K. Algra et al, Cambridge, U.K.: Cambridge University Press, 1999). Major texts and philosophical commentary are found in A. A. Long and D. N. Sedley, *The Hellenistic Philosophers* (2 vol.; Cambridge, U.K.: Cambridge University Press, 1987). For the sciences, G. E. R. Lloyd's *Greek Science after Aristotle* (London: Chatto and Windus, 1973) remains fundamental. For optics and its philosophical setting see Gérard Simon, *Le regard l'être et l'apparance dans l'optique de l'antiquité* (Paris: Seuil, 1988). H. von Staden, *Herophilus: the art of medicine in early Alexandria: edition, translation and essays* (Cambridge, U.K.: Cambridge University Press, 1989) and S. Cuomo, *Ancient Mathematics* (London: Routledlge, 2001) illuminate the intellectual world of Hellenistic medicine and mathematics.

Brad Inwood (2005)
Alexander Jones (2005)

HELMHOLTZ, HERMANN LUDWIG VON

(1821–1894)

Hermann Ludwig von Helmholtz, the German physiologist and physicist, was born in Potsdam and educated at the Potsdam Gymnasium, where his father taught philology and classical literature, and at the Royal Friedrich-Wilhelm Institute of Medicine and Surgery in Berlin, from which he graduated as a doctor of medicine at the age of twenty-one. Helmholtz's outstanding scientific talent led to the curtailment of his required ten-year service as a Prussian army physician and surgeon. After the presentation and publication of his famous paper *Über die Erhaltung der Kraft* (On the conservation of energy) in 1847, he held only academic posts. He was instructor in anatomy at the Academy of Arts in Berlin (1847–1848), professor of pathology and physiology at Königsberg (1848–1855), professor of physiology and anatomy at Bonn (1855–1858), professor of physiology at Heidelberg (1858–1871), professor of physics at Berlin (1871–1888), and the first president and director of the Physico-Technical Institute in Berlin from 1888 until his death.

Helmholtz contributed over two hundred papers and books of outstanding importance in medicine, anatomy, physiology, psychology, and physics. He also published papers in mathematics and in philosophy, and delivered many popular lectures to publicize significant scientific investigations and to point out their philosophical implications. He was the first to measure the speed of nerve impulses, and he invented the ophthalmoscope. His paper *Über die Erhaltung der Kraft* became the cornerstone of the science of thermodynamics and set the direction of much of physics for the next half century. His monumental three-volume *Handbuch der physiologischen Optik* (*Handbook of Physiological Optics,* 1856–1866), frequently called the principia in its field, was matched in 1863 by a work equally basic to physiological acoustics, *Die Lehre von dem Tonempfindung* (*On the Sensations of Tone as a Physiological Basis for the Theory of Music*). In mathematics he was a pioneer in the field of non-Euclidean geometry, arriving independently at conclusions similar to those of Bernhard Riemann and seeing more quickly than others the philosophical importance of these new developments. In physics he contributed substantially to the establishment of the Faraday-Maxwell conception of electrical phenomena, both by his own theoretical investigations and through his encouragement of his most famous student, Heinrich Hertz. Helmholtz greatly influenced the intellectual climate in many German universities, and he may rightly be considered one of the fathers of the philosophy of science.

EMPIRICISM AND OPPOSITION TO METAPHYSICS

Helmholtz wrote only one long essay, *Die Tatsachen in der Wahrnehmung* (The facts of perception; 1878), that he explicitly considered to be in the field of philosophy. Most of his philosophy is contained in a number of short, popular essays and in the body of his various scientific works. The scientific works, however, contain frequent passages of philosophical importance and always show a clear awareness of philosophical issues. Furthermore, many of his papers on science and mathematics, such as those on the foundations of physics and mathematics, would now be included in the philosophy of science.

