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ANATOMY AND PHYSIOLOGY.

1. The Cyclopædia of Anatomy and Physiology. Edited by *Robert Todd*, M.D. F.R.S. &c. &c. Parts XV. XVI. XVII. and XVIII.

We have hitherto omitted noticing the latter Parts of this excellent work. This has been owing to the press of other matter, for the work itself has maintained its character and continued to do credit to its writers and its editor.

We shall select from among the articles contained in the Parts before us, two or three of a physiological, and generally interesting character. Our senior readers will not, perhaps, be displeased at occasionally having the opportunity afforded them of bringing up their knowledge of physiology to the actual level of the day.

The first subject to which we shall allude is hibernation. It has been treated very happily by Dr. Marshall Hall, who has devoted, as our readers must be well aware, considerable pains and his usual talents to its investigation.

I. On Hibernation.

Dr. Hall observes:

"It has not hitherto been distinctly ascertained to what extent the state of hibernation prevails in the animal kingdom; the bat, the hedgehog, and the dormouse, are the genera which present us with the most marked examples of this singular physiological condition in this country; to these the elegant authoress of 'Sketches of Natural History' has added the water-rat and the wood-mouse, observing of the former—

> "And when cold winter comes and the water-plants die,
> And his little brooks yield him no longer supply,
> Down into his burrow he cozily creeps,
> And quietly through the long winter-time sleeps."

The following quotation will be found to afford the key to Dr. Hall's views on the nature of hibernation. It is long but indispensable.

"There is in my opinion, an ultimate *law* of animal existence, which seems to regulate the different forms in which the different classes of animals present themselves. The quantity of respiration is inversely as the degree of irritability of the muscular fibre, the former being marked by the quantity of oxygen consumed in a given time, ascertained by the pneumatometer, the latter by the force of galvanism necessary to demonstrate its existence. The bird tribes have a high respiration and a low irritability; the reptiles have a high degree of irritability and little respiration. This law obtains not only in the different tribes of animals, but also in the different stages or states of the same individual, the *structural* changes from one stage to another being always a change from a lower to a higher respiration, and from a higher to a lower degree of irritability, and the change of state, a change in the opposite direction: thus the changes from the egg to the bird, from the tadpole to the batrachian form, from the larva to the chrysalis and the insect condition, are changes in which, whilst a due ratio is constantly maintained, the quantity of respiration is augmented and the de-

gree of irritability diminished; on the other hand, the *physiological* changes in the degree of activity in animals, during sleep, for example, but especially in that remarkable change which is the subject of this article, the respiration is diminished whilst the degree of irritability is, *pari passu*, augmented.

On what this susceptibility of change depends, and especially on what the power of taking on an augmented irritability depends, is at present unknown. But I think I may affirm that it is upon this power that the capability of passing into the state of hibernation reposes. I suppose that all animals have the faculty of sleeping; during sleep the respiration is slightly diminished, the irritability probably proportionately augmented—probably one ultimate object of this state of repose; but the phenomenon has its appointed limit which it cannot pass. In certain animals, that limit is not so confined,—the quantity of respiration is still further diminished, the degree of irritability still further augmented, and the deeper sleep, or lethargy, of hibernation takes place.

During this lethargy, the law of the inverse ratio of the respiration and of the irritability still prevails, and the animal merely puts on a reptile state in these respects. Were the respiration to be diminished without the appointed augmentation of the irritability, the heart would cease to be stimulated, and the animal would die, as in the cases of torpor and slow asphyxia; were the respiration augmented without the proportionate diminution of the irritability, the heart would be over-stimulated, and death would alike ensue, as in the case of a hibernating animal too suddenly roused from its lethargy, and as (probably) in the case of an animal placed in pure oxygen gas.

The difference between the hibernating and all other animals then is, an ultimate faculty of assuming an augmented degree of irritability of the muscular fibre—a power possessed by all animals within certain limits, but by the hibernating animal beyond the usual limit." 765.

This is the dominant idea of the article. It has been generally believed that hibernation depends on the animal's not being able to generate heat sufficiently to resist a low temperature. Dr. Hall lays it to the faculty of assuming an augmented degree of irritability of muscular fibre. It must be owned that neither theory explains the phenomenon satisfactorily. Milne Edwards the advocate of the former, remarks:—" Nous voyons que les chauves-souris produisent habituellement moins de chaleur que les animaux à sang chaud, et que c'est principalement à cette cause qu'il faut attribuer l'abaissement de leur température pendant la saison froide. En comparant cette expérience sur la chauve-souris adulte avec celles que nous avons faites sur les jeunes animaux à sang chaud, on y aperçoit un rapport remarquable; ils ne produisent pas assez de chaleur pour soutenir une température élevée, lorsque l'air est à un degré voisin de zéro. Mais il y a cette difference, que c'est un état passager chez les jeunes animaux à sang chaud, et qu'il est permanent chez les chauves-souris.

