Changing Concepts of Heat in the Early Nineteenth Century

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Rival theories developed early in the nineteenth century, concerning the nature of heat, may be grouped into two opposing camps. Although perhaps differing in detail among themselves, the theories in one camp were unanimous in agreement on one fundamental point: heat phenomena were to be explained by a subtle, imponderable fluid called caloric. The other camp agreed that heat was due to vibrations of the particles of matter. The caloric theory was orthodox and held by the great majority of scientists. This concept of heat provided a simple, common-sense, easily visualized explanation of most common heat phenomena. The exceptional case was that of frictional heat.

In 1798, Benjamin Thompson (Count Rumford), the American scientist and soldier of fortune, published an account of his experiments conducted in a cannon-boring factory in Bavaria.[1] The results of these experiments showed that an apparently unlimited amount of heat could be produced by friction. Caloricists, caught unawares by the impressive results of Thompson's experiment, could offer no immediate explanation of this phenomenon. These data led Thompson to reject the idea that heat was a material substance and to propound the theory that heat was nothing more than the vibrations of the particles of matter. With these seemingly irrefutable data, Thompson converted a few persons to his vibratory theory. However, in applying the new theory to other heat phenomena, this minority group got into trouble. Their explanations were imprecise, rambling and were supported, if supported at all, by the vaguest and most general analogies between the effects of heat and the effects produced by light and sound.

In spite of the apparently anomalous phenomenon of frictional heat, the inability of the vibratory theory to explain adequately other heat effects was thought to be sufficient cause for its rejection. The caloricists felt that the motionists were advocating the overthrow of a powerful and useful theory on quite insufficient grounds. Unable to come up with more plausible explanations of phenomena other than that of frictional heat, the vibrationists seemed to have given up the argument.

There appears to be a gap of twenty years, from 1812 when Sir Humphry Davy advocated the motion theory in his *Elements of Chemical Philosophy*,[2] to 1832 when Andre Ampére restated the motion hypothesis, during which no one seriously supported the caloric theory. The idea was frequently mentioned, but it was brushed aside, and discussions were carried on in terms of the material caloric. However, the tone of these discussions changed. During the early part of the nineteenth century, when the caloric theory was under attack, caloricists' arguments had been dogmatic, sanguine and sometimes even violent. After 1812, when the motionists had seemingly quitted the field, the caloricists were less inclined to argue so vehemently for their theory; and some were even willing to admit that the existence of caloric had never really been proven. In spite of such hedging statements, however, there was no doubt in the minds of the various authors as to the reality of caloric. These hedging statements increased in number and extent after 1820 so that by 1830 there were a number of scientists who not only stated that the materiality of caloric had never been proven but readily admitted that caloric was a purely hypothetical substance and that they believed in it only because it best explained heat phenomena.

Andre Ampére (1832), revived the vibratory theory as the cause of heat phenomena.[3] With Ampére began a trend toward the vibratory theory; and by 1840 it was the caloric theory which seemed to be on the defensive. The proponents of caloric were in the minority and appeared to be fighting a rear-guard action in an attempt to save a theory which was in the process of being abandoned.

At first glance, it would seem that the foregoing is a description of what should be expected in an attempt to explain natural phenomena. A theory devised to explain certain phenomena is found wanting in some area and a rival theory is created. These two theories vie for a period of time in open and above board competition until one or the other wins out.

However, a closer look at the situation in question suggests that this is not what happened at all.

An examination of discussions and experiments of "ordinary" heat phenomena reveals no evidence as to why the shift in opinion from one theory to the other should have taken place. By "ordinary" heat phenomena is meant for example, latent heats, specific heats, coefficients of expansion, and changes in these with changes in temperature and volume. Experimental data available in 1800 and data subsequently obtained during the first thirty years of the nineteenth century did nothing to weaken the caloric theory; and in one instance at least, the theory even predicted the experimental results. With respect to frictional heat, the caloric theory was only slightly less secure. It had withstood the staggering blow delivered by Thompson, and caloricists were quick to devise an explanation of this frictional phenomenon which was completely compatible with the caloric theory. In short, the arguments which were sufficient in the early part of the nineteenth century to support the caloric theory were insufficient in the 1830's, despite the fact that nothing appears to have been presented in the intervening years to make the old arguments invalid.

In 1832, Ampère brought the vibratory theory in the back door, so to speak, and attacked the caloric theory in an area which the caloricists were not prepared to defend. Ampére made no attempt to discuss the old arguments and in effect completely side-stepped these objections and transplanted the argument into the field of light and radiant heat. Caloricists continually harkened back to the explanation of ordinary heat phenomena, but their protestations were generally ignored.

Ideas on light and radiant heat were developing during the period in question; but until the 1830's, they appear to have had little influence on the question of the nature of heat.

There was no differentiation between radiant heat and the heat which caused other heat phenomena. Although the identity of these heats was not questioned, they were usually discussed and investigated separately. In 1800, Sir William Herschel reported the results of his experiments on the heating effect of various parts of the solar spectrum.[4] As experiments continued, the similarities between radiant heat and light became more and more apparent. Radiant heat could be reflected and refracted; it could be polarized; and it could be transmitted through transparent substances. These experiments, performed and re-performed during the first thirty years of the nineteenth century, although admittedly not conclusive, were indicative enough to cause many less conservative writers in the 1830's to state that radiant heat and light were identical.[5]

Thus, the question of the nature of heat was changed to a question of the nature of light. And light, according to Fresnel, was a wave produced by the vibrations of the particles of matter. The acceptance of the wave theory of light preceded many of the experiments on radiant heat. Fresnel presented his theory in 1815 and again in a more complete form in 1818; and although it received severe criticism at first, it quickly became orthodox. By 1822 it was "confirmed by the most delicate tests."[6] If light is produced by a vibration, and if heat and light are the same thing, then heat must also be a vibration.

These first steps in the overthrow of the caloric theory illustrate the point that the deciding factor in the acceptance or rejection of a theory need not be the ability or inability of the theory to explain the specific phenomena. The data around which the arguments developed confirmed the caloric theory in the early part of the nineteenth century and seemed to have provided stronger support for it in the 1830's. The same was true of the objections made against the vibratory theory. And yet, these arguments were of little weight in saving the caloric theory. The questions of the nature of light and the relation between light and radiant heat appear to have been the decisive factors in beginning the overthrow of the caloric theory.

NOTES

[1]Benjamin Thompson, Count of Rumford, "An Inquiry concerning the Source of the Heat which is excited by Friction," *Philosophical Transactions of the Royal Society of London*, LXXXVIII (1798), 80-102.

[2]Sir Humphry Davy, *Elements of Chemical Philosophy* (London: J. Johnson, 1812), 95-98.

[3]Andre Ampére, "Heat and Light Considered as the Results of Vibratory Motion," *London and Edinburg Philosophical Magazine,* VIII (1835), 342-49; taken from *Annales de Chemie et de Physique,* LVIII, 434-44.

[4]William Herschel, "Investigation of the Powers of the Prismatic Colours to Heat and Illuminate Objects," *Philosophical Transactions of the Royal Society of London,* XC (1800), 255-326, 437-538.

[5]A summary of experiments in the area of radiant heat is given in E. S. Cornell, "The Radiant Heat Spectrum from Herschel to Melloni," *Annals of Science*. III (1938), 119-37, 402-16.

[6]William Whewell, *History of the Inductive Sciences* (3 vols.; London: John W. Parker, 1837), II, 437.

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