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Buffon, which is a *tantalus*; nor the *ibis* of Haffelquist, which is an *ardea*; nor that of Maillet, which is a vulture; but a *numenius* or curlew, which has not yet been named by systematic authors, and of which Bruce has given a figure under the name of the *abou-bannès*. I call it *numenius ibis*, *albus, capite et collo nudis, remigibus pennis tropygi elongatis, rostro et pedibus nigris*.

The *tantalus ibis* of Linnæus, in the present state of his synonymy, comprehends four species, of three different genera:

A *tantalus*, the *ibis* of Perrault and Buffon;

An *ardea*, the *ibis* of Haffelquist;

Two *numenii*, the *ibis* of Belon;

And the *ox-bird* of Shaw.

The reader may judge by this instance, and many others, of the state in which the *Système Naturæ* still remains, and of what importance it would be to free it gradually from those errors with which it abounds, and with which naturalists seem to load it still more, by accumulating, without choice and proper examination, species, characters, and synonyms.

IX. *A brief Examination of the received Doctrines respecting Heat or Caloric.* By ALEXANDER TILLOCH. Read before the *Askefian Society*, December 1799*.

TO detail the various theories maintained at different periods, and applied to explain the phenomena to which heat gives rise in the numerous changes presented by Nature in chemical combinations and decompositions, would be taking up the time of this Society unnecessarily, as every member must be well acquainted with them. I shall therefore confine myself to the modern doctrines on this subject; and even with these I shall be brief, as my chief object is, to inquire, Whether none of the circumstances that accompany the known facts in this department of physics (such of them, I mean, as the limits I have prescribed to the present essay will

* For a short account of this Society, see Note, p. 353, Vol. VII.

allow me to notice) have been overlooked? and whether, If all of them had been attended to, and the legitimate inferences been drawn from them, the theory now generally received would ever have been admitted into science?

The ground I am about to take may perhaps expose me to the danger of being considered as an innovator, or, what may be deemed worse by some, a sceptic as to certain opinions, rendered respectable by the great names that have embraced and maintained them; and at the same time extremely plausible from the apparent facility with which they are applied to explain many phenomena that daily present themselves to the eye of every attentive observer. My only answer is, that I am in search of truth; and so decided an enemy to mere theoretical speculations, that I neither admit myself, nor wish others to admit in physics what cannot be proved to be truth. When the human mind acquiesces on any ground short of this, it is either through misconception, indolence, or pusillanimity, than which nothing has tended more to retard science and shackle men with prejudices, leading them to receive great names for argument, and, for demonstration, long quotations. But, to proceed, I use the term *heat* to denote that substance which possesses those properties, is governed by those laws, and produces those effects which shall be immediately enumerated; and I prefer it to the term *caloric** for no other reason but because the latter is employed by many to denote heat existing in a certain state, in which, they say, it may be considered as having actually lost its original character: whereas I hold, and I even hope to convince the members of this Society, that it invariably retains the same character, properties, and mode of action.

* The term *caloric* has been adopted in the new nomenclature to avoid that ambiguity and misconception which might, it is said, arise from employing the same term to express a substance, and the sensation produced by the action of that substance. By the same mode of reasoning, all the *substantives* should be changed in any language that has similar *verbs*. But suppose the argument for change, in the present instance, to have full force in some languages, it has little or none in regard to the English, which employs the word *warmth* to express the sensation occasioned by *heat*. I shall, however, use the terms heat and caloric indifferently.

(A) Heat is diffused through all the bodies in nature; whether solids, liquids, or æriform fluids.

(B) Heat tends to an equilibrium; so that, when by any means it is accumulated in particular substances, a portion is quickly given off to the surrounding bodies to bring the whole to one common temperature. On the other hand, where bodies have been deprived of a portion of it, heat is given off to them by, or heat passes to them from, the surrounding bodies, to restore the equilibrium.

(C) Solids, by the addition of heat, assume the form of liquids, and liquids the æriform state. On the other hand, gases, by an abstraction of heat, become liquids; and liquids, solids.

(D) The dimensions of bodies are enlarged when heat is poured into them, and *vice versa*.

The laws we have enumerated are general, and the objections that may be stated against the truth of any of them so few, and so easily obviated, that they cannot affect any inference drawn from them. The apparent exceptions relate chiefly to the change of volume in some particular substances when passing from the liquid to the solid form, or the contrary. Water, for instance, in passing into the state of ice, assumes a larger volume, though heat is then passing out of it. The substance, however, is only apparently enlarged. In freezing, the water assumes a crystalline form; the crystals, shooting in every direction, crowd against, and, as it were, jostle each other, causing vacuities, which constitute no real part of the matter. We may compare this phenomenon to what takes place in a bundle of chips of wood, which will always, however closely packed, occupy an apparently larger space than the same weight of ligneous matter as arranged by nature in the tree. Another apparent exception may be noticed in clay, which diminishes the more in bulk the greater the quantity of heat poured into it; but here there is a misnomer—it is not clay, but a mixture of clay and water that is diminished in bulk. The water is driven off; and, where there is a diminution of matter, a reduction of volume must follow. Clay is therefore not an exception to the

the general law—drive all the water out of it, that is, convert it into glass, and it then obeys the general law.

