ARTICLE XVI.

A DISSERTATION READ BEFORE THE

MASSACHUSETTS MEDICAL SOCIETY,

ON

HEAT AND COLD.

BY THOMAS WELSH, M. D.

PROVISIONALLY appointed by the council to prepare a dissertation, it was my hope, and till lately, my expectation, that the gentleman, previously elected, would either have attended on this occasion, or have transmitted to the Society his Dissertation, and have rendered unnecessary the regret we now experience by this disappointment.

I AM therefore constrained to entreat your candour while I make a few observations, on *Cold* and *Heat.*

I WOULD premise, that it is not my intention, were it within the compass of the present time, or of my abilities, to enter into a minute chemical inquiry into their nature and properties; I mean only to mention a few of each as they appear in inanimate matter, and some of those which are observed in animals; having for an object principally the design of turning your attention to the important and extensive subject of *animal heat.*

COLD, in a relative sense, signifies the sensation which accompanies a transition of the fine vessels of the human body from an expanded to a more contracted state; in an absolute sense, it signifies the cause of this transition, or, in general, the cause of the contraction of every substance, whether solid or fluid, in nature.

COLD is a quality, whose nature, like that of *fire*, is best known by its effects. Whatever are the properties of *fire*, those of *cold* seem to be directly opposite; *fire* increases the bulk of bodies, *cold* contracts them; *fire* tends to dissipate their substances, *cold* condenses them, and strengthens their mutual cohesion. But though cold thus seems, by some of its effects, to be nothing more than the privation of heat, as darkness is only the privation of light, yet *cold* is seemingly possessed of another property, which has induced some to think it is a distinct substance from heat, and of a peculiar nature. It is universally known, that when cold, by being continued to substances, contracts and condenses them, to a certain degree, if *then* its power be increased, instead of continuing to contract and lessen their bulk, it expands and enlarges them; so that extreme cold, like heat, swells the substance into which it enters. Thus in fluids, they contract sensibly with cold, till the moment they begin to freeze; from thence forward they dilate, and take up more space than they possessed when in a state of fluidity. When liquor turns to ice in a close cask, it is often known to burst the vessel; when ice is broken upon a pond, it swims on the surface;

a certain proof that it is of a larger bulk than so much water.

Whatever definition philosophers may give of the word *heat*, it is quite sufficient for our purpose to say, that as *cold* contracts, so heat expands bodies, in all directions, from a centre to the circumference; but when the expansive action of heat is confined within the surface of any body, it is called its latent heat, a certain degree of which exists in all bodies whatever, when at the common temperature of the atmosphere; and this is called the specific heat of the body.

Heat is, in the material world, the chief principle of activity; hence plants and animals derive their growth and vigour; and nature, perfect in every energy, has endowed the animal body with the power of generating its own heat. Without this, the temperature of the air in various climates would have been destructive of life, and man could only have been the inhabitant of the temperate zones.

If a thousand different inanimate bodies, heated to various degrees, be brought together in a place where there is no positive cause of heat, the heat will immediately begin to flow from the hotter to the colder bodies, till all become of one temperature; but this is by no means the case with animated matter, for whatever may be the particular degree of heat of individual animals, they preserve the same degree, stable and unchanged, in every temperature to which they can be exposed; provided it be not altogether incompatible with life and health. Thus we find that

the body is not only capable in certain circumstances of supporting, without any material change, a degree of heat, in which the thermometer rises considerably above the heat of boiling water, but likewise that it maintains its usual temperature, whilst the surrounding medium is below the point of congelation. It is therefore evident that animals neither receive their heat from the bodies around them, nor suffer from the influence of external circumstances, any material alterations in that heat which is peculiar to their nature. Late accurate observations show, that the degree of heat in the more perfect animals of the same genus and species, continues very uniformly the same, whether they be invironed by mountains of snow, near the pole, or exposed to a vertical sun, in the sultry regions of the torrid zone.

The stability and uniformity of animal heat, under such a disparity of external circumstances, and so vast a latitude in the temperature of the ambient air, leaves no room to doubt that the living body is furnished with a peculiar mechanism, or power of generating, supporting, and regulating its own temperature; and that this is so adapted to the circumstances of the economy, or, to speak more accurately, so immediately dependant upon them, that whatever be the heat of the atmosphere, it shall have very little influence either in diminishing or increasing that of the animal. It is observed that all animals are, one degree at least, warmer than the ordinary temperature of the element they inhabit.