" Il est évident que les autres mammifères hibernans doivent participer plus ou moins de cette manière d'être. Les faits que j'ai exposés suffisent pour nous faire considérer ce groupe d'animaux sous le point de vue suivant; qu'au printemps et en été, dans leur état d'activité et de veille, lorsque leur température est assez élevée pour ne pas différer essentiellement de celle qui caractérise les animaux à sang chaud, ils n'ont pas la faculté de produire autant de chaleur; et tout en admettant que d'autres causes peuvent influer sur leur refroidissement pendant leur hibernation, il faut cependant l'attribuer en grande partie à cette particularité de leur constitution." But as Dr. Hall observes this explanation would account for torpor, a pathological

and a fatal state, not for hibernation, a natural and a harmless one. Dr. Hall's own explanation does little more than put the fact of hibernation in scientific terms—when analysed it resolves itself into the expression, *that* certain animals have the power of hibernating. To say that the irritability of the muscular fibre is increased, is to say little else than all were aware of, for as the heart was known to beat while the respiration was imperfect, and the changes in the blood incomplete, it followed of course that the heart contracted under the influence of a feeble stimulus, or, in other words, that its irritability was augmented.* The *how* is left involved in the same obscurity as heretofore; indeed, supposing Milne Edwards' explanation unobjectionable, it would be more satisfactory as an explanation than that of Dr. Hall.

This gentleman not only compares hibernation with sleep, but he even goes so far as to believe that it is nothing but profound sleep. He says:—Hibernation appears more extraordinary only because less familiar than sleep. Most animals are, in fact, naturally awake and asleep every revolving day, some being diurnal, others nocturnal. But in summer the bat actually hibernates, loses its respiration, and with its respiration its temperature, acquires vastly augmented irritability, and presents the other phenomena of *complete* hibernation, regularly and periodically every twenty-four hours; and the hedgehog and the dormouse present similar phenomena, only after other intervals.

This would seem to shew that Dr. Hall looks on the law of periodicity, whatever that may be, as being essentially the law of hibernation. He holds the influence of diminished temperature cheap. He goes on to state:—

"Sleep then is the first stage of hibernation. The faculty of passing into the second is identical with that of assuming a greatly augmented irritability of the muscular fibre. Such are the results of my long attention to this interesting physiological question. Much error has arisen from viewing hibernation as a simple effect of cold. The influence of cold in inducing hibernation is merely its well-known influence in inducing sleep, concurring with the other causes of this condition. The direct effect of cold on the animal frame is, as I shall shortly have occasion to state particularly, totally different from hibernation. Hibernation is a physiological condition; the direct effect of cold, or *torpor*, is, on the contrary, a pathological and generally a fatal one.

The term hibernation has usually been applied to designate what its etymology implies, the condition in which certain animals pass the *winter* season. An error is, as I have already stated, involved in this view of the subject; for the condition termed hibernation is not confined to the winter season. Cuvier observes, in speaking of the Tenrecs, 'ce sont des animaux nocturnes qui passent trois mois de l'anné en lethargie, quoique habitants de la zône torride. Burguière assure même que c'est pendant les grandes chaleurs qu'ils dorment.' Hence the term *Sommerschlaf* employed in Germany. It is plain too, from this circumstance, that the state of hibernation is not necessarily connected with a low degree of external temperature, and we are surprised to find this celebrated naturalist, whom I have just quoted, observing, 'la seule condition de la lethargie est le froid et l'absence des causes irritantes.'

I must repeat that hibernation is, in every respect, but the parallel of ordinary sleep, varying only in force and duration. It is equally modified by co-operating

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* It must, on consideration, be obvious to Dr. Hall himself, that he has enunciated no new law. We were all aware that the reptilia and amphibia whose blood is but semi-aerated are distinguished for irritability of muscular fibre.

or opposing causes; and it is equally manifested in its peculiar effects, only varying in degree and intensity." 766.

Dr. Hall goes on to remark that, to understand hibernation, we must look at it as it affects every function; and he deems it necessary to ascertain first what sleep, the initiative of hibernation, is. Sleep affects the cerebral system only—the true spinal, or excito-motory retains all its energies. But, he remarks, in the state of activity, the cerebral system exerts a peculiar and continual influence over the true spinal, which ceases during sleep. In this manner the functions of the latter appear impaired; the respiration especially, and with the respiration the circulation, with which it always maintains a certain relation, becomes slower, irregular, and suspended at intervals. These phenomena observable in ordinary sleep are still more remarkable in the deep sleep or lethargy of hibernation or diurnation.

Of the Sleep of Hibernating Animals.—Dr. Hall states, as the result of his own observations, *that*, in the sleep of the hibernating animal, the respiration is more or less impaired: if the animal be placed in circumstances which best admit of observation, the acts of respiration will be found to have greatly diminished; if it be placed in the pneumatometer, little alteration is induced in the bulk of the air; if its temperature be taken by the thermometer, it will be found to be many degrees lower than that of the animal in its active state; if it be deprived of atmospheric air, it is not immediately incommoded or injured.

"The bat, which is a crepuscular or nocturnal feeder, regularly passes from its state of activity to one which may be designated *diurnation*. The respiration and the temperature fail; the necessity for respiration is greatly lessened.

During the summer of 1831, I carefully observed a bat in this condition. If it were quite quiet, its respiration became very imperfect; its temperature was but a few degrees above that of the atmosphere; being placed under water, it remained during eleven minutes uninjured, and on being removed became lively and continued well.