We shall first attend a little to the operation of the foregoing laws in some given cases; and afterwards examine the doctrines which have been established from the phenomena observed to accompany them:

If two bodies of the same nature, unequally heated, be brought into contact, the heat will diffuse itself equally through them, and the quantities in each will bear the same proportion to each other as the masses themselves; but, if the bodies differ in kind, though equilibrium take place, and each indicate the same temperature, yet the proportions of heat in each will not be as the masses, but vary according as the bodies differ.

(E) This property of bodies to hold different quantities of heat, even when that fluid is in a state of equilibrium, Dr. Black calls *the capacity of a body for heat*; the quantity itself he calls *specific heat*. The distinction is perfectly philosophical, nor need the terms be objected to; but they should be accurately defined, that they may never be employed to convey ideas different from the facts that gave rise to their adoption.

That the sense in which we understand and use the terms may be clearly conceived, we shall substitute another substance for heat, all other circumstances being as before. If two substances of the same kind (two pieces of chalk), unequally wetted with water, be brought into contact, the one will give off water to the other (or the one will absorb water from the other) till the quantity in each be *as their masses*. If two bodies different in kind (chalk and wood) be thrown into water, the quantity they will each take in will be *as their capacities*: this will also be the case if, instead of throwing them into water, we suspend both in the same damp atmosphere; and the quantity in each, whether received by immersion in water or in the atmosphere, is *specific*. The latter term must be thus considered, otherwise we shall lead ourselves into error; for there is at least as great a difference between the extremes of the general temperature in summer and in winter as there is between a moist, and a comparatively dry (but yet moist) atmosphere.

Some philosophers tell us that *the cause* of this phenomenon of different bodies requiring different quantities of caloric to indicate the same temperature (or, in other words, the cause of their having different capacities for heat) arises from the different degrees of affinity which different bodies possess for heat! Is this an explanation?—Different bodies hold different quantities of heat, *because they have different capacities*:—Different bodies hold different quantities of heat, *because they have different affinities*!—yet we are to consider the one term as expressive of a *property*, and the other as expressive of *the cause* of that property! Is this consistent with that accuracy and precision which should prevail in the language of science?

But this is not all. Heat is considered as existing in two distinct states; free, and in chemical union. When heat is in equilibrium in any place; in other words, when a body is in equilibrium with the bodies which surround it with respect to its heat [that is, has received heat from the common stock proportioned to its capacity]; that quantity which it contains is termed *latent heat* or *caloric*; *combined caloric*; *heat in chemical union*. We are told that in this state it is not perceptible by any external sign or organ of sense; that it does not affect the thermometer, but remains quiescent in those bodies of which it constitutes a principle; and that it is then, more or less, in a state of confinement.

Is the heat in any body termed *latent* because the body has not a capacity to receive more? No; for if, by any means, an addition be made to the common stock of a prescribed system of bodies, each individual substance will still provide lodging for a share of the added quantity, proportioned to its capacity, in relation to the capacity of the rest. It should be observed too, that, let the common temperature be what it may, if heat be in equilibrium, the portion in each body is, by some at least, held to be *latent*, in contradistinction to what they term *free heat*. Hence it follows, that the quantity of *latent heat* in a given body differs in different seasons of the year; for heat may be in equilibrium in any system of bodies in summer as well as in winter. An assemblage of different bodies, in equilibrium as to caloric, in
Jamaica,

Jamaica, the quantity in the whole is *latent*, and in each *specific* and *latent*: the same holds with regard to a system of substances in England in the month of January. The heat in both cases is *latent*. If the one system of bodies could be transported to the other in a moment, and placed in contact with it, a portion of that heat which was *latent* in Jamaica, would be counted *sensible* heat in London! This is exactly where the doctrine lands us when viewed generally; and yet we are to consider heat as having two distinct modes of existence! But let us take a closer view of it:

When by the passing of a solid body into a fluid form the surrounding atmosphere is found to have lost heat, this heat, they say, has not been merely absorbed by the substance that has become fluid, but has become latent in it. When a liquid passes into the æriform state, the same phenomenon accompanies the change, and also the same assertion; and the doctrine is meant to convey the idea that heat has not only been changing its place, but has itself undergone a change as to its state, its properties, and mode of action.

It is a generally received axiom, that no more causes should be admitted in physics than what are true and sufficient to account for the phenomena. Let us inquire whether this axiom be not violated in the cases stated, when recourse is had to the doctrine of latent, as distinguished from free, heat, to assist in explaining the phenomena.

The dimensions of bodies are enlarged when heat is poured into them (D). The primitive molecule (independent of the heat) of which the bodies are formed, are forced farther from each other by the interposed matter of heat. Continue the action of the same cause, their cohesion will be destroyed entirely (C), and they will be diffused through the predominating substance (heat), as the particles of saline substances diffuse themselves through water when dissolved in that liquid. In the case just put for illustration, who ever supposes the water to have undergone any change as to its essence or properties, whether directly poured upon the saline substance or furnished to it by the atmosphere.

