, we are led again to the inquiry, in what way does the suspension of the respiration involve the arrest of circulation? It has been already shewn, that this phenomenon depends primarily, not on deficient action of the heart, but on an obstruction within the lungs; and the remaining question therefore divides itself

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[+] Loc. cit. p 31. Mr E. does not expressly state that this observation applies to dogs, but a comparison with other parts of his paper would lead us to infer so.

into two separate lines of investigation, the one, into the cause of the obstruction within the lungs; the other into that of the arrest of the heart's action. We shall now consider these points in succession.

The stagnation of the blood within the smaller pulmonary vessels was ascribed by Haller to the collapse of the lung which ensues in the absence of respiration. This, he argued, ~~would~~, by ~~obscuring~~ rendering more acute the angles of the smaller blood-vessels, retards the flow of blood through them, upon known mathematical principles. It is unnecessary to enter into the refutation of this view by Bichat, Goodwyn, and Kite; as ~~an experiment of~~ Dr Williams has fully proved that asphyxia takes place with equal certainty, and with the usual phenomena, when the trachea is closed at the moment of full inspiration, and the vessels of the lungs consequently in the most favourable state for the transmission of fluid. The theory of Haller is therefore untenable.

Another mechanical theory of this stagnation of the blood is that which ascribes it to the cessation of that movement in the lungs,

which, it is asserted, is in the ordinary condition the great auxiliary to the power of the heart in propelling the blood through the pulmonary vessels. But the inadequacy of this theory also is proved by an experiment of Dr Alison, in which he has shewn, that an animal may be asphyxiated with all the usual phenomena, while freely respiring nitrogen gas.+ A rabbit was confined in this gas till insensibility was nearly complete, and on its being removed, the brain was suddenly crushed, with the effect of suspending the heart's action till the chest was opened; which being immediately done, the right side of the heart was found considerably more distended than the left, thus obviously shewing, that all the normal mechanical conditions of respiration might be maintained without the obstruction in the lungs being prevented from occurring.

Nevertheless it is clear, that the expanded state of the lung, and also the pulmonary movements do, to a certain extent, favour

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+ Edin. Medical and Surgical Journal Vol 45 – p 104: and also – See the article already quoted, by Dr Reid – p 438

the transmission of blood; for both Coleman and Kite observed, that when the lungs were kept mechanically distended, more blood was propelled into the left ventricle than when they were allowed to collapse; and Mr Erichsen, on keeping up artificial inflation by means of a syringe in which the air was not changed, found both that the heart contracted longer than the average time, and that the quantity of blood in its two sides was not so different in amount as in ordinary asphyxia. These experiments undoubtedly show, that mechanical causes are not without influence in promoting the circulation through the lung; but on the other hand, they corroborate the conclusion, which is indeed all that can be legitimately inferred from Dr Alison's experiment; that the cessation of the mechanical movements of the chest is not in itself an adequate cause for the stagnation of blood in the lungs.

Under these circumstances, one other view remains. The obstruction to the circulation through the pulmonary vessels must be in con-

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+ Loc. cit - p 5

sequence of some impediment connected with the cessation of the chemical changes exerted on the blood in these vessels. This doctrine is the necessary corollary of what has been already demonstrated; but it has been most beautifully illustrated and corroborated by the experiments of Dr. Reid and Mr. Blake, which seem to give a fair promise of some more definite solution of this curious problem than has yet been obtained.

Dr. Reid found (loc. cit. p. 442) that the obstruction within the capillaries of the lungs was only a part of the phenomena occurring in that system of vessels; for on inserting the hæmadynamometer into the artery of an animal, which was then asphyxiated by stopping the trachea, the mercury indicated a great increase of pressure, for at least two minutes after insensibility had supervened; while in the veins there was a corresponding diminution. This state lasted until the blood began to flow up freely into the left side of the heart, when the pressure rapidly diminished in the arterial system. Thus it is clearly proved that the obstruction is not

local merely, but is directly connected with the ~~change~~ particularly conditions of the blood circulated in the system, and distributed to all the tissues. It will be at once observed, however, that the chemical changes going on in the pulmonary capillaries are precisely the opposite of those which take place in the systemic vessels, so far as the reaction of the blood with oxygen is concerned; and hence we are obliged to admit that the capillaries of the two vascular systems are not similarly engaged while producing the obstruction to the flow of the blood in asphyxia. The analogy afforded in this and other respects between the phenomena of asphyxia and those observed by Mr. Blake are most striking. He found† that many of the inorganic bases and their salts have the effect, when introduced into the circulation, of acting on the capillaries so as to prevent the transmission of blood through them; and some of these, which act on the lungs, give rise to all the phenomena of asphyxia in their usual succession.

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† Ed. Medical and Surgical Journal Vol 56 - p 104

But the salts of silver and soda, which have this effect upon the pulmonary capillaries, pass freely through the systemic vessels; and the salts of potassa and ammonia, which have no effect whatever on the lungs, act on the capillaries of the system. Lead and its salts act on both systems. Hence it is plain, that the two sets of capillaries are liable to be affected in different or even opposite ways by the same substances, and there is therefore no inconsistency in the idea, that an opposite condition of the blood may affect them in the same manner.

I do not intend at present to enter into much speculation as to the intimate nature of this effect on the capillaries. On the one hand it may be supposed, that the contractility of the capillaries or of the smaller arteries is directly stimulated; or on the other, it may be maintained with Dr Alison that the blood ceases to flow through them in consequence of the arrest of those vital attractions and repulsions which are considered in this theory to be essential to the circulation. So far as I am able to form

an opinion, it would be in favour of the former view; which appears to agree better than any other with the fact, that the arrest of the capillary circulation does not begin till after the blood is completely darkened; a fact clearly established by Dr. Reid, contrary to the opinion of Dr Kay. At the same time it appears to me quite clear, that the microscopic observation of Mr Erichsen upon the mesentery of the rabbit, in which he supposes that he has verified by ocular inspection the hypothesis of contraction, is quite fallacious; as there is no doubt that the action of the air on the vessels would produce precisely the effects described by him. (loc. cit. p 28) By repeatedly asphyxiating and reviving an animal while the vessels were under observation, the truth might be arrived at.

What has that to do with it?

I have said nothing of the theory of "paralysis" of the capillaries"; because, if such a condition were known to exist, I am at a loss to conceive how it could prevent the blood from gaining the left side of the heart in asphyxia: or how upon this theory the

inflation of the lung, even after the heart has ceased to beat, could cause the instant passage of the blood through the paralysed capillaries.

The other point which it is necessary to touch upon before closing this article, is the inquiry into the arrest of the heart's action.

It is scarcely necessary to notice the theory of Goodwyn, that the left cavities of the heart are incapable of contracting upon venous blood; as besides the experimental proof which Bichat adduced of the opposite position; it is now very well known, that in asphyxia the heart contracts for several minutes, (although with somewhat impeded action, when nothing but venous blood occupies ~~its~~ the left cavities. It is much more reasonable to seek for the cause of this phenomenon partly, at least, in the unfavourable mechanical conditions to which it is subjected from obstruction in the capillaries; and indeed we have the evidence of Dr Kay to prove, that in some cases of asphyxia the heart continues to beat until

the distension of the right and emptying of the left side are manifestly inconsistent with its action. It may therefore be assumed with considerable confidence, that the two sides of the organ cease to contract from opposite mechanical conditions — in the left side, deficiency of blood — in the right, over-distension.

If the cavity of the left ventricle were found completely destitute of blood in all cases of pure asphyxia, this explanation might suffice. But the observation that this cavity almost uniformly retains a small quantity of blood (as is admitted by Dr Kay himself, and corroborated by other observers) plainly points to the conclusion, that the emptying and obliteration of the cavity is not the sole cause of the impeded contraction of the parietes, but that some other circumstances

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+ That the heart can, under proper circumstances, contract so as completely to obliterate its cavity, is proved by a simple experiment; if a small puncture be made into the auricle, the ventricle will gradually expel all its blood, and remain in the state of tonic spasm.

in connexion with the as physical condition tends to enfeeble the circulation by acting in a deleterious manner upon the power of the heart. This conclusion is farther supported as regards the right side by an experiment of Mr Ericksen formerly related (p 105), in which by keeping up respiration and the free passage of blood in one lung, he enabled the heart to propel a certain amount of black blood through the vessels of the other, thus clearly proving that if the power of the heart remained undiminished, the obstruction in the lungs would not be adequate to the total suspension of the circulation.

Under these circumstances, Mr Ericksen proposes to revert partially to the theory of Bichat, and maintains, that the contractions of the heart are much influenced by alterations in the quantity and quality of the blood circulating in its muscular texture; not indeed from a poisonous quality in that blood, but simply from its being defective in the qualities necessary to sustain the action of the heart. Accordingly he has afforded experimental proof that the arrest of the coronary circu-

lation is attended with rapid diminution, and ultimate suspension of the hearts power; and that the circulation of venous blood in these vessels produces a similar effect, although not so rapidly. Mr Erichsen's results harmonize well with those of Dr Kay as regards other muscles; and although the admirable experiments of the latter leave us in no doubt, that the primary cause of the arrest of circulation is not, as Bichat supposed, a loss of power in the heart, yet there seems no reason to deny, that such an effect may be a secondary phenomenon, the consummation, although not the primary cause of the series of changes which take place in asphyxia. The time of the first diminution in the strength of the hearts action corresponds very closely with the first obstruction to the pulmonary circulation, which, as was formerly stated, is immediately after the complete clarkening of the blood.

We see, therefore, that in asphyxia, as in syncope, there is a diminution of power in the heart as one of the essential

phenomena; but in the latter it is the first remarkable symptom, and the cause of most of the others; while in the case we have just been considering, the action of the heart continues till most of the other signs of life are extinct. Hence the difference both in the symptoms and in the post-mortem conditions.