I have more recently watched the habits of two hedgehogs, in a temperature varying from 45° to 50°. These animals alternately awake, take food, and fall asleep. One of them is frequently awake, whilst the other is dormant, and goes to sleep at a time that the other awakes, but without regularity. When awake, the temperature of each, taken by pressing the bulb of a thermometer upon the stomach, is about 95°; when dormant, it is 45°; that of the atmosphere being 42° or 43°. The duration of this sleep is from two to three days, according to the temperature of the atmosphere. On the 4th of February, 1832, the temperature of the atmosphere being 50°, both the hedgehogs were dormant,—the temperature of one was 51°, and that of the other 52°; on the succeeding day, the temperature of the atmosphere had fallen one degree, the temperature of one of the hedgehogs was 49°, whilst that of the other, which had become lively, had risen to 87°; on the succeeding day, the first had become somewhat lively, and its temperature had risen to 60°, that of the other being 85°, and that of the atmosphere 47°.

I have observed precisely the same alternations in the dormouse; except that this animal awakes daily in moderate temperatures, takes its food, and re-passes into a state of sleep, in which the respiration is greatly impeded, and the temperature little higher than that of the atmosphere.

On the day on which the observations were made on the hedgehogs, the atmosphere being 49°, that of two dormice was 52°; on the succeeding day, the external temperature being 47°, that is, lower by two degrees, the temperature

of one of these dormice was 92°, and that of the other 94°; and only three hours afterwards, the temperatures were 60° and 70° respectively, with a slight appearance of lethargy.

The hedgehog and the dormouse appear, in fact, to awake from the call of hunger, then to eat, and then again to become dormant, in temperatures which may be termed moderate. The bat, which could not find food if it did awake, does not undergo these periodical changes, except in the summer season. It appears to me, from the most careful observation, that there is every degree between the ordinary sleep of these animals and the most profound hibernation.

It is quite obvious, from these observations, that the ordinary sleep of hibernating animals differs from that of others, by inducing a more impaired state of the respiration and of the evolution of heat, with an augmented power of bearing the abstraction of the atmospheric air. This sleep probably passes into true hibernation, as the blood which circulates through the brain becomes more and more venous, from the diminution of the respiration, and as the muscular fibre of the heart acquires increased irritability." 767.

Dr. Hall continues:—

It is absolutely necessary, in comparing the powers of hibernating and other animals, of evolving heat, accurately to observe whether there be any tendency to sleep. Mr. Hunter's and M. Edwards's experiments are deficient for want of this attention. Mr. Hunter, comparing the common mouse and the dormouse, exposed to a very low temperature, observes, that the temperature of the former was "diminished 16° at the diaphragm, and 18° in the pelvis; while in the dormouse it gained five degrees, but lost on a repetition." The explanation of these facts is afforded by the observation, that when the dormouse increased in temperature it was "very lively," but that on the "repetition" it had become "less lively;" the mouse was probably in a state of languor from apprehension or for want of food.

M. Edwards omits to mention whether the hibernating animals, in his experiments, were disposed to be lively or dormant, or whether they had recently recovered from the dormant state. He does not even mention whether the experiments on the bat were performed in the evening, its period of activity, or in the morning or day, its period of lethargy or diurnation. Without a particular attention to these points, no correct result could be obtained. The hibernating animal, in a state of vigour and activity, is a totally different being from the same animal disposed to become dormant.

In order to perform this experiment in a satisfactory manner, the bat, for example, should be employed in the evening, when it has naturally awoke from its deep day-slumber, the hedgehog when it has awoke spontaneously to take food; otherwise the disposition to sleep may explain the loss of temperature.

Of Perfect Hibernation.—Dr. Hall offers as the abbreviated result of a series of observations and experiments made in the course of the years 1831-2, *that*, there is *one* special cause of hibernation,—that law imposed by the Creator, according to which *all* animals become affected with sleep at some period of each revolving day, and the hibernating animal at some period of the revolving year. We have thus presented to us the phenomena of diurnal and nocturnal animals, and the winter-sleep and the summer-sleep of hibernating animals.

Exposure to cold, not too severe, disposes to hibernation, as it disposes to

ordinary sleep. Severe cold, on the contrary, first rouses the hibernating animal from its lethargy, and then plunges this and all animals into a state of fatal torpor.

The absence of every kind of stimulus or excitant, and a somewhat confined atmosphere,* also conduce to hibernation.

Every excitement, on the contrary, that of hunger, that of the sexes probably, tend to disturb this peculiar lethargy. It is in this manner that we explain the periodicity of sleep and hibernation, though there is probably also some hidden influence of the seasons, of the day or of the year, influences which have been traced by Dr. Prout and by M. Edwards in regard to the quantity of respiration.

Dr. Hall proceeds to examine the influence of hibernation on the several functions.

A. *Sanguification.*—"There is much difference," says our author, "in the powers of digestion, and in the fact of omitting to take food, in the hibernation of different animals. The bat, being insectivorous, would awake in vain; no food could be found: the hedgehog might obtain snails or worms, if the ground were not very hard from frost: the dormouse would find less difficulty in meeting with grain and fruits. We accordingly observe a remarkable difference in the habits of awaking from their lethargy or hibernation, in these different animals.

I have observed no disposition to awake at all in the bat, except from external warmth or excitement. If the temperature be about 40° or 45°, the hedgehog, on the other hand, awakes, after various intervals of two, three, or four days passed in lethargy, to take food; and again returns to its state of hibernation. The dormouse, under similar circumstances, awakes daily.