In chemical combinations it is admitted that we cannot,
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a priori,

a priori, determine the properties of the compound from a previous knowledge of those of the ingredients. Every substance has, for one of its properties, a capacity for heat. If two be united chemically, the capacity of the compound for heat may not be that of the sum of the capacities of the ingredients for the same substance. Indeed it seldom or never turns out so. If by any process then we change the capacity of two or more bodies; or, by uniting them, produce a third, whose capacity for heat is greater than the sum of that of the ingredients, this new compound must demand from the common stock of heat diffused through the atmosphere and other neighbouring substances (A) an additional portion. Is there any thing in all this to lead us to the notion that the passage of heat from the atmosphere, or other contiguous bodies, into the new compound, is the operation of any other than the general law by which heat tends to an equilibrium among all the bodies in a system (B), and diffuses itself among them in proportion to their capacities for heat (E)? Is not the operation of these laws sufficient to explain the phenomena without the aid of any others?

But, besides, is it not a general fact, in all cases where a capacity for a greater quantity of heat is produced in a compound than the sum of the capacities of the ingredients, that the sum of the volume of the compound is greater than that of the ingredients? And is it not equally true, that, when ingredients, before in union, are found, on being separated, to have acquired capacities for heat, whose sum is greater than was that of the body in which the ingredients were united; the sum of the volume of the ingredients is greater than the volume of the compound was *? Can it be correct to say that it neither affects our senses, nor is cognisable by any external sign! when we can see with our eyes its effect in the increase it has made in the volume of

At the moment of writing I do not recollect a single exception. In cases where crystallisation is concerned there may be some apparent ones, as in the case of water and ice; but these will not affect my argument. It is enough for me that the *effect* holds generally in the cases to which the doctrine of latent heat is applied—an *effect* perfectly conformable to the general law (D), and also *cognisable by our senses*.

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the compound substance before us; or in the sum of the masses of two or more substances over that of the compound from which they were separated?

Again—When gases pass into the form of liquids, or liquids into the solid state, heat is found to pass from them into the atmosphere, “the heat that was latent in them before now becomes sensible.” Was it *not cognisable* before? It ought not to have been so when latent. I find, however, that the volume of the body from which it has been separated is now *less* than before; and this is exactly what ought to take place from the general laws, not only of heat but of matter—a substance, heat, has been separated from a body in which it formed a part of the mass or volume, and the remaining mass is diminished in bulk.

Let us, however, alter the mode of expression. A body, no matter by what means, is reduced into a less volume; it is so constituted as to admit of this effect being passed upon it; for one of its ingredients, heat, is a subtile fluid which may be dislodged; nay, will even run out, when the capacity of the body which held it is lessened. It is no way strange, in this case, that a fluid poured out of its recipient, and which, by its tendency to equilibrium, must diffuse itself through the surrounding bodies in proportion to their capacities to receive it, should make itself manifest to our sense of feeling, we being immersed at the moment in one of the neighbouring substances, the atmosphere, which affords a lodging for a portion of the dislodged heat, and serves to transport other portions of it to all the neighbouring bodies. Nor is it strange that a substance which, while it formed an ingredient in the body from which it has been removed, constituted also a part of its volume, should, when it passes into another body, mercury in a glass tube, cause an increase in its volume proportioned to the quantity that has passed in.

It constituted *sensible bulk* in the first body, and was *latent heat*; it constitutes *sensible bulk* in the second body also, but there it is *sensible heat*!! Is there no absurdity in all this?

Heat in those combinations, in which the term *latent* is employed, not cognisable by our senses! Is it not obvious
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from the preceding statement that this is a mistake? Before the heat passed out of its then combination it made a part of the volume which we contemplated with our eyes, and the proportion that this part bore to the whole might, in many cases, be determined by actual measurement. Is sensible heat, or rather heat in such combinations as it is in when that term is used, cognisable by any other means?

To me it would appear as correct, when, by any power, the capacity of a vessel filled with a liquid (water) is diminished, to say that the portion of liquid thereby ejected is set at liberty; meaning thereby that it has undergone an essential change as to its form, properties, or mode of existence; as to say, when the volume of a substance containing heat is abridged, and a proportionate quantity of the heat is dislodged, that the heat, so dislodged, has undergone any such change.

The fact in my opinion is, the substance in which the caloric resided has undergone the change, where there is a change; not the heat: or, if it be changed, the change is of that kind which passes upon a brick or any other body when we move it from one room to another. This, I think, must be pretty clear from what we have already stated; but I hope to make it still more so by examining a particular case or two which have been made to serve for a foundation, as it were, for the doctrine which I oppose.

[To be continued.]

NEW PUBLICATIONS.

An Account of the Irises or Coronæ which appear around, and contiguous to, the Bodies of the Sun, Moon, and other Luminous Objects. Cadell and Davies, 1799. 46 pages. With One Copperplate.

THIS treatise is by the author of the *Observations on the Inflections of Light*, of which a short account was given in the Philosophical Magazine for September. In making these observations, that ingenious gentleman perceived that
a ray