The relations of Syncope and asphyxia to the animal functions will be considered in the course of the next chapter

Chapter IV

In this chapter we have to consider the connexion of life with the animal functions; and the modes in which death may ensue from causes acting primarily upon them.

The general nature of the relation between these functions and the organic life has been adverted to in the 2ᵈ Chapter. It was there shewn that the functions subservient to nutrition form in the vegetable a complete and independent series, and that the essential difference between the plant and the animal consists in this, that, in the former, all the external conditions necessary to the excitement of function are provided by the nature of its organization placed in direct relation with the organ to be acted upon; whereas, in the latter, the action of stimuli may take place through the medium of a series of organs whose function it is to transmit and harmoniously to combine the impressions necessary to excite the organic life. We are therefore prepared to expect that many of the causes of death may be fatal not by acting directly upon the organic functions, but upon these

through the intervention of the nervous system; and it is therefore of importance to determine exactly in what manner this effect may take place.

As it has also been proved that the circulation, in the higher animals, is the great source and centre of the organic life, so we may expect that in a great number of instances the fatal effect of lesions of the nervous functions will be produced through the suspension of the circulation, either in the way of Syncope or of Asphyxia. Whether the whole of the phenomena attendant on such lesions are to be thus explained, will be afterwards considered

In estimating the effect of nervous lesions on the organic functions, it is of course of paramount importance to ascertain in the first place the mode in which these functions are affected by simple suspension of the nervous power; the more so as we shall have occasion to shew that very different effects are produced upon the nervous system by the same agent under different circumstances; whereas the phenomena which attend the suspension of function are quite constant in regard to similar portions of the nervous

matter. It will therefore be worth while to devote a short space to the consideration of the effects of isolation of portions of the nervous centres, as ascertained either by removing them, or by destroying their continuity with the others, so as to prevent the transmission of impressions through them. But it is necessary that the injury of the nervous substance be as slight as is consistent with the object to be attained: for there are experiments which most unequivocally prove that severe injuries of the nervous substance produce effects quite different from the functional loss implied in the amount of nervous substance removed. It is necessary also, for the same reason, to use carefully the evidence derived from pathological inquiries, and to form our opinion principally on physiological experiments.

1. Of the encephalon

It would be superfluous to enter into discussion on the functions of different parts of the cerebrum and cerebellum; since we have the most distinct evidence that the whole of the encephalon may be removed, down to the medulla oblongata, without its being in the first in-

stance fatal. According to the experiments of Flourens* and Hertwig the complete removal of the cerebral hemispheres is attended with stupor and loss of sight, hearing, taste, and smell; but "the animal continues to respire, to move about when irritated, and to cry out when violently irritated". A similar condition seems to exist after the removal of the cerebellum except that the power of regulating the voluntary movements is destroyed. And that this is not the result of a merely temporary persistence of the functions necessary to life is proved by the fact that birds survive this injury for an indefinite period; they are able to swallow freely, if the food be placed at the back of the tongue, within the range of the reflex movements; they commonly lie motionless, but are capable of being roused so far as to move a few steps; in some cases pigeons will fly when thrown into the air; they can always stand quite firmly. Indeed M. Flourens, (who kept pigeons in this state for periods varying from a few weeks to ten months) states that they are in every respect like an animal in the profoundest natural sleep, absolutely without

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*Recherches exp. sur les propriétés &c du systeme nerveux p. 219

dreams

But after these portions of the encephalon have been removed the limit is attained in this direction; for the medulla oblongata is of the utmost importance to life; injury to it being immediately fatal, as was long ago shewn by Galen. Le Gallois was the first to shew that the dependence of life on this part of the nervous system was owing to its being the seat of the associated movements of respiration. This view has been still further carried out by Flourens, who has shewn that a space from immediately above the origin of the pneumo-gastric nerve to about two or three lines below it is the centre of reflexion for all the movements of respiration. That this does not depend on any thing in the pneumo-gastric nerve itself, however, is demonstrated by the section of that nerve on both sides of the neck; a proceeding which an animal will survive many hours while the injury of the medulla is immediately fatal by asphyxia.

Hence we draw the conclusion, that the fatal effect of removal of the encephalic portion of the nervous centres is due to a suspension of the respiratory movements; the only part necessary to which, however, is a limited portion of the medulla

oblongata

2 Of the Spinal Cord

Le Gallois believed that as the medulla oblongata was the centre of the respiratory power so the Spinal cord was the seat of the heart's motory power * He considered the heart as deriving its power not from any one portion, but from the whole of the spinal marrow, through the sympathetic nerve, and conceived that he had proved that its motions were necessarily enfeebled by the removal of any considerable portion of the cord, and instantly abolished by its entire destruction. But the evidence on which Le Gallois' view was founded was otherwise explained by Dr Wilson Philip †, who, in addition afforded experimental proof, that, both in warm and cold blooded animals the whole of the cerebro-spinal centres might be removed without interfering with the circulation, provided that artificial respiration were kept up. Of course the conclusion that death by syncope is a necessary result of the removal of the nervous centres falls to the ground.

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* Le Gallois Experiences sur le principe de la vie

† Wilson Philip on the laws of the vital functions p. 69

In fact it is sufficiently evident, from experiments on animals, that section or removal of the spinal cord is fatal by first arresting the respiration and so producing death by asphyxia; and that the power of the spinal cord over the respiration is solely due to the various respiratory nerves which arise from the upper two thirds of it, and maintain, through it their connexion with the medulla oblongata. By far the most important of the respiratory nerves are the phrenic, which arises from the third and fourth cervical, and the intercostals, or anterior divisions of the dorsal nerves; to which may be added as completing the set the ilio-inguinal branch of the first lumbar nerve. The others, including the spinal accessory, and the portion thoracic (nerve of the serratus magnus) may be considered as accessory nerves of respiration, only used in strong inspiratory efforts when the shoulders are elevated and thrown back..

In conformity with what we know of the origins of these nerves we find that a section or disorganization of the spinal cord in its lumbar portion, although it produces paralysis of the bladder and the lower extremities,

does not necessarily involve life; because the parts thus cut off from the influence of the rest are not of vital functional importance, and none of the respiratory actions are involved. When the section is made about the seventh dorsal vertebra, the abdominal muscles are paralysed, but the inspiratory muscles remain intact.* At various points between this and the middle of the neck the intercostal nerves of inspiration will be more or less involved, the espiratory muscles as in the last case, inactive, and the acts of coughing, sneezing &c impossible; the inspiration will, however, be continued by the diaphragm, the sterno-mastoid, and trapezius muscles, and perhaps by the serratus magnus† although this state would be very apt to be fatal after a time by a gradual asphyxia particularly if any cause of obstruction to the bronchial tubes existed. If the injury be above the origin of the phrenic nerves, it is necessarily very rapidly fatal;‡ the spinal

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* Longet Systeme nerveux I 283 † Sir Charles Bell on the nerves; case of Percy Ward p 225; appendix to do - Case of Palmer p 124. Flourens Recherches &c 2d Ed. p. 178 ‡ Flourens Recherches &c Bell op. cit. case of James Sanders p 231

accessory being quite inadequate to keep up the respiratory movements: But nevertheless there are facts which shew that in some cases, where the diaphragm is partially paralysed, the respiration may still continue for a short time by the action of the sterno-mastoid, trapezius, and serratus magnus. (See a case of ramollissement of the cord by Abercrombie,* Case (XXVII). Of course a section involving the cord immediately below the medulla oblongata, gives rise to as rapid dissolution as a wound of the medulla itself, and in the same way.†

From the above observations we see clearly that the main tie which connects the nervous function with the general life of the animal is to be found in the influence of that function on the respiratory movements. It may also be inferred that when a fatal effect is found to take place in this way, from causes acting by the simple removal of the nervous influence, the seat of the lesion is to be looked for principally in that part of the nervous matter lying between the middle cervical region and the origin of the pneumogastric nerve; or, at

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*Diseases of the Brain and spinal cord P IV Sect 2. † Flourens op. cit. Bell op. cit. p 233, 4 (Dislocation of the processus Dentatus)

least it is clear that such an effect would not be physiologically explained by referring it to a cause acting either above the medulla oblongata or below the dorsal portion of the cord.

These observations, of course, relate only to those forms of injury which without any active interference with function interrupt the chain necessary to the transmission of reflex or other impressions, and thus deprive certain organs of their normal stimulus. We shall afterwards have to notice the fact that particular forms of nervous injury have the power of influencing functions not directly dependent on the cerebro-spinal centres; as is known to take place particularly in regard to the Heart in that kind of lesion which will presently be described as producing the condition of nervous shock or concussion. It will be better also to delay till the end of this chapter the consideration of a dilemma which presents itself vividly at this stage of the inquiry; but which has nevertheless, received much less attention from physiologists than its importance and interest demand. If the organic life were dependant upon the animal functions solely through the medium of respiration, (a process which we can

render quite independent of nervous influence by means of artificial inflation of the lungs) then it would naturally follow that we have in our hands the means of prolonging life indefinitely, even in the absence of the nervous centres; a conclusion which is certainly unwarranted by facts. Le Gallois* showed that when an animal was decapitated and the vessels tied, the immediate reason for the death of the trunk was defective respiration; and he ascertained that life might be prolonged for a considerable time by careful inflation of the lungs. Sir Benjamin Brodie†, who, about the same time announced a similar observation to the Royal Society of London has pushed the inquiry a step further than Le Gallois, by shewing the effects of decapitation upon the animal heat and some of the organic functions, and demonstrating that life could not be prolonged more than a few hours even by artificial respiration. I am not aware that the questions suggested by his researches have been fairly and adequately discussed, or that the general inquiry mentioned above has been conducted to any satis-

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* Introd. to the Exper. sur les principes de la Vie. † Philos. Transact. 1811.

fectly satisfactory conclusion. On this account I shall place this subject last in the present chapter; although there are several inferences which appear to flow from the researches of Brodie and Chossat which are too important to be passed over

I have not said any thing, in the preceding remarks, on the sympathetic nervous system; for although the study of that system may be expected to furnish results most important to the present inquiry, its relation to the cerebro-spinal system is as yet too imperfectly understood to justify our application of this department of Physiology to the investigation of the subject of death otherwise than by a few isolated speculations.