Proportionate to the disposition to awake and take food, is the state of the functions of the stomach, bowels and kidneys. The dormouse and the hedgehog pass the fæces and urine in abundance during their intervals of activity. The bat is scarcely observed to have any excretions during its continued lethargy.

In the dormouse and the hedgehog, the sense of hunger appears to rouse the animal from its hibernation, whilst the food taken conduces to a return of the state of lethargy. It has already been observed, that there are alternations between activity and lethargy in this animal, with the taking of food, in temperatures about 40° or 45°. Nevertheless, abstinence doubtless conduces to hibernation, by rendering the system more susceptible of the influence of cold, in inducing sleep and the loss of temperature. The hedgehog, which awakes from its hibernation, and does not eat, returns to its lethargy sooner than the one which is allowed food." 769.

Dr. Hall observes that the *respiration* is nearly suspended in hibernation, which is proved, 1st, by the absence of all detectable respiratory acts; 2dly, by the almost entire absence of any change in the air of the pneumatometer; 3dly, by the subsidence of the temperature to that of the atmosphere; and 4thly, by the capability of supporting, for a great length of time, the entire privation of air.

1. "I have adopted various methods to ascertain the entire absence of the acts

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* M. de Saissy observes, "la marmotte, que j'ai engourdie par deux fois différentes, ne l'a été, je crois, que parceque je me suis avisé, quand la respiration a été bien affaiblie, de boucher le trou du couvercle. Ce n'a été que de cette manière que je suis parvenu à l'engourdir; car toutes les tentatives que j'avais faites avant ont été vaines."

of respiration. I placed bats in small boxes, divided by a partition of silk riband, the cover of which consisted of glass, and in the side of which a small hole was made to admit of placing a long light rod or feather under the animal's stomach. The least respiratory movement caused the extremity of this rod to pass through a considerable space, so that it became perfectly apparent.

Over the hibernating hedgehog I placed a similar rod, fixing one extremity near the animal, and leaving the other to move freely over an index. During hibernation not the slightest movements of these rods could be observed, although they were diligently watched. But the least touch, the slightest shake immediately caused the bat to commence the alternate acts of respiration, whilst it invariably produced the singular effect of a deep and sonorous inspiration in the hedgehog. It is only necessary to touch the latter animal to ascertain whether it be in a state of hibernation or not: in the former case there is this deep sonorous inspiration; in the latter, the animal merely moves and coils itself up a little more closely than before. After the deep inspiration, there are a few feeble respirations, and then total quiescence. The bat makes similar respirations without the deep inspiration, and then relapses into suspended respiration.

2. As the acts of respiration are nearly suspended during hibernation, so are the changes induced in the atmospheric air.

On January the 28th, the temperature of the atmosphere being 42°, I placed a bat in the most perfect state of hibernation and undisturbed quiet, in the pneumatometer, during the whole night, a space of ten hours, from 1h. 30m. to 11h. 30m. There was no perceptible absorption of gas.

Having roused the animal a little, I replaced it in the pneumatometer, and continued to disturb it from time to time, by moving the apparatus. It continued inactive, and between the hours of 1h. 20m. and 4h. there was the absorption of one cubic inch only of gas.

Being much roused at four o'clock, and replaced in the pneumatometer, the bat now continued moving about incessantly; in one hour, five cubic inches of gas had disappeared. It was then removed. A further absorption took place of ·8 of a cubic inch of gas.

Thus the same little animal, which, in a state of hibernation, passed ten hours without respiration, absorbed or converted into carbonic acid, 5.8 cubic inches of oxygen gas in one hour when in a state of activity. In an intermediate condition, it removed one cubic inch of oxygen in two hours and forty minutes." 769.

Dr. Hall twice repeated the experiment with substantially similar results. For, 3·4 cubic inches of oxygen gas disappeared in sixty hours, from the respiration of a bat in the state of lethargy; while, during the state of activity of the animal, an equal quantity of the same gas disappeared in less than half that number of minutes.

"It may be a question whether the slight quantity of respiration I have mentioned be cutaneous. The absence of the acts of respiration would lead us to this opinion. But it may be observed, that these acts have not been watched, and can scarcely be watched continuously enough, to determine the question of their entire absence. Some contrivance to ascertain whether the rod has moved along the index during the absence of the observer would resolve every doubt upon this interesting point. And I think it right to remark, that after the apparent total cessation of respiration, as observed by the means which have just been described, there is probably still a slight diaphragmatic breathing. I am led to this conclusion, by having observed a slight movement of the flank in a favourable light, unattended by any motion of the thorax or epigastrium." 769.

4. Dr. Hall insists on the necessity of great precautions in ascertaining

the comparative temperature of the animal and of the atmosphere. He subjoins a table which gives the result of observations made during many days, in very varying temperatures. From this, he says, it is obvious that the temperature of the hibernating animal accurately follows that of the atmosphere. When the changes of temperature in the latter are slight, the two thermometers denote the same temperature. If these changes are greater and more rapid, the temperature of the animal is a little lower or higher, according as the external temperature rises or falls; a little time being obviously required for the animal to attain that temperature.