All physiologists agree in allowing a necessary connection betwixt the *degree of heat generated*, and the *state of circulation;* and every one must have observed that whilst the motion of the circulating mass continues vigorous and unimpaired, the temperature of the body suffers no change from the influence of external circumstances; but no sooner has the heart ceased to play, and the blood began to stagnate in its canals, than the absence of the generating cause of heat becomes manifest: for the lifeless mass sinks to the temperature of the bodies around it.

The phenomenon of animal heat hath, from the earliest ages, been the subject of philosophical discussion; and like most other subjects of this nature, the cause is not yet ascertained. The best treatises which have appeared upon the subject, are those of Dr. Dugud Leslie, and Mr. Adair Crawford; from the first of these performances, the following account of the different opinions on this subject is extracted.

"The ancients possessed not the requisites for minutely investigating the science of nature; and, prone to superstition, attributed every phenomenon which eluded their investigation, to the influence of a supernatural power. Hippocrates, the father and founder of medicine, accounted animal heat a mystery, and bestowed on it many attributes of the Deity. In treating of that subject, he says, in express terms, 'What we call *heat*, appears to me, to be something immortal, which understands, sees, hears, and knows every thing present and to come.' Aristotle seems to have considered the subject particularly; but noth-

ing is to be met with in his works, that can be used to throw light upon it. Galen tells us that the dispute between philosophers and physicians of his time, was "whether animal heat depended on the motion of the heart and arteries; or whether, as the motion of the heart and arteries was innate, the heat was not also innate. Both of these opinions, however, he rejects; and attempts a solution of the question on his favourite system, namely, the peripatetic philosophy."

To enter minutely, and in detail, into all the opinions offered by the moderns on the cause of animal heat would far exceed our limits. Dr. Leslie's theory depends on the following principles.

1st. That the blood does contain phlogiston.

2d. That this phlogiston is evolved, extracted, or brought into a state of activity and motion by the action of the blood vessels, to which it is subjected in the course of circulation.

3d. That the evolution of phlogiston is a cause which throughout nature produces heat, whether that heat be apparently excited by mixture, fermentation, ignition, percussion, friction, inflammation, or any similar cause.

4th. That this heat, which must be produced in consequence of the evolution of phlogiston, from the blood of different animals, is in all probability equal to the highest degree of heat, which these animals in any case possess.

This theory is founded upon the principle, that the venous is warmer than the arterial blood; which

is denied by Dr. Crawford, and the contrary affirmed, whose theory is contained in the following propositions, and the experiments made pursuant thereto. He begins with an explanation of his terms. The words *heat* and *fire*, he tells us, are ambiguous. *Heat*, in common language, has a double signification. It is used indiscriminately to express a sensation of the mind, and an unknown principle, whether we call it a quality or a substance, which is the exciting cause of that sensation. The latter, he calls *absolute heat*, the former *sensible heat*, and then proceeds to say,

" 1st. HEAT is contained in great quantities, in all bodies, when at the common temperature of the atmosphere.

2d. HEAT has a constant tendency to diffuse itself over all bodies, till they are brought to the same degree of sensible heat.

3d. IF the parts of the same homogeneous body have the same degree of sensible heat, the quantities of absolute heat will be proportionate to the bulk or quantities of matter. After reciting a number of experiments, he continues, " thus it appears, that in respiration, the blood is continually discharging phlogiston, and absorbing heat; and that in the course of circulation, it is continually imbibing phlogiston and emitting heat."

WE know that sensible heat is produced by the circulation of the blood; and we have proved by experiments, that a quantity of absolute heat is communicated to that fluid in the lungs, and is again disengaged from it in its progress through the system;

if therefore, the whole of the absolute heat which is separated from the blood, were absorbed by those parts of the system, from whence it receives the phlogiston, it would be necessary to have recourse to some other cause to account for the sensible heat which is produced in the circulation; but by the rules of philosophizing, we are to admit no more causes for natural things than such as are both true and sufficient to explain the appearances; for nature delights in simplicity, and affects not the pomp of superfluous causes. We may therefore, conclude safely, that the absolute heat which is separated from the air in respiration, and absorbed by the blood, is the true cause of *animal heat.* It appears therefore, that the blood, in its progress through the system, gives out the heat which it had received from the air in the lungs; a small portion of this heat is absorbed by those particles which impart the phlogiston to the blood; the rest becomes redundant, or is converted into moving or sensible heat."