§ I *On the modes in which general death may supervene upon lesions of the nervous system and of its functions.*

The mode in which merely local lesions of the nervous structure may be important to the other functions through the respiration has been investigated in the preceding remarks; the object of this Chapter is to investigate the causes which act with somewhat of general effect upon the nervo-

ous centres, and the nature of the lesions thus produced. Such lesions may be described as of two great kinds; the first comprehending those which arise from circumstances acting ostensibly on the nervous matter, in which the abolition of function is co-extensive with the action of the cause, and leads ultimately (upon principles already laid down) to interference with the respiration; the second including those lesions which are universal, whether produced by atonal or general injury, and which affect functions not directly dependant on the nervous centres. Under the former of these heads, or the simple form of nervous lesion, the important subject of death by Coma will come to be considered; the second or diffusive form involves the investigation into death by nervous shock

A Of the simple form of general nervous lesion. Coma.

The distinctive character of the condition now to be discussed is to be found in the fact that its phenomena are in all cases those of simply impeded or interrupted nervous function, and are therefore merely the more extended or general form of the local lesions

already described; and that there is no tendency to the implication of functions which are not under the direct control of the nervous system. As a consequence of this essential distinction we have this apparent or symptomatic character of such lesions; that up to the moment of death the action of the heart continues strong and is only stopped at last by the establishment of Asphyxia, in consequence of the failure of the respiratory movements. Accordingly we must keep in view the Physiological fact that the fatal effect, in the cases now under consideration, is to be looked for from some cause acting on the medulla oblongata or upper part of the spinal cord; and although there may be some difficulty in illustrating this fact from every individual instance we are still bound to conclude that the exceptional cases are not real, but only seeming departures from a law which we know to be very general

These remarks being premised as to the most essential facts to be observed when the suspension of the nervous functions occurs in this form, there are several remarkable

circumstances which demand notice in regard to the phenomena of this condition when the causes producing them are of such a nature as to act upon the whole nervous centres as uniformly as possible

It is of great importance to remark, in the first place, that, in this form of lesion, the symptoms are always progressive and gradual in their mode of accession, and never attain their maximum at the first moment of invasion. The progress is often most distinctly marked — beginning with the slightest possible impairment of the normal activity of function, and proceeding, without sudden accessions, until, many of the other functions having been previously affected, the respiration becomes perceptibly slower; then, very gradually, the blood is imperfectly aërated, and, according to the principles already laid down, arrested at the lungs and only when this takes place, is the complete suspension established of any function animal or organic

In the next place it is to be observed that the train of symptoms has a definite succession, invariably beginning by affecting the conscious-

ness, and, only afterwards, the reflex motion. This fact is extremely well illustrated by the phenomena of narcotic poisoning; but it also occurs very distinctly in other circumstances, when the exciting cause of the symptoms may be supposed to be general and uniform in its operation on the nervous system. The mental functions are the first to suffer; there is stupor more or less profound, and gradually increasing; the sensibility to light and sound is diminished; the pupils are generally dilated, unless where febrile irritation is present; and the general sensibility is also impaired; all the symptoms being like the deepest natural sleep, or like the condition of animals in which the cerebral hemispheres have been removed (see p 123). Afterwards there is complete insensibility; the body lies relaxed and powerless; the faeces and urine are passed involuntarily; the breathing is slower, and sometimes stertorous, from a relaxed condition of the velum pendulum palati; but the pulse, although perhaps less frequent than natural, continues strong at the wrist. The symptoms are now consummated by the gradual supervention of asphyxia

as before stated, and death follows the obstruction of the circulation at the lungs

It is convenient to designate this train of symptoms by the general name of Coma; and it is important to observe that in the most purely comatose cases there is no evidence whatever of any degree of excitement; and although such excitement sometimes concurs with these symptoms, it is not to be considered as the natural concomitant of this form of nervous lesion. That death is produced in the manner stated is proved by the fact, that when the cause of coma is transitory life may be prolonged, when death is imminent, by means of artificial respiration; as was shewn by Sir Benjamin Brodie in the case of the Woorali and various other narcotic poisons*. It is also to be observed that the succession of symptoms in pure coma is exactly that produced in the experiment of Flourens by removing successive slices of the nervous matter from above downwards until death is produced by interference with the medulla oblongata. There is, therefore, the strongest reason for assuming as a general

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* Philosophical Transactions of Royal Soc. of London, 1812.

law that the impressibility of the nervous system by the effects of deleterious influences acting uniformly upon its substance is first manifested in the cerebral lobes, and afterwards regularly downwards towards the spinal cord.

The causes of coma have been very variously stated. It is evident that the greater part of the narcotic poisons act more or less as such by a specific deleterious effect on the nervous system; although their action is often to a certain degree local and partial, and in one instance (strychnia) appears to affect exclusively the spinal cord, and to produce death, not by suspension of function but by excessive and exhausting irritation. It is also well ascertained that the effect may be modified by a simultaneous action on other functions, particularly the heart, as in the case of tobacco, digitalis and even hydrocyanic acid; but the mode of the action, in these cases, is not so clearly understood, as it may either be a nervous affection (as will afterwards be seen) or an effect produced upon other tissues

Besides this specific action of various substances on the nervous system there are many injuries

and other pathological conditions of the brain and spinal cord, in which coma is either an essential part of the symptoms or a very common concurrent phenomenon. The different kinds of apoplexy, if we except that kind called the apoplexia fulminans of the older writers evidently produce death in this way; and similar phenomena are observed, in various other morbid states, in which the cavity of the cranium is encroached upon by foreign substances, either intruded from without, as in the case of depressed bone, or arising within the cavity itself, as happens with various cerebral tumours, or the effusions consequent on inflammation of the brain and meninges. It is difficult to understand how all these causes act in producing the general effect observed from them; more especially as many of the disorganizations of the brain, which produce this effect, act at a considerable distance from the part which, as we know from physiological considerations, must be involved. But the following remarks appear to me to afford grounds for supposing that many of them may be referred to a general law.

There is no difficulty in explaining how causes which prevent the due nutrition of the

nervous texture should interfere seriously with its function. It will be recollected that the capillary system of the brain and spinal cord is very extensive and contains a very large proportion of the blood in these organs; and that the blood is collected almost directly from the nervous substance into the large venous sinuses of the dura mater and into the veins of the pia mater and the medullo-spinal veins which form an intricate interlacement around the body of the cord. Now it is sufficiently clear that it is only the portion of the blood contained within the capillary system at any particular moment which is available for the purposes of nutrition; and accordingly the activity of the nervous function must be very considerably affected by any thing which tends to diminish the absolute quantity of blood in these capillaries, to retard its motion, or, in any other way, to interfere with the free and rapid performance of the nutritive changes occurring in these vessels. Hence we are able to explain the effects of stagnation of the blood the consequence of obstruction to the venous return; a state well illustrated by those cases, principally occurring in a very asthenic state of the system, where the blood has spontaneously coagulated within

the sinuses, and death has taken place by coma*. There is little doubt that similar effects would follow a complete obstruction to the venous return in the neck; and the fact that the jugulars may be tied in the dog and rabbit almost with impunity, is no proof to the contrary, because in these animals such an operation causes scarcely any material obstruction from the freedom with which the vertebral veins and other anastomosing vessels carry away the blood from the head. A similar effect might certainly be expected when the arterial supply is interrupted; but I shall afterwards adduce ample proof that the effect of this injury is of a different kind, not dependent on the want of blood in the capillaries, but on the removal of the homostatic pressure.

Alterations in quality of the blood passing through the capillaries of the nervous centres, if such as to render it unfit for purposes of nutrition, also produce all the symptoms of coma. This is, I think, clearly seen in the early stages of asphyxia, where no change has taken place in

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* Williams, principles of Medicine on Anæmia, p 127. Copland Med. Dict. Art. Brain § 40. 41

the circulation except the presence of dark blood in the arteries, and where accordingly we have the suspension, first of sense and voluntary motion, and afterwards of respiration — the phenomena in short of coma but with unusually rapid succession of symptoms. This subject will be resumed hereafter.

To understand properly the conditions which may produce alteration of the quantity of blood in the capillary circulation, it is necessary to advert to the peculiarities which attend the circulation of blood in the cerebro-spinal centres from the circumstance of their being shut up in a close cavity of fixed dimensions, and lined with a firm membrane; and this may be made sufficiently clear upon physical principles. It is manifest that in a cavity of this kind the entire volume of contained matters (solid and fluid taken together) must be, like the dimensions of the cavity itself, a fixed quantity; always supposing the space to be kept constantly full, as it certainly is in the case before us. Now the normal solids of the cranio-vertebral cavity are these — nervous matter, the coats of the vessels, and membranes covering the whole; the fluids

are blood, and extra-vascular serum, with which latter is included the cerebro-spinal fluid. The united volume of these must of course be at all times determined by the dimensions of the containing cavity, and therefore invariable. If the solids continue unchanged in bulk, as under ordinary circumstances is probably the case, then the entire bulk of the fluids must also remain the same; but the relation of the extra-vascular to the intra-vascular fluid may nevertheless vary, and the blood itself may alter in its relative distribution, and may predominate in one set of vessels at the expense of the rest.