It is only necessary to add to these observations, that the internal temperature is about three degrees higher than that of the epigastrium. In two bats, the external temperature of each of which was 36°, a fine thermometer, with an extremely minute cylindrical bulb, passed gently into the stomach, rose to 39°.

4. It is not astonishing that the lethargic animal is enabled to bear the total abstraction of atmospheric air or oxygen gas, for a considerable period of time. Dr. Hall remarks that:—

Spallanzani placed a marmot in carbonic acid gas, and makes the following report of the experiment in a letter to Senebier: "Vous vous ressouviendrez de ma marmotte qui fut si fortement léthargique dans l'hiver sévère de 1795; je la tins alors pendant quatre heures dans les gaz acide carbonique, le thermomètre marquant—12°, elle continua de vivre dans ce gaz qui est le plus mortel de tous, comme je vous le disais: au moine un rat et un oiseau que j'y plaçai avec elle y périrent à l'instant même. Il-parait donc que sa respiration fut suspendu pendant tout ce tems-là. Je soumis à la même experience des chauve-souris semblablement léthargiques et le résultat fut le même."

A bat which was lethargic in an atmosphere of 36° was immersed in water of 41°. It moved about a little, and expelled bubbles of air from its lungs. It was kept in the water during sixteen minutes, and then removed. It appeared to be uninjured by the experiment.

A hedgehog which had been so lethargic in an atmosphere of 40° as not to awake for food during several days, was immersed in water of 42°. It moved about and expelled air from its lungs. It was retained under the water during 22½ minutes. It was then removed. It appeared uninjured.

It seems probable that the motions observed in these animals were excited through the medium of the cutaneous nerves.

The power of supporting the abstraction of oxygen gas, or atmospheric air, belongs solely to the hibernating state, and is no property of the hibernating animal in its state of activity. Dr. Hall immersed an active hedgehog in water. It expired in three minutes, the period in which immersion proves fatal to the other mammalia.

5. "The *circulation* is reduced to an extreme degree of slowness, according to a law well-known, but hitherto, I believe, unexplained, according to which the respiration and the circulation are always proportionate to each other.

The wing of the bat affords an admirable opportunity of observing the condition of the circulation during hibernation. But it requires peculiar management. If the animal be taken from its cage, and the wing extended under the microscope, it is roused by the operation, and its respiratory and other movements are so excited, that all accurate observation of the condition of the circulation

in the minute vessels is completely frustrated. Still greater caution is required in this case than even in the observation of the respiration and temperature.

After some fruitless trials, I at length succeeded perfectly in obtaining a view of the minute circulation undisturbed. Having placed the animal in its state of hibernation, in a little box of mahogany, I gently drew out its wing through a crevice made in the side of the box; I fixed the tip of the extended wing between portions of cork; I then attached the box and the cork to a piece of plate-glass; and lastly, I left the animal in this situation, in a cold atmosphere, to resume its lethargy.

I could now quietly convey the animal ready prepared, and place it in the field of the microscope without disturbing its slumbers, and observe the condition of the circulation.

In this manner I have ascertained that, although the respiration be suspended, the circulation continues uninterruptedly. It is slow in the minute arteries and veins; the beat of the heart is regular, and generally about twenty-eight times in the minute.

We might be disposed to view the condition of the circulation in the state of hibernation as being reptile or analogous to that of the batrachian tribes. But when we reflect that the respiration is nearly, if not totally, suspended, and that the blood is venous, we must view the condition of the circulation as in a lower condition still, and, as it were, sub-reptile. It may, indeed, be rather compared to that state of the circulation which is observed in the frog from which the brain and spinal marrow have been removed by minute portions at distant intervals.

In fact, in the midst of a suspended respiration, and an impaired condition of some other functions, one vital property is augmented. This is the irritability, and especially the irritability of the left side of the heart. The left side of the heart, which is, in the hibernating animal, in its state of activity, as in all the other mammalia, only arterio-contractile, becomes veno-contractile.

This phenomenon is one of the most remarkable presented to me in the whole animal kingdom. It forms the single exception to the most general rule amongst animals which possess a double heart. It accounts for the possibility of immersion in water or a noxious gas, without drowning or asphyxia; and it accounts for the possibility of a suspended respiration, without the feeling of oppression or pain, although sensation be unimpaired. It is, in a word, this peculiar phenomenon, which, conjoined with the peculiar effect of sleep in inducing diminished respiration in hibernating animals, constitutes the susceptibility and capability of taking on the hibernating state. On the other hand, as the rapid circulation of a highly arterialized blood in the brain and spinal marrow of birds probably conduces to their activity, the slow circulation of a venous blood doubtless contributes to the lethargy of the hibernating animal." 772.

6. When we turn to the *nervous system*, our author assures us that sensation and volition are quiescent, while the excito-motory, the true spinal system, retains its energy. Thus the slightest touch applied to one of the spines of the hedgehog immediately rouses it to draw a deep inspiration. The merest shake induces a few respirations in the bat. The least disturbance, in fact, is felt, as is obvious from its effect in inducing motion in the animal.

It is from misconception on this point that the error has arisen, that the respiration is not absolutely suspended in hibernation. This function has been so readily *re-excited*, that it has been considered as appertaining to the state of hibernation.

