

IS IT TRUE? WAS IT TRUE? WILL IT ALWAYS BE TRUE?

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Students often perceive science as a collection of laws and facts, all "scientifically proven" to be part of a permanent body of certain knowledge. Perhaps the most powerful way to remove this misconception in a TOK context, and hence introduce the idea of a paradigm and the work of Thomas Kuhn, is to allow them to see what students from an earlier generation might have learnt in their science lessons. The extract below is from *Encyclopaedia Britannica*, I believe an 1856 edition:

HEAT

The term Heat, in common language, is applied both to the sensation excited in us by the approximation of a warm body, and to the cause of that sensation. To obviate this ambiguity, chemists and other cultivators of physical science have employed the word caloric to designate the cause of heat; but as there are few disquisitions in which this distinction is material to perspicuity, in this article we shall use either term to signify the cause of the sensation.

One of the first inquiries that suggests itself is, what is caloric? Two opinions on this subject have divided philosophers. The most generally received opinion is, that heat, or caloric, is a material agent of a peculiar nature, highly attenuated, and, from its affinity or attraction for all other matter, universally distributed amongst the particles of bodies, in quantities proportional to their mutual attractions, or, as it has been termed, the capacities of different substances for heat; whilst its tendency to diffuse itself amongst contiguous bodies has been explained on the supposition of its own particles being repellent of each other. The other opinion, which has been maintained by Bacon, Boyle, and several other philosophers, considers heat as a mere quality of matter, and ascribes it to a vibratory movement among the intimate particles of bodies; an idea which was adopted by Rumford, to explain his curious experiments on the excitation and communication of heat by friction. This opinion, however, seems vague and unsatisfactory. If we say that heat is motion amongst the particles of matter, still we have no explanation of the manner in which this motion is produced; for we cannot conceive any movement without an impulse, nor an impulse without a material agent. Heat pervades all sorts of matter: it remains in some circumstances dormant, or, as it is termed, latent, and may be again elicited from bodies by various means. Did it consist in vibrations or motions of

the particles of other matter, it should pervade elastic bodies with the greatest celerity; which we know not to be the fact. It will, for instance, pervade a rod of lead, or of the softest copper, far more readily than an equal length of glass or of marble. If we mingle together equal quantities of water at different temperatures, the resulting temperature will be an exact mean between the extremes. But if heat consisted in such vibrations, there ought to have been a loss of heat, as in all other communicated motions. If we mix together equal quantities of different substances at different temperatures, the resultant temperature is not a mean: one body has lost more heat than the other has appeared to gain, or a part of the heat of the one has become latent in the other, and that in a constant ratio to the power of each substance of absorbing heat, as tried by comparing each with a third body in the same manner. It is very difficult to conceive this species of interchange, if heat merely consisted in vibrations amongst the particles of matter. Still more difficult is it to conceive how a permanent temperature could subsist among a great system of bodies, as the planets, if heat were nothing more than a vibration of the particles of bodies; for the original impulse ought to diminish with each communication.

It is possible, however, to modify this theory, by supposing that heat is produced not merely by the motions of the particles of the heated substance, but by the vibrations or undulations of a very subtile matter existing in all bodies. This will approximate the vibratory theory to that which has been generally considered as its antagonist, will accord well with some recently discovered facts, and will assimilate with the vibratory hypothesis of heat to the undulations now so generally received as explanatory of the phenomena of light, to which heat has so intimate a relation. Caloric, like light, has been proved to be capable of radiation, of reflection, and refraction, whilst

later investigations have distinctly proved that refracted heat is susceptible of polarisation. But it is transmitted, reflected, refracted, and polarised by different substances in a different manner and degree from light; and hence some have inferred that light and heat are not the same agent, but are produced by different kinds of matter. Other philosophers have regarded them as modifications of the same matter, depending on the greater celerity or velocity of the undulations that produce them. Such speculations, however, are not yet susceptible of any direct proof; and, in the present state of our knowledge, it is safer to consider light and heat as produced by different but intimately connected agents.

These views lead us to the conclusion that the phenomena of caloric are owing to the movements of a subtile matter, universally diffused throughout other bodies, the particles of which are strongly repellent of each other, and have an affinity for those of all other bodies, differing in force according to each kind of matter. We may further conceive, that heat or caloric is the cause why the particles of the most solid bodies are not in absolute contact. If we diminish the temperature of a bar of iron, for instance, it shrinks in all its dimensions, i.e. its particles approximate; and the more we reduce the temperature, the nearer they approach. Each particle of matter would seem to be surrounded with an atmosphere of heat, which remains latent, or quiescent, until disturbed by the approach of bodies of a different temperature, when the vibrations or undulations of the subtile matter of heat are induced, by the tendency of this matter to produce an equilibrium of temperature; and then we become sensible of the existence of heat.

The subtilty of the matter of heat is such, that we cannot ascertain its accumulation in any body by the nicest balance; its fluidity may be considered as proved by the ease with which it insinuates itself amongst the particles of matter; its affinity for other matter is shown by its being universally contained in all bodies, in proportions differing in each kind of substance; its repulsion amongst its own particles is proved by its tendency to exist in a state of equilibrium in contiguous bodies.(p.260)

At this stage in their education, almost all students will be absorbed into the paradigm that all matter is made up of particles and that heat simply the amount of energy that a body pos-

sesses by virtue of the movement of these particles. Some may have heard vaguely of the "Caloric Theory", but will probably regard it as a mere curiosity of scientific antiquity. It will come as something of a shock for them to encounter this strange view of heat as a "subtile, highly attenuated fluid", being presented as a theory preferred to the kinetic theory. (An entry on Heat from an earlier edition, giving only the caloric theory, might be even more interesting.)

There will usually be some discussion centred around "How could they believe something like that! "At this point it may be worthwhile introducing a few other defunct theories - The Phlogiston Theory, Archimedes' concept of matter returning to rest, the spontaneous creation of life(i.e. horse hairs turning into worms, meat turning into flies), etc. This might be a good opportunity to entice a science specialist into the TOK classroom. The examples could even be extended to topics such as Relativity and Quantum Mechanics, where the present day paradigm of the physicist differs from that of the "man in the street". I also reinforce the idea of paradigm changes by pointing out that when I was at school, plate tectonics was not taught in Physical Geography, even though it now seems so obvious and explains so much.

From a TOK perspective, perhaps a more relevant discussion could be centred around the sequence of questions:

- Is the Caloric Theory of Heat true?
- Was this theory true in 1856?
- If the truth has changed, when did it change and why?
- Is our Kinetic Theory of Heat true?
- Will it always remain so?
- Is there any such thing as ultimate truth and if so can we ever know that we have attained it?

I personally then lead the discussion towards whether regarding, for example, lightning as an electrostatic discharge, rather than the anger of the gods is merely a cultural preference and then on to a preparatory discussion for one of my favourite essay titles:

"Atoms exist." Is this statement more closely related to the statement "This piece of paper exists." or to the statement "God exists"? Explain.