These facts, in themselves simple and mathematically certain, are illustrated by the experiments of Dr Kellie† of Leith, which shew that the brain of an animal may be completely drained of its blood by general blood letting if an opening be made through the dura mater so as to admit the atmospheric pressure and allow of the shrinking in volume of the mass within the cranium; while this is not the case to the same extent if the external coverings of bone and membrane remain entire. In 1843 Dr Burrows published some experiments to prove

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the possibility of over loading or depleting, to a certain extent, the vascular system of the Brain*: and he directs attention to the circumstance, too much overlooked by Dr Kellie, that changes in the amount of the cerebro-spinal fluid may occur as a compensation for depletion of the vascular system. This circumstance was indeed pointed out most distinctly by Dr Seeds‡, so far back as 1816 in experiments which on this point, are far more satisfactory than either of those already cited, although performed with no special view to this subject. The extreme rapidity with which the volume of extra-vascular fluid may be increased is indeed most remarkable. Thus in an animal (Exp. 6) bled to death in ten minutes by opening the jugulars there were the following appearances "the lateral ventricles contained a great quantity of water" — the brain and plexus choroides were depleted — "the sinuses were

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† Edin^r Med. Chir. Trans. Vol I, 1824 * Medical Gazette April 1843. I do not think it necessary to refer to the discrepancies between Dr Burrows and Dr Kellie; they are not irreconcilable to an attentive reader. ‡ Med. Chir. Review April 1816, Also Med. Gazette Vol V p 423.

quite bloodless – no serous blood was to be seen in any part of the vertebral column". In another animal (Exp. 8) the abdominal aorta was divided, producing death in six minutes: "the dura mater cerebri was moist and some few red vessels were ramified through it. Vessels, red and blue, were conspicuous in the other tunics; the plexus choroides was pale; the ventricles were moist, the 4th full of serum, a good deal of which was effused around the optics, the accessories and the 8th pair. The greater sinuses were full."

This view of the circulation in the brain tends to explain the circumstance that serous effusion may exist, as was insisted on by Abercrombie, to a large extent, without derangement of the functions of the brain; while in other cases it is found accompanying the apoplectic attack. For there is little doubt that in old age, and in some forms of disease, the solid substance of the brain becomes, to a certain extent, atrophied; in which case serous effusion takes place, and, by filling up the vacant space, prevents the vessels from being over distended and thereby the normal state of the circulation in the remaining nervous matter is continued. But in hydrocephalus and serous apoplexy the production of

serum is distinctly morbid; and being necessarily followed by a diminished amount of blood in the capillaries & vascular system generally, the nutrition is impaired and symptoms of coma supervene. In the state denominated "compression" of the brain, occurring from tumours or in fracture with depression, the cause of the symptoms is in all probability the same: the cavity is encroached upon by a foreign matter and room is gained by the exclusion of a portion of the nutritious fluid; the consequence is that the symptoms are not confined to the part immediately in contact with the foreign body, but extend more or less generally over the nervous substance, and so produce true coma. It is at least evident that in such a case there can be no true permanent increase of pressure on the general nervous substance, for the encroachment on space properly occupied by cerebral matter can only have the effect of causing absorption of the fluid of the ventricles, or emptying of the vascular system.

But further I think it is every way probable that the capillaries of the nervous matter may be affected per se. The effect of any cause acting so as to diminish the space in the capillary system

would probably be to throw the blood on the venous or arterial systems, thus producing that peculiar state of derangement which Dr Abercrombie supposed to be concerned in simple apoplexy. If there be any thing of truth in Cullens pathology of fever, "the spasm of the extreme vessels" would account for much of the peculiar tendency to head affection in that disease. The derangement of the actions of the capillaries also in inflammation and in ramollissement of the brain (a morbid action which may very well be conceived to be more widely extended than the apparent disease) is probably the reason why the general action upon the nervous system may be fatal before there are any local indications of pressure from effusion

The effect of hemorrhage within the nervous substance must be to empty the capillaries around the point where extravasation has taken place; but the first effects of this lesion are usually not referrible to this circumstance, but rather to the sudden change in the local tension of the vascular system

Lastly, there is no doubt that the phenomena of coma are often produced under circumstances which cannot be explained in any of the ways

now stated; indeed the whole subject is one of great obscurity as well as intense interest to the pathologist

B. Of the diffusive form of general nervous lesion. Nervous Shock.

We have now to consider a condition of the nervous system corresponding with that of coma in the general suspension of function, but differing materially from all the lesions already considered, general and local, both in the way in which the organic life becomes affected, and in the mode of suspension of the nervous functions themselves. This state I shall call Nervous Shock as being its most descriptive title; but it presents itself under various forms to the medical practitioner, and is recognized by him under the names of concussion and collapse. Its mode of origin will presently be adverted to

The most essential peculiarities which serve to distinguish the nervous shock from the general and local lesions before mentioned are the following: 1st the equal disturbance of all the nervous functions whether the exciting cause be general or local, whether applied to the most essential or the least essential parts of the nervous substance; 2d the simultaneous disturbance of all the functions, and the

entire absence of the gradually progressive character which so generally marks the symptoms of coma; 3dly the peculiar tendency, observed in this affection, to depression of the heart's power and consequent syncope, with the symptoms which have been described as attending that state; the weak, fluttering pulse, the slow, often imperceptible respiration, the coldness of surface, and utter prostration of all vital action. The law of this form of nervous lesion may accordingly be said to lie in its diffusive character, or in other words, in the fact, that the depression of function is sudden and universal, and presents no variation of character according to the seat of the injury. The effect is usually transient, being either powerful enough to produce death at once, or ending in the rapid return of function; unless it be prolonged by a succession of shocks similar to the first in character, and acting in the same way; in which case the sensibility and voluntary motion may not return for a considerable time. But in such case the symptoms are usually marked by Emissions and relapses, which, when they are at all observable, are very distinct in character from the gradually progressive symptoms of coma; and the feeble action of the heart, even from the very first attack, serves to

complete the distinction

All these peculiarities are well illustrated by the manner in which mental emotions often affect the nervous system; and indeed this form of lesion is invariably observed to arise from some cause acting <u>strongly</u> and <u>suddenly</u>, either directly on the nervous matter or its function. The first recognition and verification of this principle was by Wilson Philip who shewed that although the removal of the nervous centres might be accomplished without affecting the circulation (artificial respiration being kept up); yet that the sudden destruction of any portion of these centres at once had the effect of rendering the heart's contractions feeble and intermitting. That the particular portion of nervous matter so destroyed is of no consequence to the general effect is well shewn in the following experiment which may be quoted from Dr Wilson Philip as an illustration of the facts which he adduced to shew "that the heart although its power is independant of the brain and spinal marrow is capable of being influenced through these organs". "The thorax of a large frog was laid open and the motion of the heart observed, which performed the circulation perfectly and with great force. The brain was then crushed by the blow of

a hammer. The heart immediately performed a few quick and weak contractions. It then lay quite still for about half a minute. After this its beating returned, but it supported the circulation very imperfectly. In ten minutes its vigour was so far restored that it again performed the circulation with freedom, but with less force than before the destruction of the brain. An instrument was then introduced under the heart, and after ascertaining that this had produced no change on its action, the spinal marrow was crushed by one blow, as the brain had been. The heart again beat quickly and feebly for a few seconds and then seemed wholly to have lost its power. In about half a minute it again began to beat, and in a few minutes acquired considerable power, and again supported the circulation. It beat more feebly however, than before the spinal marrow was destroyed. In another frog, after the brain and spinal marrow had been wholly removed, the heart beat nine hours, gradually becoming more languid."

An attempt has been made by several physiologists, and especially by Dr Calvert Holland* to shew that the whole of the effects which are here enumerated are to be referred, not to a primary

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action on the nervous centres, but to a derangement of the circulation resulting in too great an accumulation of blood within the heart, which ceases to contract from over-distension. But in answer to this it is sufficient to mention that similar derangements in other parts of the circulating system, as when the abdominal aorta is tied, produce no such effects; that causes which undoubtedly act on the nervous system produce this concurrent effect on the circulation, as in the case of mental emotions; and that many diseases of the nervous system preeminently dispose to such a result, as well as those of the circulating system in which the mechanical phenomena of Syncope take place. Indeed it is quite clear that no considerable derangement of the circulation does or can take place in such experiments; and the accumulation of blood in the heart may be quite as reasonably explained by supposing it the effect, as by considering it the cause of the paralysis of the organ

We assume then as a fact that a condition of the nervous system such as is described in

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* Inquiry into the laws of organic and animal life p. 263

the beginning of this section, actually exists; and that in this condition the heart is invariably more or less affected simultaneously with the other functions; indeed that a certain amount of effect on the pulse is often manifest when the intellectual faculties and reflex functions are still nearly entire. The rationale of this effect on the heart cannot be profitably discussed in the present state of our knowledge of the nervous system, and we are therefore content to recognise it, for the present, as an ultimate fact in physiology. It is interesting to remark, however, that part of this influence is exerted through the medium of the pneumo-gastric nerve; as Dr J. Reid, in his experiments on that nerve found that when it was divided on both sides of the neck, the effect of the brain on the heart was produced with much greater difficulty.

The diffusive form of nervous lesion seems to be prone to follow injuries in the direct ratio of the amount of nervous matter involved, and of the violence and suddenness of the injury. The functional importance of the injured part is not at all concerned in the primary effect but may afterwards modify the phenomena by preventing a recove-

ry which, under these circumstances would have
taken place

It is not however direct injury to the nervous
centres which alone produces this form of lesion;
various other causes act in a similar manner
giving rise to sudden depression of the heart's ac-
tion. As the phenomena are substantially the same as
those of Syncope, formerly described, it is unnecess-
sary to occupy space with their detail; but the causes
of syncope when produced in this manner are impor-
tant to be considered.