7. In the midst, says our able physiologist, of a suspended or partially

suspended respiration, the *irritability* of the muscular fibre becomes proportionately augmented.

The single fact of a power of sustaining the privation of air, without loss of life, leads alone to the inference that the irritability is greatly augmented in the state of hibernation. This inference flows from the law already stated, and the fact is one of its most remarkable illustrations and confirmations.

It might have been inferred from these premises, that the beat of the heart would continue longer after decapitation in the state of hibernation than in the state of activity in the same animal; an inference at once most singular and correct.

"This view," he continues, "receives the fullest confirmation from the following remarkable experiment: on March the 9th, soon after midnight, I took a hedgehog which had been in a state of uninterrupted lethargy during 150 hours, and divided the spinal marrow just below the occiput; I then removed the brain and destroyed the whole spinal marrow as gently as possible. The action of the heart continued vigorous during four hours, when, seeing no prospect of a termination to the experiment, I resolved to envelope the animal in a wet cloth, and leave it until early in the morning. At 7 o'clock A.M. the beat of both sides of the heart still continued. They still continued to move at 10 A.M., each auricle and each ventricle contracting quite distinctly. At half-after 11 A.M. all were equally motionless; yet all equally contracted on being stimulated by the point of a penknife. At noon the two ventricles were alike unmoved on being irritated as before; but both auricles contracted. Both auricles and ventricles were shortly afterwards unirritable.

This experiment is the most extraordinary of those which have been performed upon the mammalia. It proves several interesting and important points: 1. That the irritability of the heart is augmented in continued lethargy in an extraordinary degree. 2. That the irritability of the left side of the heart is then little, if at all, less irritable than the right,—that it is, in fact, veno-contractile. 3. That, in this condition of the animal system, the action of the heart continues for a considerable period independently of the brain and spinal marrow.

On April the 20th, at six o'clock in the evening, the temperature of the atmosphere being 53°, a comparative experiment was made upon a hedgehog in its state of activity: the spinal marrow was simply divided at the occiput; the beat of the right ventricle continued upwards of two hours, that of the left ventricle ceased almost immediately; the left auricle ceased to beat in less than a quarter of an hour; the right auricle also ceased to beat long before the right ventricle." 773.

Dr. Hall quotes from a paper of Mangili, in the Annales du Muséum, some further experiments strikingly corroborative of the preceding, and highly interesting in themselves. We shall seize the opportunity of quoting them:—

"J'observai à peu près les mêmes choses dans une autre marmotte en léthargie, que je décapitai le 22 de Mars, 1807. Mais en ouvrant celle-ci, j'avois deux objets: le premier, d'examiner l'état des viscères les plus importans, comme le cœur, les poumons et le cerveau. Le second étoit de voir comment procédent les phénomènes de l'irritabilité musculaire; parce qu'ayant entendu dire à un célèbre naturaliste, que l'engourdissement avoit pour cause l'altération ou la suspension de cette irritabilité, il m'importoit de savoir si cette assertion étoit vraie. Dans la chambre où se trouvoit la marmotte, le thermomètre étoit à 6 degrés et demi; l'ayant introduit dans le bas ventre, il monta d'un degré, c'est-à-dire à 7 degrés et demi.

Je trouvai le les poumons dans leur état naturel. Le cœur continua à battre pendant plus de trois heures. Les pulsations, d'abord vives et frequentes, s'affoiblirent et se ralentirent peu-à-peu. J'en avois compté de seize à dix-huit par minute au commencement de la première heure; à la fin de la troisième je n'en comptois plus que trois dans le même temps. Les veins du cerveau me parurent gonflés de sang.

La tête unie au cou ayant été séparée du tronc, je la mis dans un vase avec de l'esprit-de-vin, et j'y remarquai, même après une demi-heure, des movemens assez sensible. Ce fait prouve, ainsi que plusieurs autres dont je parlerai bientôt, que si dans l'état de léthargie conservatrice la vie est beaucoup moins énergique, le principe vital répandu dans les diverses parties, a beaucoup plus de tenacité, et tarde bien plus à s'éteindre.

Je séparai du corps de l'animal plusieurs morceaux des muscles qui obéissent à la volonté, et je vis avec étonnement que, trois heures après la mort, ils se contractoient fortement chaque fois que je les soumettois à l'action galvanique. Ces mouvemens convulsifs ne se ralentirent qu'au bout de quatre heures.

Il suit de là que les marmottes tuées pendant qu'elles sont en léthargie, présentent, relativement à l'irritabilité, à peu près les mêmes phénomènes qu'on remarque dans plusieurs animaux à sang froid.

Pour savoir ensuite si les phénomènes d'irritabilité étoient les mêmes dans l'état de ville et dans celui de léthargie, le 25 de Juin, j'ai fait périr, précisément de la même manière, une seconde marmotte qui étoit éveillée depuis deux mois, et qui faisoit de frequentes courses dans le jardin. Mon thermomètre marquoit ce jour-là 18 degrés: l'ayant introduit dans le ventre de la marmotte au moment où je venois de la décapiter, il s'éleva à 29 degrés.