Differing from both of these authors, Dr. John Bell, in his anatomy of the human body, treating of the heat of the blood, says, that " to suppose but for a moment that all the heat which warms the whole body emanates from the lungs, were a gross error in philosophy; it were to suppose an accumulation of heat in the lungs equal to the vast effect of heating the whole body. But were it so, we should feel a burning heat in the centre, a mortal coldness at the extremities, and marked differences, in the heat of each part, in proportion to its distance from the lungs. In fevers, we should

feel only the intense heat of the centre; we should be distressed, not with the heat in the soles of the feet or palms of the hands, or in the mouth and tongue; we should feel only the heat of the lungs. When the limbs alone were cold, would the lungs warm them? How could it warm them up to the right temperature without over-heating the whole body? When a part were inflamed, how could the heat go from the lungs, particularly to that point, and rest there? From the lungs the heat could not be regularly diffused. While the vapour which issues from the lungs keeps to the temperature of 96°, and while the lungs and heart do not exceed in heat the rest of the body, there can be little chance of any heat being generated in the lungs, except what is balanced and carried off by the halitus from the natural secretions of the lungs."

That the animal heat is produced by the action of the vessels; that heat does not proceed from the lungs, but is produced in each part of the body; is beautifully proved by what happens in *aneurism*, where the artery is tied up (in the thigh, for example); and where we make, as it were, a great experiment upon animal heat, not upon any animal, but upon the human body.

1st. Immediately after the operation, the pulse is stopped, the limb is benumbed, it grows cold, and sinks one or two degrees below the standard of its natural heat. This is the moment of total interruption in the great trunk, and of particular danger. 2dly. In a little while the limb begins to grow warm;

it swells, and gradually the limb, which at first was warm only, becomes hot, and the heat rises many degrees above the standard heat of the limb, and above the general heat of the rest of that system to which it belongs. In this second stage there is still no pulse; which proves that the circulation in the great artery is not restored; the heat, swelling, and slight inflammation which passes the whole limb, plainly proceed from the universal action of all the smaller arteries; for the blood has not yet found out any one artery fit to dilate so far, as to carry on the circulation easily, and restore the pulse. 3d. But in the next period the blood begins to creep; at last it is plainly felt; then it waxes stronger from day to day, till in process of time it beats as vigorously as in the sound limb. Now the blood has forced and dilated some great artery, the blood flows through the limb, as formerly, in one main channel. The smaller arteries are freed from their load, and cease from their excessive action; and, in exact proportion as the pulse returns, the unnatural heat subsides gradually, till at last it is reduced to the common heat of the body. Thus we may perceive, very clearly, that it is while the communication with the system (and lungs of course) by the blood vessels is most difficult, that the heat rises; that when the free communication is restored, it falls; that the intermediate period, in which there is plainly, from the redness and swelling of the limb, an excess of action in all its smaller arteries, is the period of excessive heat; and we may observe, though in a less striking

way, the same phenomenon in every inflammation, or in other words in every local disease, viz. the temperature changed, without any apparent dependence on that of the system at large. We perceive in the clearest manner that heat is continually formed in all the extremities of the system; and when we think of the processes which are going on continually in the various parts, we cannot but believe that the oxygen is completely assimilated, and gives out its heat, not when it is received into the blood, with which it seems so slightly emitted, but when it is distributed through the body, and assimilated with its parts, of which it forms so important a principle. In the human body, various acids are produced; the phosphoric acid; the lithic acid, or that which is excreted by the urine; the acidum pingue, or the acid of fat; these certainly are proofs that the oxygen is deposited in the blood.