The phenomena of the "collapse from injury",
which is essentially a form of the diffusive nervous
lesion, are probably due to the violence of the im-
pression on the sensorial functions acting like a
sudden injury upon the nervous centres themselves.
It is observable that all very violent and exten-
sive impressions, on the sensory nerves have a tendency to produce this con-
dition; while the motor function may be very
strongly and generally irritated, as in tetanus, without
any such tendency. The effect on the heart is also pe-
culiarly apt to take place from such injuries as
excite strongly the sensations of those parts sup-
plied with nerves from the sympathetic system;
and hence the effect of a blow on the abdominal

parietes and particularly at the epigastrium. To the same cause we are to refer the peculiarly powerful depressing effects of inflammations or injuries of the peritoneum which are attended with the most agonizing sensations and are often fatal in a few hours from the first attack.

Mere bodily pain when very intense, without any disorganization of texture or inflammation, may undoubtedly produce a state of collapse, and even rapid death, just as in the case of the most violent injuries. To this cause is to be ascribed the rapid sinking of persons under the rack and thumb-screws of ancient times; and from time to time instances occur of death from long protracted parturition, which can be ascribed to no other cause* The primary effect of burns, one of the most frequent kinds of rapidly fatal collapse, is described by Mr Travers to be greatest where a large extent of skin is involved; "where the cuticle, rovelled up into rolls, like wetted paper, leaves the living cutis bare† The effect of opium, in such cases, in relieving the

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* See a letter from Dr Cooke in Travers on constitutional irritation p.68 † Id Opus p.103.

nervous system from the strong impression and consequently increasing the strength of the pulse, is well known.

The state of collapse produced in any of these ways may last for a considerable number of hours, if the cause shall continue to act. In some of these cases it is not difficult to observe a succession of shocks with intervals of remission, not indeed very well marked, but sufficiently so to be observable; indicating the tendency to restoration of the nervous function, which is arrested by the renewed effects of the irritation upon the sensorium. But at last the period of immediate danger passes over, reaction comes on, the consciousness is restored, and the pulse becomes strong, the suddenness of the impression having passed away. Sometimes, however the first shock is fatal, and the patient sinks prostrated without reaction.

The effect of concussion of the brain by a fall, which communicates an impulse to the whole body, is very like that of collapse, and is evidently due to the suddenness of the shock communicated at once to the whole nervous system. Emotions of mind or sudden fits of passion may have especially similar action on the heart: and that they may some-

times be even fatal is illustrated by several remarkable examples given by Mr Travers. In one of these a man affected with femoral aneurism but otherwise in good health, was operated upon, and died during the operation; and in this case it is remarkable that the heart presented after death the same entire emptiness which was observed in Mr Chevalier's cases (see page 91 of this essay). The transition from pain to ease which so frequently causes syncope may also cause death. Sir Astley Cooper saw a man die in this way after the opening of a whitlow *

Syncope is often produced by the sudden removal of causes which have excited symptoms of compression of the nervous matter. Thus drawing off the hydrocephalic fluid, or the elevation of a depressed bone which has induced comatose symptoms, will often bring on this condition. The effect may be in part due to the change of pressure in the parts of the brain which are in contact with the compressing substance, but has also probably some connexion with the increased flow of blood into the organ and consequent sudden renewal of function. The effects

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* Travers on constitutional irritation, pp 24.25

of suddenly diminished homostatic pressure will be spoken of under the next head as they are remarkably important in reference to the theory of primary syncope and asphyxia

§ II Of the modes in which the nervous functions are affected in primary syncope and asphyxia

We are now in a position to examine into the question - what is the condition of the nervous system when syncope and asphyxia are produced by causes acting purely on the heart and respiratory organs, the cessation of the nervous function being entirely secondary?

It has already been intimated that the first stages of asphyxia, occupying about two minutes from the time of the respiration being obstructed, present an example simply of altered quality of the blood circulating in the nervous centres. Bichat was the first to direct attention to this vitiation of the blood as a probable cause of the arrest of the sensorial functions, and his view in this respect has been borne out by later inquiries particularly those of Dr Reid, in which it is established that the time of the completion of insensibility corresponds very closely with the period when the blood acquires

the completely venous character. The kind of nervous lesion also corresponds with the supposition that the alteration in the constitution of the blood is the cause of the first symptoms; for the progressive suspension, first of the sensibility, and then of the reflex action, has all the characters of the attack of true coma, which on the other hand is often known to follow alterations in the quality of the circulating fluid.

But such vitiation of the blood may tend to produce coma in one of two ways; either by exerting upon the nervous system a positively deleterious influence like the effect of a narcotic poison; or by being simply inconsistent with the due nutrition, and consequently with the functional activity of the nervous matter. Bichat* observed that the injection of black blood into the carotid artery has the effect of suspending the functions of the brain while arterial blood or water produces no such effect; and if this observation could be substantiated, it would certainly prove that the ve-

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* Recherches &c P. 2 art 7 Bichat certainly seems to have experimented with considerable care and with full consciousness of the effects of pressure See Art II

nous blood has something more than a negative influence. Dr Kay, on the other hand, rightly suspecting that Bichat may have erred by using too much force in injecting, repeated the experiment, and found that, with sufficient care, about four drachms of venous blood may be injected towards the brain of a rabbit, through the carotid artery, without producing deleterious effects.* It may however be, in turn, objected to Dr Kay's experiment that the quantity injected is much too small to bear any analogy to the large influx of venous blood into the nervous system when respiration is interrupted. Accordingly while we have, on the one hand, not sufficient proof that a poisonous action is exerted on the nervous centres by venous blood, it would, on the other hand, be improper to assert dogmatically that no such effect takes place; although the exceedingly rapid restoration of function when the proper kind of blood is restored, goes far to support the idea that the impaired function is due to imperfect nutrition and ceases when that cause ceases to act

Dr Kay maintained that the insensibility in asphyxia was owing in part to diminished quantity of the blood, and partly to its defective power of stimu-

lation. But the former of these two conditions cannot now be admitted to be a cause of this first part of the phenomena; because experiments with the hæmadynamometer have distinctly shewn that for about two minutes after insensibility is complete, the pressure in the arteries is "even greater than at the commencement of the experiment."* Afterwards, indeed when the obstruction at the lungs begins to operate, both the amount and the static force of the column of blood are very much diminished; so that these circumstances are not to be overlooked in accounting for the phenomena of the later period of Asphyxia We shall presently see how they may be made to bear upon it

If we now advert to the phenomena of pure syncope, such as is produced by tying a ligature round the base of the heart, we may observe, that the arrest of the nervous phenomena is instantaneous and universal; and, unlike the first changes in asphyxia, presents all the symptoms of the diffusive form of nervous lesion. We observe also that the diminished pressure (which in asphyxia does not occur till during the third minute) is in syncope

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* Reid's article on Asphyxia before quoted p 446

the first material alteration being a direct consequence of the removal of the vis a tergo.

The investigation, therefore, of the precise consequences ~~effects~~ of the removal arterial pressure from the nervous system, as regards the strength of the circulation, seems to be important both in relation to the phenomena of syncope, and also of the latter stages in asphyxia. ~~In the first of these I will briefly request leave to state~~ that these are many circumstances which tend to shew that the alteration of pressure on any part of the nervous system is followed by symptoms characteristic of the diffusive form of lesion; as for instance in the case of the rapid removal of the ascitic fluid which is well known to be apt to produce fainting; because by allowing of a more free passage of blood through the great abdominal vessels, the circulation is suddenly deranged, and the impetus in the vessels of the upper part of the body is diminished. The effects of drawing off effusions of fluid within the cranial cavity have already been spoken of

But by far the most decisive mode of attaining information on this subject, is by directly cutting off, in an animal, the arterial supply of some portion of the nervous system. This is precisely what Sir

Astley Cooper* did in the case of the brain by ligature or compression of the carotid and vertebral arteries. In this way the brain is placed in very nearly the same position as in complete syncope with the exception that the heart is not primarily affected; and thus we are enabled to trace the effects on the nervous system and on the organic functions with the greatest accuracy

Sir Astley Cooper found that the consequences of ligature of all the four arteries going to the Brain differed slightly in different animals. In the rabbit the effects were extremely sudden; there were violent convulsions; in a few seconds the respiratory movements entirely ceased, and the animal lay quite deprived of motion and consciousness. Similar effects followed from compression of the arteries with the thumbs; but he found that recovery took place after apparent death if the compression were instantly removed; and that this experiment might be repeated many times on the same animal within a few hours

The Dog, on the contrary survived in one instance the ligature of all of these arteries "within half an

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* Guy's Hospital Reports, Vol. I.

hour". On dissection, nine months after, it was found that very free anastomosis had been established by means of the superior intercostal arteries, the thyroids, and the principal arteries of the neck. The immediate symptoms, however, were insensibility, difficulty in breathing, dilated pupil, and diminished volition so that "it ran against the leg of the table or any other body, without seeing or regarding it" and "when placed on its legs it fell down on its right side and had spasmodic twitchings of the hinder extremities".* This state continued some hours. Sir Astley Cooper also established that these results, whether in the dog or rabbit, are principally due to the arrest of the circulation through the vertebral arteries; for he found that both carotids might be tied without materially discomposing the animal, of the other arteries were left intact. He shewed moreover that all the other important structures in the neck might be included in a ligature without any such instantaneous symptoms

From his experiments, Sir Astley Cooper

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* Guy's Hosp. Rep., Vol I, p. 458

concludes that death takes place in the rabbit, and the symptoms described above occur in the dog, from the obstruction of the arterial supply to the medulla oblongata and consequent defect of respiration; and that in the latter animal the circulation is rapidly restored by the other branches of the subclavian artery communicating with the vertebral in the neck.

