Chapter 2
New Directions in Physiology in the Johannes Müller Circle in Berlin

Helmholtz's academic career began with the study of chemistry, clinical medicine, and physiology. The research with Johannes Müller, which led to a doctoral dissertation in 1842 at the University of Berlin, put Helmholtz in contact with the ideas of Müller and Müller's students, and convinced him at the very start of his studies of the importance of experimental medicine and the urgency of launching a programme within the discipline of physiology based on observation and experimentation using the techniques of chemistry and physics.

Johannes Müller (1801–1858), Professor of Anatomy and Physiology and Director of the Museum of Comparative Anatomy at the University of Berlin, more than any other individual of his time, came by the end of the nineteenth century to be recognized as Germany's prime mover for an experiment-inspired programme in biological and medical research. In large part the robustness of Müller's programme was owing to the fact that his students had achieved considerable eminence in the life sciences by the end of the century. As will be shown, Müller's own exemplary experimental investigations were realized within the context of the doctrine of *Naturphilosophie* – a philosophy of nature most closely linked with German idealism and the romanticism of the philosopher Schelling.

In a work of 1826 on the comparative physiology of the sense of sight Müller discovered that the sensory systems of the body are able to respond to various stimuli in a fixed and characteristic way with an energy (the term Müller used) specific not to the nature of the stimuli but to the particular organ of sense that receives the stimulus. According to Müller's law of specific nerve energies [*die Lehre von den specifischen Sinnesenergien*] which encapsulates the law, the eye registers the sense of sight, the ear registers the sense of sound, and so forth. This discovery turned out to embody far-reaching scientific and epistemological implications and demonstrates that what can be known about the so-called objective world of nature is registered in the mental apparatus of the body subjectively, and depends more on the physiological structure of human sensors such as the eye or the ear than on the objective physical agents of sensation. These implications go a long way toward explaining why physicists such as Helmholtz and Ernst Mach became so deeply involved in the principles and the terminology of sensory physiology and

E. Hiebert, *The Helmholtz Legacy in Physiological Acoustics*, Archimedes 39,
DOI 10.1007/978-3-319-06602-8_2,

psychology in the course of working on problems whose origins spring from physics. Müller's two-volume *Handbuch der Physiologie des Menschen* (1834/1840) was translated into several languages and represents a landmark in physiological research and teaching texts. Throughout the second half of the nineteenth century, Müller's views on sensation provided strong support for the mechanistic or physicalistic conception of life.

A pioneer in the study of comparative and pathological anatomy, embryology, and physiology using methods drawn from the physical sciences, Müller nevertheless held fast to the notion of a non-physical vital force, a *Lebenskraft* that exists apart from the forces that are at work in the domain of physics and chemistry. The concept of *Lebenskraft* was regarded by Müller, in a general sense, as an essence akin to the soul, or as a reality living in the body next to the soul. In some contexts the *Lebenskraft* concept was placed alongside the so-called "imponderables of nature" – immaterial essences such as the nerve principle, animal heat, and galvanic electricity. For Müller, *Lebenskraft* was taken to be the unitary cause and steward of all living phenomena. Fundamentally different from inorganic forces, the *Lebenskraft* was in conflict with inorganic forces. As Müller expressed it, the secrets of the laws of physics and chemistry were known to *Lebenskraft* and had developed alongside the sensory and motor organs of the breathing and digestive apparatus. They had developed as a part of the organization of the body. *Lebenskraft* had no specific locus in the body, was present everywhere, and acted at no specific point. It possessed the potential not only of being able to control nutrient material and invigorate matter capable of becoming living, but also of rejecting matter after it had served its function in the living process. In regard to the basic tenets of *Lebenskraft* Müller had the good company of the physiologist Rudolph Wagner (1805–1864) and the chemists Justus Liebig (1803–1873) and Friedrich Wöhler (1800–1882).[1] On the other hand Müller's own students rejected *Lebenskraft* outright. For them it would have been antithetical to postulate a philosophy that condones behind-the-scene explanations or metaphysical principles that appeal to non-physical vital properties or forces.

