viction in that direction. The experimental result did not satisfy Helmholtz, who, about the same time, was led to consider the origin of animal heat in living organisms, a problem with which Liebig[1] had been greatly occupied for several years. Without himself devising or instituting new experiments, or attempting any determination of the equivalent as others—notably
14. Helmholtz. Colding and Holtzmann—were doing, Helmholtz, in 1847, undertook a theoretical investigation which has since become classical—a corner-stone in the philosophy of the subject. He first of all gave the principle involved a correct mathematical expression, showed how it could be considered as an extension of the theorem known in abstract dynamics as the conservation of the *vis viva* of a mechanical system, attempted to define the nature of forces, in the Newtonian sense, which would be subject to the new principle, and brought it into logical connection with the axiom laid down and used by French philosophers, that perpetual motion is an impossibility. After clearing the ground so far as abstract dynamics is concerned and giving the necessary definitions, sharply distinguishing between acting (living) forces and mere tensions (dead forces), Helmholtz proceeds to draw all

established according as strict definitions, experimental proofs and figures, and mathematical formulæ took the place of vague speculations. Joule did the experimental, Helmholtz the mathematical, part of the work; but it is interesting to see how little the latter without the former was able to impress contemporary German writers with the value of the principle which he established. He himself even did not for a long time develop the line of reasoning which he had begun.

[1] See Helmholtz, 'Bericht über die Theorie der physiologischen Wärmeerscheinungen,' 1845, reprinted in 'Wissenschaftliche Abhandlungen,' vol. i. No. 1, also on Joule's early experiments in 'Ueber die Erhaltung der Kraft,' ibid., vol. i. p. 33.