It appeared to me, however, of importance to determine the exact effect of this operation on the motion of the heart; as the symptoms, particularly the immediate loss both of voluntary and reflex movement, seem to correspond much more closely with the diffusive form of nervous lesion than with coma or merely obstructed respiration. An excellent opportunity seems to be afforded by this experiment for observing the effects, upon the circulation, of diminished static pressure on a considerable portion of the nervous system, uncomplicated with any vascular lesion which would be in itself adequate to account for sudden syncope.

My experiments were performed on rabbits, because as the operation is in them directly and invariably fatal. I thought the results were more likely to be decisive than in the dog, which appears to have less susceptibility of impressions of this kind.

I shall first note three experiments in which the carotids were tied, and afterwards the vertebrals compressed by the thumbs planted firmly upon the transverse processes of the last cervical vertebra; the state of the circulation as indicated by the impulse of the heart being meanwhile minutely observed. It should be remarked, that in all these experiments, the frequency of the pulse and respiration is noted by the quarter-minute; and the rate of the pulse was usually remarked both by myself and others[+] several times before the experiment was begun, in order to insure against fallacy from its great rapidity and variableness: the pulse in the rabbit when the animal is placed on the table ranging from 120 to 150 beats in the minute, or even higher in some cases. In no instance was any very decided change produced by tying the carotids; the quickening of the respiration alluded to by Sir A. Cooper was certainly not observed, although this point was particularly attended to.

+ I was more particularly assisted by Mr Nicholson, Mr Peltier, Mr Smith, and others of my fellow-students.

Experiment 1st

A moderately large rabbit. At the commencement of the experiment, the pulse was noted — about 32 beats in the quarter of a minute, and the respirations 26 in the same space of time. The Carotid arteries were then tied, and after this the pulse was 38 — the respirations 17 or 18. The functions of the animal were not at all impaired.

The vertebrals were then compressed on both sides of the vertebral column, the trachea being carefully excluded from prepare. A few convulsive gasps followed, and in 20-30 seconds there were violent convulsions of the whole body. On the ceasing of the convulsions at 1 min. after compression, the pulse was 16 per ¼'; the nostrils had ceased dilating; there was no movement.

At 2 minutes from compression of vertebrals the pulse was 34; body motionless — no respiration.

At 2½ minutes — P 41

— 3 minutes ——— P 41 — very weak

— 4 minutes ——— P 33

— 5 minutes ——— P 29 Heart beating much weaker

At 6 minutes the beat of the heart was intermitting; at 7 minutes it was 12, very weak and intermitting;—

in a few seconds more it had ceased to be felt

The thorax was immediately opened. The heart was found to be motionless, with the exception of the auricles which still contracted feebly. On cutting open the pericardium, the ventricles began to contract slightly but without ex= pelling their contents. Both sides of the heart were full of blood; the right was rather more distended; the blood in the left side was not florid, but it was still of a different colour from the other.

Experiment 2nd.

A small rabbit. Before commencing the experiment — Pulse 40 per ¼ minute. Respirations 24 per do.

After tying the carotid arteries

Pulse 35 — Respirations 16.

Heart acting very strongly. The vertebrals were now compressed, and almost immediately violent convulsions followed.

In ½ a minute, ~~the~~ ceasing of the con= vulsions the pulse was gone. There were a few more movements but slower.

At 1 minute after compression of vertebrals, pulse intermitting and slow — could not be counted

At 1½ minutes – Pulse 44, weak. No respiration

— 2¼ minutes P. 40 to 45 very weak – slight motion of whiskers – another convulsion.

— 3½ minutes – Pulse scarcely perceptible.

— 4 minutes – Pulse ceased – motion completely gone

— 5 minutes – Slight thrill at the heart again.

— 6 minutes – Pulse again quite imperceptible – surface cold – no motion.

The compression was now removed, and after about a minute more the thorax was laid open. As a comparative observation the thorax of a rabbit asphyxiated by drowning was also opened. In this latter instance there was great congestion of the veins of the neck and of the intestines:– in the heart the right ventricle and auricle were found gorged with venous blood, – the left ventricle was empty and hard – being in fact spasmodically contracted so that its cavity was obliterated. In the rabbit which was the subject of experiment, the heart was found replete with blood in all its cavities, both sides being about equally distended; the auricles were still performing inefficient contractions,

and the ventricles pulsated slightly on exposure. The venous system was notably less congested than in the asphyxiated rabbit, and the lungs were somewhat paler.

Experiment 3rd

A small rabbit. At commencement

Pulse 33 per ¼ minute Respirations 22

After ligature of the carotids

Pulse 29 — Respirations 19.

Vertebrals compressed.

The pulse at the heart immediately ceased. Convulsions soon occurred as before and the respiratory movements ceased. At the end of the 1st minute the pulse began to be felt, but so small that it could not be counted

At 2½ minutes from compression. Pulse 42

— 3½ minutes — pulse 35, intermitting

— 4½ minutes — pulse disappeared

— 5 minutes, slight thrill at heart — very intermitting and cannot be counted

— 5½ min. pulse completely gone. Pressure removed.

The appearances on opening the body did not differ materially from those in last experiment (No 2)

It will be seen from these experiments, the results of which correspond with several others performed in the same manner, that immediately on compressing the vertebrals, the pulse at the heart becomes imperceptible, and the respiration is entirely ~~imperceptible~~ absent from the period of the convulsions. From this time the body lies quite flaccid and motionless; in one instance only I saw one or two slow movements of the extremities. The pulse generally recovers somewhat in about a minute, but it never becomes strong; ~~and~~ sometimes the heart gives merely a few intermitting beats, and then stops entirely. The time when it ceases to be felt is generally from 4 to 6 minutes after the compression of the vertebrals; but the contractility of the heart is not destroyed, for on opening the thorax it is still found acting feebly; and its contractions may be renewed by irritating it mechanically.

In all these respects the phenomena correspond very closely with those which present themselves when a large portion of the brain is crushed, as in Wilson Philip's

experiment quoted at page 150. The appearances on opening the body also favour the idea that death took place by syncope; the large quantity of partially darkened blood in the left side of the heart proving that it had ceased to contract from deficient power, and not from an obstruction within the lungs as in ordinary asphyxia; although the few feeble contractions which occurred after the respiration had ceased, sufficed to propel a quantity of venous blood through the pulmonary circulation into the left heart. This circumstance suggested the repetition of the experiments, artificial respiration being kept up; by which proceeding all possibility of death from asphyxia is obviated. This accordingly was done in the following experiments. In the first of them the deprepion of the heart's action was very remarkable, the impulse ceasing within 2 minutes

Experiment 4th.

A moderate sized rabbit. At commencement
Pulse 27 per ¼ minute. Respirations 16
After tying the carotids
Pulse 30 — Respiration not noted.
On the vertebrals being compressed, there were powerful convulsions of the trunk and extremities (opisthotonos) Half a minute after, the pulse was gone, and there were no respiratory movements. Artificial respiration was now applied by a tube inserted in the trachea.

At 1 minute after the compression, pulse returned but intermitting. At 1½ minutes there was a barely perceptible thrill at the heart, and within ½ minute more it was gone. Artificial Respiration was kept up till the 8th minute but without return of the pulse. The prepare was then removed, and the experiment discontinued.

On opening the thorax, the auricles were found pulsating pretty strongly. The heart was distended in all its cavities with blood, which on the left side was very florid, much more so than any previous experiment. Lungs pale,

integuments ecsanguine.

Experiment 5th.

At commencement, Pulse 33 per ¼ minute Respirations 17.

The carotids being tied, and a tube adapted to an opening in the trachea

Pulse 26 — Respirations 14.

On compressing the vertebrals the pulse could not at first be counted from convulsions. Artificial respiration was applied as soon as the animal was quiet.

At 1 minute from compression Pulse 16

— 1½ minutes — Pulse 6

— 2 minutes — Pulse 10

— 2½ minutes — P. 11

— 3 minutes — P 16

— 4 minutes — Pulse still 16

— 5 minutes — Pulse gone

— 6 minutes — heart still not perceptible Compression removed.

At 7½ minutes — heart not acting — inflation kept up till the 8th minute.

The thorax was then opened. The auricles were contracting feebly, both ventricles were

motion left and equally distended; the left contained quite florid blood

Experiment 6th

Pulse at commencement 39 per quarter-minute
Respirations 25.

The carotids were tied, and a tube inserted into the trachea, after which the pulse was 36-40, the resp. 24. Artificial respiration was now applied and the vertebrals compressed, with the usual effects.

Half a minute after — Pulse intermittent, but strong
2 minutes after compression — no pulse
Convulsions continue
3 min. — convulsions ceased, no pulse.
4 min — no movement — pulsation not returned — compression kept up till the 7th minute, when it was removed. Artificial respiration was discontinued at the 9th minute, after which the body was opened.

The heart, on being irritated, still contracted with tolerable strength. All the cavities were full of blood, which rapidly darkened in the left side as the contractions went on; the left ventricle seemed even more gorged than the right. On evacuating the auricles about 3 minutes after opening the

body, they were found both to contain dark blood.

In all these experiments the depression of the heart's action was quite as evident as in the former series; indeed in Experiment 6th it was particularly great and sudden. In all of them also the artificial respiration was quite ineffectual in restoring the circulation; but the florid appearance of the blood in the left side of the heart shewed that the respiratory chemical changes had been effected up to the last moment of life. In six experiments in which artificial respiration was applied, it only succeeded in prolonging life in a single instance; the details of which are worth relating to shew that here also the depression of the circulation was evident, although the disappearance of the pulse at first was not in this instance observed, owing to the violence of the convulsions.