The close-knit group of four physiologists in the Müller circle – a group that for an entire generation came to be looked upon as the founders of the new German physiology – included Hermann Helmholtz, Ernst Brücke, Emil Du Bois-Reymond, and Karl Ludwig. All except Ludwig had studied personally with Müller in Berlin in the late 1830s and the 1840s. Helmholtz, in particular, went out of his way to recognize Müller as the one person who had convinced him that he would not have to abandon his first love, physics, even if he dug himself into problems traditionally considered to belong to physiology. He remarked that his acquaintance with Müller had "definitely altered his intellectual standards."[2]

[1] Emil Du Bois-Reymond, "Festrede zur Feier des Leibnizschen Jahrestages." *Sitzungsberichte der königlichen Preussischen Akademie der Wissenschaften zu Berlin*, Berlin, 1894, 625–628.

[2] Johannes Steudel, "Johannes Müller," *Dictionary of Scientific Biography* (referred to hereafter as the *DSB*) *9* (1974) 567–574. Quotation on 568. See also R. Steven Turner, "Hermann Helmholtz," *DSB*, *6* (1972) 241–253.

Karl Ludwig (1816–1895), an enthusiastic Müllerite, was a medical student at the University of Marburg, and, in fact, was the senior physiologist in the Müller circle. He became the most outspoken proponent for the explanation of living phenomena in terms of mechanics. He had invented the kymograph and the blood pump, introduced graphic methods into physiology, and made major contributions to knowledge about blood circulation. A visit to Berlin in 1847 brought him in contact with Helmholtz, Brücke, and Du Bois-Reymond and led to a lifelong collaboration in the pursuit of problems in experimental physiology based on physical principles. Ludwig's mastery of physicochemical principles, and his ingenious experimental use of custom-built instruments, enabled him to become one of the most prominent experimental physiologists of the nineteenth century. As chair of physiology at the University of Leipzig, and as a phenomenally successful teacher (an accolade that Helmholtz never received), Ludwig in 1865 established an institute for physiology in Leipzig that acquired worldwide recognition.[3]

Ernst Brücke (1819–1892), assistant to Müller, graduated from the University of Berlin with a doctorate in medicine and surgery. One of the most versatile physiologists of his day, Brücke exhibited a lifelong fascination with the theory of art. His programme for the new physiology led to observations on optical images, after-images, stereoscopic vision, and reflections from the retina of the eye – foundational studies that Helmholtz was able to draw on in his three classic volumes on physiological optics. In 1849 Brücke was appointed Professor of Physiology in Vienna. In this city, with its flourishing scientific and artistic cultures, Brücke not only established an internationally recognized school for physiology but was able to pursue his persuasion that it is meaningful to engage in the rational study of the humanities and the arts using scientific methods. He wrote a work on the characteristic features of the physiology and taxonomy of linguistics based on the transcription of sounds of one language into the alphabetic characters of another language. Using a lip-measuring device he studied the lengths of strongly and weakly accented syllables in verse. Highly acclaimed not only as a man of enormous learning and prodigious scholarly output but as an outstanding teacher, Brücke was known among his students for his modesty. It was said that "[He] was interested only in explaining the events of nature with a view to their objective regularity."[4]

Emil Du Bois-Reymond (1818–1896) is counted among the founders of a physiology that is based predominantly on physics, chemistry, and the mechanistic interpretation of living phenomena. An outspoken mouthpiece for antivitalistic philosophy, he provided the essential inspiration and laid out well-defined methods of research that led to the establishment of the new field of electrophysiology.[5] As an assistant to Johannes Müller in the 1840s, Du Bois-Reymond remained in close contact with Brücke, Helmholtz, and Ludwig. When Müller died in 1858

[3] George Rosen, "Karl Ludwig," *DSB*, *8* (1973) 540–542.

[4] Erna Lesky, Ernst Brücke, *DSB*, *2* (1970) 530–532. Quotation on 532.

[5] K. E. Rothschuh, "Emil Heinrich Du Bois-Reymond," *DSB*, *4* (1971) 200–205.

Du Bois-Reymond, 40 years old at the time, inherited the chair in physiology in Berlin. From that time on his contributions to the development of modern physiology display a strong preference for the explanation of processes in living organisms based not so much on mechanics as on molecular and atomic mechanics – a unique position even among the Müllerites. His physics-directed research ventures into physiology led to significant contributions in animal electricity, electrophysiology, and the physics of muscles and nerves. After much agitation in Vienna, and with support from the Prussian government, he was able to establish a physiological institute in Berlin that apart from Ludwig's institute in Leipzig and Brücke's institute in Vienna became the largest and most handsomely equipped physiology institute in all of Germany. When the original Müller foursome disbanded in 1858 it was Du Bois-Reymond who would become the most outspoken voice for the physicalistic and mechanistic physiology that had received its initial stimulus in the Berlin of the Johannes Müller circle.[6]