Helmholtz's philosophy was at all times closely related with his scientific investigations. One of the motives for the work that led to the paper *Über die Erhaltung der Kraft* was his desire to discredit vitalism as a scientific hypothesis and as a metaphysical position. Indeed, from the beginning of his career he was opposed in general to metaphysical speculation, feeling that the idealists, Friedrich Schelling and G. W. F. Hegel in particular, and a number of materialists had perverted philosophy and turned it from its main function, which was the study of human knowledge. Helmholtz was close to Immanuel Kant in his philosophy; he believed that in *The Critique of Pure Reason* Kant had asked the right questions and had moved part of the way toward answering them. He was also close to the classical British empiricists, believing that a scientifically and mathematically sophisticated empiricism along the lines initiated by John Locke would provide highly reliable answers to a number of the basic questions of philosophy.

KNOWLEDGE AND PERCEPTION

For Helmholtz the central questions in philosophy were "In what ways do our ideas correspond to reality?" and "What is true in our sense perception and thought?" Answering these questions was the common task of both philosophy and the sciences, the two disciplines approaching them from opposite directions. The task of philosophy is to study the formal aspects of knowledge, our forms of intuition and representation, and the general categories in terms of which we order knowledge. The task of the sciences is to study the world of reality and to find the laws of nature that cause or determine both objective sequences of events and the sensations we experience. The formal aspects of knowledge, our forms of intuition and representation, and our intellectual categories, condition the ways in which we should and do formulate scientific knowledge. Scientific investigations, specifically the findings of physiological optics and acoustics, help us to understand our forms of intuition and the mental operations involved in knowing.

Although Helmholtz's position was basically Kantian, it was markedly different from Kant's on certain important points because of Helmholtz's study of physiological optics, physiological acoustics, and non-Euclidean geometry. His answer to the question "In what ways do our ideas correspond to reality?" was based upon certain discoveries in the physiology of sensation and, in particular, upon the principle of specific nerve energies. This principle was implicit in the psychological theories of a number of British empiricists; it was made explicit by Johannes Müller and was extended significantly by Helmholtz. Fundamental to this view is the theory that all we know about the external world is brought to consciousness as the result of certain changes produced in our sense organs by external causes. These changes are transmitted by the nerves to the brain, where they first become conscious sensations. In the brain they are interpreted and combined to produce our perceptions of external objects by mental processes that Helmholtz called unconscious inferences—processes he considered to be the same as those that are operative when a child learns his native language. Thus, in the case of vision, excitations of the nerves of the retina are transmitted by the optic nerve to the brain, where they are experienced as sensations and where they are unconsciously interpreted and combined to form visual perceptions of objects and their properties.

According to the principle of specific nerve energies, there is no one-to-one correspondence between a sensation experienced and a specific property of the object causing that sensation. It is perfectly possible for similar or identical sensations to be the effects of diverse causes or for a single cause, because it affects more than one kind of nerve, to result in qualitatively distinct sensations. As a result, the most that can be claimed is that sensations are caused by external objects, that they are the subjective signs of these objects and their properties, but are in no way images of them. The relation is one of sign to object signified, and even so, as such it is not an invariant relation. The only exception—an important one—is the correspondence in temporal sequence between external events and subjective sensations. Indeed, it is this correspondence that enables the scientist to determine the order of external events—that is, to determine the invariant laws of nature.

Because, with the notable exception of temporal sequences, there are no invariant, but only fairly uniform, relations between the sensations we experience and the objective world, Helmholtz felt that we can speak of our ideas as true only in a practical sense. Sensations are signs that we learn to use in order to regulate our movements and actions. When we have learned to interpret these signs, we are able to control our actions and are able to bring about results we desire or to avoid dangers.

> [To ask, however,] whether the idea I have of a table, its form, strength, colour, weight, etc., is true *per se,* apart from any practical use I can make of this idea, and whether it corresponds with the real thing, or is false and due to an illusion, has just as much sense as to ask whether a certain musical note is red, yellow, or blue. Idea and thing conceived evidently belong to two entirely different worlds, which no more admit of being compared with each other than colours and musical tones or than the letters of a book and the sounds of the words they form. (*Handbook of Physiological Optics,* Vol. III, p. 19)