Experiment 7.th

A moderate-sized rabbit. Pulse when ~~the~~ the animal was placed on the table 38-40 per ¼'. Respirations 14. In tying the carotids, the pneumogastric nerve was accidentally included on the left side. After the operation the pulse was rather stronger, and of the same frequency. Respirations about 12 rather laborious.

On compressing the vertebrals, convulsions ensued. At 1 minute after the compression, respiration had ceased; the pulse when felt for a few seconds together seemed to be gaining in frequency and numbered 26 per ¼'. Artificial respiration was then applied

4 minutes after compression - P. 40 feeble

9.th minute. Pulse about 36 stronger. Muscles of trunk slightly acting. Nostrils dilating.

12.th minute. Pulse 40, still not weak.

At 12½ minutes, the pressure was removed.

14.th minute Pulse about 40, perhaps slightly feebler.

18.th minute. ~~Pulse~~ Animal now breathing spontaneously. Respirations about 7 per ¼'.

18.th minute. Pulse still 40

20.th minute. Respirations 7, somewhat convulsive.

26th Minute. Pulse 50. Respirations 15.
33rd " Pulse not weaker, about 45
Respirations 28. The animal attempts
to stand, but cannot control its movements.
At 37 minutes after the compression of the
vertebrals, the animal was moving about.
Experiment discontinued.

I think it must now be admitted as sufficiently proved, that the effect of diminishing suddenly the arterial pressure on a considerable portion of the nervous system is to induce a syncope precisely analogous to that of a sudden and extensive injury of the nervous substance; which in the rabbit is very apt to be fatal, but less so in the dog, on account of the system of that animal being less susceptible or less liable to the diffusive form of lesion.

The application of these results to the case of primary syncope, is quite clear. When the heart is paralysed, or even much weakened from any local cause, the vis-a tergo is removed, and the diminution of arterial pressure thus induced acts on the nervous system in the way of shock, so as not

only to produce complete cessation of nervous function, but to react on the heart, combining its depressing influence with that of the primary cause. On the other hand, where the syncope is of the purely nervous kind, it has a tendency, unless unusually severe, to spontaneous resolution; because the nervous lesion on which it depends is of a form usually transient, and the healthy heart, not being totally depressed, keeps up a certain force of circulation till the return of the nervous function; and in this it may be much assisted by stimulation. But in the case of a heart affected with any organic disease impeding it materially in the exercise of its function, the supervention of any of the causes even of slight nervous shock must be extremely dangerous; because the heart, prostrated under such circumstances is quite unable to propel any amount of blood; and the arrested circulation completes and perpetuates the nervous lesion.

When syncope is fatal, therefore, we may observe the following condition of the system; the nervous function is unable

to revive, because the total absence of nutrition, co-operating with the primary lesion, unfits it permanently for the discharge of its functions; and the heart is unable to revive, because the whole of the vital functions being in abeyance from the arrest of circulation, and its own power weakened, partly by defective nutrition, partly by nervous shock, it is wholly inadequate to overcome the resistance opposed to its contractions, particularly if these contractions are rendered comparatively ineffective by any structural lesion.

As it has already been shewn, that in the latter stages of asphyxia there is very great diminution of arterial pressure, and as there is also undoubtedly reason to suppose the heart's power to be at the same time diminished (see page 117), I do not see how we can avoid connecting these two facts together, and coming to these conclusions; that the final abolition of the nervous functions in asphyxia partakes of the form of shock, and that this cause of diminished power in the heart co-operates with the arrest of the circulation

in the coronary arteries to bring its contractions to a close; before the left ventricle has been completely emptied by the obliteration of its cavity. Thus we shall be enabled to explain the varying proportions of blood in the left side of the heart under circumstances where death takes place mainly by asphyxia

§ III. *On anomalous forms of death connected with lesion of the nervous system.*

It is necessary now to return to the question formerly proposed — in what manner is the life of an animal dependent on the presence of the nervous centres, even though respiration be kept up artificially? Although the knowledge of the functions is not yet in a sufficiently satisfactory state to permit of a full answer to this question, yet it is proper that the solution of it should be kept in view

Dr B. Brodie ascertained, when an animal was pithed, or when the head was removed, the vessels being tied in the neck, and artificial respiration maintained, that the circulation might be kept up with undiminished force for a considerable time, sometimes even for an hour

and a half in the adult animal. After this period however, the pulse began to decline in strength and frequency, but quite gradually, and it was found impossible to maintain an efficient circulation longer than a few hours. To the last the arterial system continued full of perfectly florid blood. He found however, by placing a thermometer in the rectum, that the animal heat declined rapidly, but gradually from the first; and in one case, by tying a ligature round the ureter at the beginning of the experiment, he ascertained that the function of the kidney had been suspended. The effects upon the pulse and animal heat are well seen in the following data, taken from his third experiment, on a small dog, whose pulse was from 130 to 140 in the minute, the heat in the rectum being 99° F.+ The animal was pithed:

In 20 minutes —	Pulse at heart 140 —	Temperature 96½
— 40 —	140 .. —	92
— 55 —	112 .. —	90
— 1 hour 10 min ...	90 —	88
— 1 h. 25 m.	30 —	85

+ Philosophical Transactions 1811. The Croonian Lecture

In one experiment (the 2nd.) the heat declined during an hour and a half at the beginning, when the pulse was even gaining in frequency, thus proving that this effect does not proceed from diminished circulation as its cause.

It has been maintained, that the diminution of the animal heat is the consequence of the imperfection of artificial, as compared with natural, respiration. But this is entirely a gratuitous assumption; for while on the one hand we have no proof whatever of any respiratory change in the blood, which does not go on quite well out of the body, and which is not connected with the change in colour, we have here direct demonstration that the arterialization of the blood was duly effected. It is therefore not of much importance to the present question whether, as Brodie supposed, the cooling is accelerated by the inflation of the lungs with cold air; or whether, as W. Philip and Legallois believed, it is somewhat retarded.

Since, then, the animal heat falls, while both the circulation and the respiration are adequately kept up, it is to be regarded

as very way probable, that the death of the animal is in some way connected with the diminution of the temperature. And to those who coincide in the view entertained by many modern physiologists, that the animal heat is the product of the entire sum of the vital actions going on in the capillary vessels, the following proposition will probably not appear objectionable; that the nervous system exerts upon the whole of these processes an influence not yet properly recognized in physiology, in virtue of which, the complete isolation of the body from its communications with the cerebro-spinal centres, and particularly with the medulla oblongata is inconsistent with the due performance of the functions of the capillary vessels; and that in such case the circulation is gradually arrested from the effect of diminished nutrition upon the muscular substance of the heart, if not also upon its nervous connexions.

In support of this opinion, I may advert to the following facts, which, along with the observations of Brodie, seem to me to demand all the attention of physiologists.

I give here only those which seem best ascertained and least liable to fallacy.

1. Chossat, in his experiments upon animal heat, found that the section of the spinal cord in any part of the cervical, or the upper part of the dorsal region, produced a great declension of the temperature; and in the experiments of Wilson Philip† the destruction of the lumbar portion caused the animal heat to fall gradually from 98° till at the death of the animal in 34 hours it was as low as 75°; although the destruction had been effected so slowly as not to affect the least in the way of syncope.

2. The paralysis of limbs is accompanied by a dry state of the skin, with constant exfoliation of the epidermis, and often also with coldness of surface. The nutrition is greatly diminished, and this is not confined to the muscles, where inaction may contribute to atrophy, but extends more or less to all the tissues; and even, as in an experiment by Dr John Reid,† to the bones themselves.

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* Influence du Syst. nerv. sur la chaleur animale. Or Longet. Syst Nerv. I-303

† Experimental Inquiry &c p 175. † Cormack's Journal Vol I – p 326

3. The secretion of urine is not only suspended in a beheaded animal, as proved in Brodie's experiments, but is much altered in character by a section of the cord in the back or loins. Kramer* found that in such a case the urine becomes limpid, and the animal constituents of it are much diminished in amount; besides which, he entirely corroborates the facts related by Brodie.+ That in various lesions of the spinal cord the urine becomes rapidly ammoniacal, being decomposed even while in the bladder, is well known§.

4. In many cases of chronic affections of the spinal cord, there is an unusual tendency to gangrene from slight causes in the paralysed parts. In chronic myelitis, and other lesions of the cord, even when so high as to involve the origins of the respiratory nerves, it is peculiarly remarkable, that death frequently takes place neither in the

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* Physiologische Untersuchungen. Vol I - p 326

+. Id. op. page 21 — and succeeding experiments

§ Brodie on the diseases of the Urinary Organs. p 161.

way of pure asphyxia, nor of coma, nor yet by any sudden influence on the heart[+]; the breathing may remain free up nearly to the moment of death; the mental faculties may be quite clear and unclouded; but there is extreme emaciation, feebleness of pulse and coldness of surface, and the patient dies from gradual exhaustion, with or without a gangrene over the sacrum, which is frequent in such cases. In a case of induration of the cord, cited by Abercrombie from Portal, it is particularly mentioned that "the pulse and breathing had continued natural until a short time before death, when both became remarkably slow; the pulse being from 30 to 40 in a minute[o]." In this case there was cartilaginous hardness of the cervical portion of the cord, so that many of the respiratory muscles must have been thrown out of action; yet the de-

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[+] See Part IV of Dr Abercrombie's Treatise on the Brain and Spinal Cord - passim; in particular Sections V, VI, VII & VIII.