Ayant mis le cœur à découvert, comme je l'avois fait dans mon expérience du mois de Mars, je comptai d'abord vingt-sept ou vingt-huit pulsations par minute. Ce nombre n'étoit plus que de douze au bout d'un quart d'heure, et de huit, au bout de demi-heure: dans les dix minutes suivantes, il n'y eut plus que quatre pulsations très-foibles par minute, et elles cessèrent totalement dans les dix derniéres minutes, c'est-à-dire cinquante minutes après la mort de l'animal; tandis que le cœur de la marmotte tuée dans l'état de léthargie, donnoit encore quatre légères pulsations par minute, trois heures aprés que la tête avoit éte séparée du corps. Cette grande différence prouve que le principe de l'irritabilité s'accumule pendant la léthargie conservatrice.

Les chairs musculaires me semblirent plus pâles que celles de la marmotte en léthargie: elles etoient d'abord très sensibles à l'action galvanique; mais ses signes d'irritabilité s'affoiblirent et disparurent bien plus rapidement. En effet les chairs musculaires de cette marmotte étoient peu sensibles au bout de deux heures, tandis que dans la marmotte tuée en hiver elles se contractoient fortement au bout de trois heures, et que l'irritabilité ne s'affoiblit notablement que quatre heures aprè la mort.

Les chairs des muscles intercostaux et abdominaux conservèrent leur sensibilité au stimulus électrique quelques minutes de plus que celles des membres; d'où l'on peut conclure que le principe de l'irritabilité se conserve d'avantage dans certaines parties du même animal. Mais ce qui est prouvé jusqu'à l'évidence c'est que ce principe a bien plus de ténacité dans les chairs de l'animal tué pendant l'état de léthargie, que dans celle de l'animal tué pendant l'état de veille."

Dr. Hall remarks on this curious, though from what we know of amphibia and reptiles, natural fact, that its due value can only be determined by observing the dependence of the functions of life on that law of the inverse condition of the respiration and of the irritability, of which so much has already been said. In the hibernating animal the respiration is nearly suspended; had not the irritability become proportionately augmented, the actions of life must have ceased!

8. The *motility* of the muscular fibre is unimpaired, Dr. H. assures us, in hibernation. If the hedgehog, he says, in a state of the most perfect lethargy, uncomplicated with torpor, be touched, its respiration is resumed, and it coils itself up more forcibly than before. The dormouse, in similar circumstances, unfolds itself; and the bat moves variously. Not the slightest stiffness is observed. The hedgehog, when roused, walks about, and does not stagger, as has been asserted. The bat speedily takes to the wing, and flies about with great activity, although exhaustion and death may subsequently result from the experiment. The phenomena are similar to those of awaking from natural sleep. Impaired motility, stiffness, lameness, &c. belong to torpor, and not to true hibernation.

3. *Of Reviviscence.*—Hibernation, observes Dr. Hall, induces a state of irritability of the left side of the heart, which, with high respiration and an arterialized blood, would be incompatible with life. Respiration suddenly restored, and permanently excited, is, therefore, as destructive as its privation in other circumstances.

"All those bats which were sent to me from distant parts of the country died. The continued excitement from the motion of the coach keeping them in a state of respiration, the animal perished. One bat had, on its arrival, been roused so as to fly about. Being left quiet, it relapsed into a state of hibernation. The excitement being again repeated the next day, it again flew about the room; on the succeeding day it was found dead.

It is in accordance with this law, that we observe hibernating animals adopting various measures to secure themselves from frequent sources of disturbance and excitement. They choose sheltered situations, as caverns, burrows, &c. secure from the rapid changes and the inclemencies of the weather and season. Many form themselves nests; others congregate together. The hedgehog and the dormouse roll themselves up into a ball. The common bat suspends itself by the claws of its hinder feet, with its head dependent, generally in clusters; the horseshoe bat *(ferrum equinum)* spreads its wings so as to embrace and protect its fellows.

All these circumstances are obviously designed to prevent disturbed hibernation.

In the depths of caverns, and other situations sheltered from changes of temperature in the atmosphere, the calls of hunger are probably the principal cause of reviviscence in the spring. The other causes of reviviscence are the return of warmth and external excitements: it is interesting to observe and trace the gradual return of respiration in the former case, and of the temperature of the animal in the latter.

If the hibernating hedgehog be touched even very gently, it draws a deep breath, and then continues to breathe for a short time. If this excitement be repeated, the animal is permanently roused, and its temperature raised. If the temperature of the atmosphere be augmented, the respiration is gradually excited, and the animal is gradually restored to its state of activity.

If a hibernating animal be excited in a very cold atmosphere, its temperature rises variously and then falls. A bat was perfectly lethargic in a temperature of 36°. A fine thermometer, with a cylindrical bulb, was introduced into its stomach; it rose to 39°. One hour afterwards, the animal not being further disturbed, the respiration was rapid, and the temperature in the stomach 95°. Shortly afterwards the temperature was 90°. The minute circulation was pretty good, and pulsatory in the arteries, the heart beating from twenty-eight to thirty-six times in the minute.

In another bat, in an atmosphere of the temperature of 36°, the thermometer in the stomach rose to 39°. The animal being continually excited, the temperature rose to 65°, but speedily fell to 60°.

The animal excited and revived in this manner is in a state of exhaustion and inanition. It is incapable of maintaining its temperature if exposed to cold, and will die unless it repass into a state of hibernation." 774.