SPACE AND GEOMETRY

Helmholtz's study of perceptions of space and of spatially oriented objects led him into the field of non-Euclidean geometry. His interest in general problems of spatial perception led to the investigation of the analytic properties that any space must have in order to permit the establishment of congruence relations between bodies and surfaces. As he saw it, congruence can be established only if rigid bodies or systems of bodies can be moved toward one another with unaltered form—that is, only if the congruence of geometrical figures is a relation independent of all movements in space. Thus, he took the actual fact of spatial measurements through the establishment of congruence as a starting point and investigated the most general analytical properties of any space in which the movements necessary for this measurement can occur. He found that such movements and measurements were possible not only in Euclidean space but also in the spaces investigated by Riemann and Nikolai Ivanovich Lobachevski or in any space with a constant measure of curvature. Helmholtz concluded that Kant was mistaken in claiming that the axioms of Euclidean geometry were synthetic a priori principles necessarily true of space. Spaces that are not Euclidean can be conceived; the geometries of these spaces can be formulated; models or interpretations of them can be given, and on the basis of experience, it is impossible to determine which of these geometries is that of real space. Kant was correct in considering space to be a form of intuition but wrong in claiming that space must necessarily possess Euclidean characteristics.

PHILOSOPHY OF PHYSICS

Helmholtz's philosophy of physics was a classic formulation of nineteenth-century mechanism. He felt that the primary function of the physical sciences was to search for laws that express observed particular processes in general terms, so that from these laws other particular processes could be deduced. The discovery of these laws is the task of experimental physical science.

> The theoretical part … endeavors to ascertain the unknown causes of processes from their visible effects, it seeks to comprehend them according to the law of causality… . Thus, the final goal of the theoretical natural sciences is to discover the ultimate invariable causes of natural processes. (*Über die Erhaltung der Kraft,* introduction)

According to Helmholtz, these ultimate causes are simple Newtonian forces, so that a causal explanation in physics is at the same time an explanation in terms of forces.

> Theoretical natural science must, therefore, if it is not to rest content with a partial view of the nature of things, take a position in harmony with the present conception of the nature of simple forces and the consequences of this conception. Its task will be completed when the reduction of phenomena to simple forces is completed, and when it can at the same time be proved that the reduction given is the only one possible which the phenomena will permit. This will then be established as the necessary conceptual form for comprehending nature, and we will then be able to ascribe objective truth to it. (Ibid.)

These statements always represented the ultimate aim of scientific explanation for Helmholtz. It was a goal that grew more distant as the nineteenth century advanced.

See also Geometry; Hegel, Georg Wilhelm Friedrich; Hertz, Heinrich Rudolf; Kant, Immanuel; Philosophy of Physics; Philosophy of Science; Schelling, Friedrich Wilhelm Joseph von.

Bibliography

WORKS BY HELMHOLTZ

Über die Erhaltung der Kraft. Berlin: Reimer, 1847.

Handbuch der physiologischen Optik. 3 vols. Leipzig, 1856–1866. Edited and translated by J. P. C. Southall as *Handbook of Physiological Optics.* New York, 1924–1925.

Die Lehre von dem Tonempfindung. Leipzig, 1863. Translated by A. J. Ellis as *On the Sensations of Tone as a Physiological Basis for the Theory of Music.* New York: P. Smith, 1948.

Populäre wissenschaftsliche Vorträge. 2 vols. Leipzig, 1865–1871. Translated as *Popular Lectures on Scientific Subjects, First and Second Series.* New York, 1873–1891.

Die Tatsachen in der Wahrnehmung (The facts of perception). Berlin, 1878.

Schriften zur Erkenntnistheorie. Edited by Paul Hertz and Moritz Schlick. Berlin: J. Springer, 1921.

WORKS ON HELMHOLTZ

Crombie, A. C. "Helmholtz." *Scientific American* 198 (3) (1958): 94–102.

Koenigsberger, Leo. *Hermann von Helmholtz.* 3 vols. Berlin, 1902–1903. Translated by F. A. Welby. Oxford, 1906.

McKendrick, John Gray. *Hermann Ludwig Ferdinand von Helmholtz.* New York: Longmans, Green, 1899.

Russell Kahl (1967)

HELVÉTIUS, CLAUDE-ADRIEN
(1715–1771)

Claude-Adrien Helvétius was born into a highly respected medical family; his father was first physician to the queen of France. After his education at the College Louis-le-Grand and at the age of only twenty-three, Helvétius obtained, through influence at court, the lucra-