[o] Case of the Marquis de Causan — Abercrombie Pt IV Sect 6 — and Portal Cours d'Anat. Medicale, tom IV.

ficiency of respiratory power seems not to have been productive of any peculiar symptoms, on account of the depressed state of the other functions.

On the whole, I think these facts lead to the unavoidable conclusion that the nervous system may have a relation to the capillary processes, which has been too much overlooked with respect to the physiology of death; and that under these circumstances the arrest of the heart's action may occur, not as the primary cause of death, but gradually, and as a part only of the general destruction of function implied in the cessation of the nutritive processes. Perhaps it is to such a form of death as this, that the name of Asthenia had better be restricted; although Dr Watson appears to use this term as synonymous with Syncope.

Conclusion.

Illustrations of the preceding chapters from some of the more complex forms of death.

In the preceding essay, an attempt has been made, principally upon physiological considerations, to arrive at certain general principles in regard to the subject of death; and this has been done by excluding every thing except the simplest possible conditions. It is presumed that if these principles be just, they will be of universal application; and all the forms of death which come under the notice of the medical man must be capable of being referred to the same general laws.

But to judge of the complex issues of disease and injury with that degree of precision which is requisite, would require both more extended opportunities, and more cultivated habits, of observation than I can

possibly ascribe to myself. Hence I am not anxious at present to follow out this part of the subject in anything like an extended form; and merely wish, before closing, to hazard a very few remarks as to the connexion between some of the more interesting of these complex phenomena, and the results of the preceding chapters.

The form of death adverted to in the end of last chapter appears to have very important applications to the phenomena observed in the terminations of disease. As it has been shewn that under particular conditions of the nervous system, the arrest of the organic functions may take place from a primary suspension of the actions going on within the capillaries, producing a gradual but simultaneous deprepsion of all the powers of life; it is interesting to remark that an exactly similar mode of death may be induced by various causes acting within the capillaries themselves, and very peculiarly by any certain changes in the whole mass of the blood. Hence the state of gradual asthenia may be induced in a great number of mor-

bid states of the System; and it is a very general accompaniment of Chronic diseases of all kinds, although it may not be ultimately the cause of death.

But a large class of diseases has been recognised in which this appears to be the normal termination, and a considerable number of which are certainly connected with some form of altered nutrition. This is the class which Cullen distinguished by the name of Marcores, or Emaciations, many of which depend on the scrofulous or other cachexies; and it may even be asserted of phthisis pulmonalis itself, though the organ especially diseased is of so essential a nature, that it is often fatal quite as much by general sinking of the powers, as by difficulty of respiration amounting to asphyxia.

When the arrested secretion, muscular debility, and progressive emaciation which attend the whole class of fevers is considered, it becomes every way probable, that an essential part of the pathology of these diseases consists, as maintained formerly by Dr Cullen, and at present by Dr Alison, in a vitiation of

the processes going on within the general capillary system; and accordingly we cannot be surprized to find, that those cases which escape the various accidental complications so apt to occur in the course of fever, are very commonly fatal by gradual sinking of the circulation.

The state of anaemia, whether occurring as an idiopathic condition, or as the result of a protracted drain upon the system, either from hemorrhage or excessive secretion, or wasting discharge, terminating in death by exhaustion, is another instance of this state of the vital functions, in which the heart is affected through the medium of the nutritive process. That it may be so, however, in the case of hemorrhage it is necessary that the drain be very gradual; otherwise the effects are referrible to the form of syncope, in consequence of the suddenly diminished pressure on the nervous system. But the state described by Dr. Marshall Hall as "sinking"

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† Hall on the Morbid and Curative effects of Loss of blood; or in London Med. Chir. Transactions, Vol XIII – p 130

from hemorrhage, is, if I am not mistaken, an instance of the asthenic form of death; although it is marked by a peculiar degree of that "mobility" of the nervous system, which leads to syncope from very slight causes.

Fasting or Inanition differs from hemorrhage mainly in the effects being more gradual and uniform, and therefore less apt to be complicated with syncope; but there is in both an impoverished condition of the blood, and consequently diminished nutrition. The elaborate investigations of Chossat upon this subject have developed a fact which seems to be important, as it may perhaps be of general application to the whole order of diseases fatal by emaciation or marasmus; which is, that while the whole of the tissues undergo a progressive ~~atrophy~~, and the heart in particular, becomes ~~wasted~~ to about half its normal weight, the nervous substance appears to be not at all diminished, being in fact nourished at the expense of the other textures. ⊕ This not only explains the progressive failure of the circula-

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⊕ Chossat sur l'Inanition p 76 and p 90

tion, but shews why the mental functions remain entire up to so late a period, sometimes even within a few hours of death. Chossat found however, that ~~in~~ starved animals during the last day of existence "the heart beats progressively slower and feebler"; the sensibility is at the same time affected, and the animal falls into a kind of stupor.+ Similar symptoms are noticed by Captain Bligh in the famous narration of the mutiny of the Bounty; in regard to his famished companions he says "a more than common inclination to sleep, and an apparent debility of understanding, seemed to me the melancholy presages of approaching dissolution."§ This state of torpidity and diminished sensibility is also noticed by Dr. M. Hall as one of the phenomena of sinking from hemorrhage.‡

The most marked case of death by exhaustion graduating into coma, is the condition described by Dr Abercrombie in his work on the Brain, and named by Dr Marshall

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+ Chossat - op. cit pp 150, 152 § See also a case of scirrhous oesophagus, with death by inanition in Med. Society of London Memoirs Vol II - p 357. ‡ Med. Chir. Transactions loc. cit.

hall the Hydrocephaloid disease; in which when excessive discharges from the bowels or other sources of exhaustion have produced a state of extreme debility, symptoms of head affection may appear, so strongly marked as to induce a suspicion of inflammatory action; but which are only to be removed by stimulants and tonics. This state probably corresponds with the "apoplexia ab inanitione" of older writers.+

The natural termination of human life, or the death by simple old age, is in all probability a simultaneous affection of all the organic processes, bearing much analogy to the death by asthenia. The changed state of the function of nutrition as life advances, is shown in the baldness and loss of colour in the hair, the arcus senilis in the cornea, the deposits in the arteries, & and the tendency to ossific transformation in all parts of the body; and also by the very gradual absorption of the fat, and consequent wrinkles in the skin. These evidences of change in the organic

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+ Abercrombie – Appendix to Part II.

functions are much earlier and more decided than the alterations of the mind and animal functions; although Bichat viewed the death of old age as primarily a suspension of the latter.

The functions of the capillaries seem to be very powerfully affected by the operation of cold; and not only is the nutrition thus depraved in the parts acted upon (an effect which may go to the extent of gangrene or frost-bite, produced still more rapidly if reaction is induced by the too sudden application of heat), but the power of evolving animal heat is very much impaired, and the farther deleterious effects of ~~cadaver~~ cold are not resisted with energy. Hence continued cold is found to produce a most insidiously destructive effect upon the system, and its general action is, as might be expected, accompanied not only by greatly enfeebled circulation, but by a comatose tendency which may ultimately combine with the general asthenia to induce a fatal result. This stupifying effect of cold has been seen on many occasions, when individuals have

been long exposed to its influence without counteracting its effects by exercise§; more especially if any other causes have co-operated to depress the bodily functions, as was the case in Napoleon's disastrous retreat from Moscow.†

If the reduction of temperature be exceedingly rapid and excessive, the effect is always complicated with more or less of sudden depression of the heart's action, which may even be fatal in the way of syncope. Dr Currie found, that in a strong healthy man the sudden immersion of the whole body in a cold salt water bath, about 40°F; produced an <u>immediate</u> lowering of the pulse to the extent of about 20 beats in a minute. At the same time, the heat under the tongue declined rapidly from 7 to 12 degrees, and then began to rise again; and in about a quarter of an hour, when the man continued in the bath, it was nearly restored to the natural standard.‡

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§ See the accounts of Parry's expedition, and of Dr Solander and Sir J. Banks in Terra-del-Fuego

† Beaupré, Sur les Effets du Froid
Larrey Mem. de Chir. Militaire

‡ Dr Currie - Med. Report &c. - Asp. North
Ed. Med. Commentaries Vol 18 - p 237

A large number of deaths both from accident and disease take place either by syncope or by asphyxias; and as some of these have been already noticed, it does not seem necessary to dwell on this subject. But it is important to remark, that there is in many instances a commingling of these two conditions; in consequence of which black blood is found in both sides of the heart in considerable quantity, although generally with more distension of the right cavities. The best illustration of this is in drowning, which although fundamentally a death by asphyxia, is most frequently accompanied by post mortem indications of the character now described. A state of fainting may be induced at the instant of immersion, either from the shock of the cold uniting with the emotion of fright to affect the heart or from direct concussion; when the fall has been considerable. When asphyxia supervenes in this weakened state of the circulation, the contractions of the heart are arrested before much obstruction has taken place in the capillaries and the right side of the heart is not so much

gorged, nor the left so empty, as whereas Physcia occurs in the normal state of the circulation. Indeed Devergie has shewn that this is the most ordinary condition of the vascular system in drowning; and also that it is not uncommon in hanging. In some cases both sides of the heart are alike distended; and in some there are the phenomena of pure asphyxia.+

In concluding this essay, it is due to myself to say, that as no part of what is here stated is, or can be, the result of long experience or study, the preceding pages may well be expected to contain many hasty and partial views, if not some positive errors. But as the object of writing them was rather to obtain a basis for future studies, than to lay down dogmatical rules from preceding investigations, it is hoped that the spirit in which they are composed is not one likely to lead astray.

W. T. Gairdner

+Devergie - Med. Legale. A large collection of cases at the end of Vol II Pt I