It may, perhaps, admit of question whether it is the high irritability of the heart which kills because of its incompatibility with excited respiration and an arterialized blood. It is not proved that such irritability remains high when the respiration becomes high, nor is it clear why it should kill, if it did so. If a hibernating animal is stimulated to activity in a low temperature, it is reasonable to suppose that it would suffer, because it is unnaturally excited to exertions disproportionate to the hibernating state which such temperature tends to produce. If, on the other hand, the animal is stimulated in a higher temperature, it is not satisfactorily shewn that the excitation proves fatal, independently of the want of food, or an excessive quantum of excitation itself. We offer these not as objections but inquiries, and shall be glad to receive information from our able author. It is only fair to add a question of his own. The fact, he says, of the fatal influence of excited respiration during the augmented irritability of hibernation, contrasted with the similar fatal effect of suspended respiration, during the diminished irritability of the state of activity, will illustrate many of the causes, kinds, and phenomena of death. Do not these resolve themselves, in fact, into irritability insufficiently or excessively excited?

4. *Of Torpor from Cold.*—As Dr. Hall observes, it is important to distinguish that kind of torpor which may be produced by cold in any animal, from true hibernation, which is a property peculiar to a few species. The former is attended by a benumbed state of the sentient nerves, and a stiffened condition of the muscles; it is the direct and immediate effect of cold, and even in the hibernating animal is of an injurious and fatal tendency; in the latter, the sensibility and motility are unimpaired, the phenomena are produced through the medium of sleep; and the effect and object are the preservation of life.

True hibernation is induced by temperatures only moderately low. All hibernating animals avoid exposure to extreme cold. They seek some secure retreat, make themselves nests or burrows, or congregate in clusters, and, if the season prove unusually severe, or if their retreat be not well chosen and they be exposed in consequence to excessive cold, many become benumbed, stiffened, and die.

Dr. Hall continues:—

"To induce true hibernation, it is quite necessary to avoid extreme cold; otherwise we produce the benumbed and stiffened condition to which the term torpor or torpidity may be applied. I have even observed that methods which secure moderation in temperature, lead to hibernation: hedgehogs, supplied with hay or straw, and dormice, supplied with cotton-wool, make themselves nests and become lethargic; when others, to which these materials are denied, and which are consequently more exposed to the cold, remain in a state of activity. In these cases, warmth or moderated cold actually concur to produce hibernation.

When we read of insensibility, of a stiffened state of the muscles, and of a

cessation of the circulation, as obtaining in hibernation, we may be certain that a state of torpor has been mistaken for that condition. The actually hibernating animal exposed to continued severe cold is, as M. Saissy correctly observes, first roused from this state of ease and preservation into a painful activity, and then plunged into a fatal torpor." 775.

He adds :—

"In conclusion, one of the most general effects of sleep is to impair the respiration, and with that function the evolution of animal temperature. The impaired state of the respiration induces a less arterial condition of the blood, which then becomes unfit for stimulating the heart; accumulation of the blood takes place in the pulmonary veins and left auricle; a sense of oppression is induced, and the animal is either roused to draw a deep sigh or awakes altogether.

Such are the phenomena in animals in which the heart has not the faculty of taking on an augmented state of irritability, with this lessened degree of stimulus. But in those animals which do possess this faculty, a property which constitutes the power of hibernation, the heart continues the circulation of the blood, more slowly indeed, but not less perfectly, although its arterial character be diminished, and its stimulant property impaired. No repletion of the pulmonary veins and of the left auricle, no sense of oppression is induced, and the animal is not roused; the respiration continues low, the temperature falls, and the animal can bear, for a short period, the abstraction of atmospheric air.

All the phenomena of hibernation originate, then, in the susceptibility of augmented irritability. The state of sleep, which may be viewed as the first stage of hibernation, induces an impaired degree of respiration. This would soon be attended with pain, if the irritability of the heart were not at the same time augmented, so as to carry on the circulation of a less arterial blood, and the animal would draw a deep sigh—would augment its respiration or awake. Occasional sighs are, indeed, observed in the sleep of all animals, except the hibernating. In these, the circulation goes on uninterruptedly, with a diminished respiration, by the means of an augmented irritability. There is no stagnation of the blood at the heart; consequently, no uneasiness; and the animal becomes more and more lethargic, as the circulation of a venous blood is more complete. This lethargy is eventually interrupted by circumstances which break ordinary sleep, as external stimuli or the calls of appetite." 776.

Our author enumerates the hibernating animals. The most unequivocal are the bat, the hedgehog, the marmot, the hamster, the dormouse. It has been said that the bear and beaver belong to the number, but this is extremely doubtful. It has been said also that the swallow belongs to the hibernating class, but this is incorrect. The cold-blooded animals, the Chelonian, the Saurian, the Ophidian, and the Batrachian tribes, all, however, indubitably pass the winter in a state of apathy and lethargy. Some of the fishes also become lethargic during the cold season. The same remark applies to some of the molluscous and insect tribes.

We cannot but think Dr. Hall's paper highly interesting. It displays his aptitude for clear and discriminating generalizations, and for resolving into simple formulæ many and apparently contradictory facts.

II.—ON ANIMAL HEAT.

THE fifteenth and sixteenth Parts of the Cyclopædia contain an article on this subject by Dr. W. F. Edwards. Some observations on it will also be