But in reflecting upon this most difficult of all subjects, the generation of heat in the human body, many things are to be taken into the calculation, which seem, on the first glance, to be far more important than this deposition of oxygen from the blood. It is a law of nature, to which, as far as we know, no exception is found, that a body, while it passes from an aerial to a fluid, or from a fluid to a solid form, gives out heat. Now, what is the whole business of the living system but a continual assimilation of new parts, making them pass from a solid into a fluid form? The whole nourishment of the body goes on in the extreme vessels, and is a conti-

nual assumption of new parts. The extreme vessels are continually employed in forming some acids, which appear naked in the secretions; in forming oxides, as the fat and the jellies of the membranes, and white parts, in the various depositions of muscle, bone, tendon, &c. for these are all continually absorbed, thrown off by the urine, and incessantly renewed. They are constantly employed in filling all the interstices of the body with a bland fluid or halitus; they are employed in forming secretions of various kinds. In performing all *this*, the power of the vessels may do much; but the ultimate *effect* in each process must be a *chemical change;* and *perpetual changes* will produce a *constant heat.* Place the organ and focus of this animal heat in the centre of the body, and you are embarrassed with a thousand difficulties; allow this *heat* to arise in each part, according to its degree of action, and each part provides for itself.

But how then, some will say, shall this heat be regulated? I say, plainly, by the heart and lungs. The lungs regulate the stimulant power of the blood; the heart regulates the action of the arteries, in so far as regards the stimulus of fulness and distention; and with these to regulate the centre, nothing can alter the heat of the extremities except partial action, that is, disease.

I will conclude, then, that oxygen, if it does communicate heat, does so, "not to the lungs, nor to the blood, but to the whole body through the medium of the blood."

THERE are various degrees of *animal heat*, some animals preserving a heat of 100° or more in all the different temperatures of the atmosphere; others keep only a few degrees warmer than the medium which surrounds them; and in some of the more imperfect animals, the heat is scarcely one degree above the air or water in which they live.

THE common heat of the human body is about 96° or 98°. It has been affirmed by some, that in its healthy state, there is a considerable difference in the heat of the internal parts, and the surface of the human body; that the degree of heat of the heart, or lungs, or any other viscus, does in fact exceed that of the external parts; but no experiment has proved this assertion. On the other hand, it is found by experiments, that in a state of health, there is no difference in the degree of heat of either the venous or arterial blood; that the heat in the cavity of the thorax or abdomen internally varies not materially from that of the external integuments of those parts; and it is admitted, that in the state of health, the velocity of the blood through the different parts of the system, is so adjusted, that the heat is equally diffused through the whole. But, if through any irregularity the balance be destroyed; if, by the increased action of the vessels, the blood be urged with greater violence than usual, through any particular part, greater heat will be excited in a given time; this heat will stimulate the vessels into more frequent and forcible contractions, by which the velocity of the blood, and the heat, will be still further increased.

On this principle we may account for the partial heats produced by topical inflammation, and for those which arise in hectic fever.

But in a diseased state, there may be great accessions of heat, and in fact there is, particularly in phlegmon, where the parts inflamed exhibit great excess of heat above that which is found in other parts. Whenever therefore any part is greatly surcharged with heat, it becomes diseased, and so far as it becomes diseased, it loses the self preserving principle of regulating its own heat; hence accumulation of heat must ensue, and in proportion to this accumulation must be the loss of the vital principle of the part, and consequently its approximation to the state of inanimate matter. Now it has been shewn above, that when inanimate bodies heated to various degrees are brought together, the heat will immediately begin to flow from the hotter to the colder bodies, till all become of one temperature. If we consider the human body, when generally or partially inflamed, partaking in a certain degree of the nature of inanimate bodies, is not the same process of cooling pointed out, which is employed in cooling other bodies?

It is a well known fact, that fluids standing in a current of air, grow by this means much cooler than before; and it is also known, that all substances grow colder, by the fluids they contain or are mixed with being evaporated; and that the quantities of heat lost in a given time, by a body, are in proportion to the excess of its heat over or above that of the sur-

rounding medium. If therefore the sensible heat of the body increase, while the temperature of the air continues the same, the quantities of heat carried off by the latter in a given time will be proportionably increased. From whatever cause it may arise, at the termination of the hot stage of fevers, evaporation succeeds from the surface of the body; we may therefore conclude, that this is one of the means employed by nature for moderating the heat, and restraining the violence of disease.

Are we not then to conclude that we are justified in the practice of applying cold substances to the surface of the human body, and such as have a tendency to produce evaporation, when a high degree of fever exists? and such an exposure of the body to the air as may be deemed sufficient to produce evaporation in other bodies?