The compilation of Du Bois-Reymond's many public lectures and published essays, the *Reden*, feature the relation of the natural sciences to philosophy, politics, history, and theology. Presented in a tone best characterized as a blend of Francophilic Bravado and Germanophilic *Gründlichkeit*, the *Reden* elicited discussions and controversy that lasted for several decades. In essence the *Reden* demonstrate Du Bois-Reymond's keen ability to identify essential and explore-worthy links between the natural sciences, the humanistic disciplines, and cultural history. He also drew attention to acknowledging that the history of science was the most neglected area of cultural history.[7]

In his scientific papers, so too in his *Reden*, Du Bois-Reymond sought to distance himself at all costs from the hypothetical vital forces that for him and most of his fellow physiologists in the Müller circle had become the *bête noir* of the discipline; this in stark contrast to the views of their own teacher who had never been able to rid himself entirely of the *Naturphilosophie* that already had dominated his own medical training at the University of Bonn in the 1820s. When Müller died in 1858 Du Bois-Reymond penned a memorial address of 182 pages for his teacher and colleague.[8] In this address he provided a well-documented and historically informative account of Müller's scientific outlook and contributions He characterized Müller's role as a leader and reformer in the development of physiology, and touched significantly on the changing ways of thinking that were taking place in the discipline of physiology during the Müller years. In the history of biology Johannes Müller has been referred to as the Albrecht Haller of the nineteenth century. In the discipline of comparative anatomy the allusion is to Müller as the

[6] The emergence of the modern physiology laboratory in Berlin in the age of electricity and the machine is examined in the career of Du Bois-Reymond by Sven Dierig, in *Wissenschaft in der Maschinenstadt: Emil Du Bois-Reymond und seine Laboratorien in Berlin*, Göttingen, 2006.

[7] Estelle Du Bois-Reymond, ed. *Reden von Emil Du Bois-Reymond*, I–XXII, 2 vols., Leipzig, 1912.

[8] Emil Du Bois-Reymond, "Gedächtnisrede auf Johannes Müller," Gehalten an der Leibniz-Sitzung der Akademie der Wissenschaften, 1858, *Reden* #VI, Leipzig, 1912, 135–317.

George Cuvier of Germany. Du Bois-Reymond intimates that Müller's death in 1858 was the greatest loss to the University of Berlin since the death in 1851 of Carl Jacobi, who apart from Karl Friedrich Gauss at Göttingen was the leading German mathematician of his time.[9]

An examination of Du Bois-Reymond's comprehensive mid-century evaluation of the Müller period in physiology convinced its author – who was well aware of the enormous changes that had taken place in physiology – that on behalf of his other closest colleagues in the Müller circle (Ludwig, Brücke, and Helmholtz) it was his duty to put on record the full story of how the discipline of physiology had come to be recognized and certified as a modern *scientific* discipline alongside physics and chemistry. With unreserved high praise for Müller's physiological and medical research, Du Bois-Reymond acknowledged, in particular, the effectiveness of Müller's rapport with students and the widely acclaimed efficacy of his teaching and publications – singling out especially the 2-volume *Handbuch der Physiologie des Menschen* (1840). He nevertheless recognized that it was imperative to come to terms with an ostensibly inconsistent collusion of ideas in Müller's scientific outlook. On the one hand Müller had championed the mechanistic conception of life. In his own physiological research, and in the research of his students, he had promoted the principles and the use of experimental methods that draw on physics and chemistry. On the other hand Müller had condoned the notion of *Lebenskraft* throughout his entire career. In spite of this fundamental concept as anchor point in Müller's perspective, his students, to a person, had rejected *Lebenskraft* as an empty metaphysical hangover from the *Naturphilosophie* of earlier times. By the middle of the nineteenth century, a decade before Müller died, the *Lebenskraft* idea virtually had vanished from the writings of physiologists – a state of affairs that was taken proudly to be the result of the implementation of the mechanistic philosophy and physicalistic methods set in motion almost exclusively by Müller and the Müllerites.

Du Bois-Reymond's reconstruction of Müller's reasoning on this score is compelling and complicated and need not be drawn out here. The gist of the argument is given by the following excerpt from one of Du Bois-Reymond's *Reden*.

> A description of Müller as physiologist would not be complete if his relationship to the principle question of biology and the essence of life processes and their active forces were left untouched. Everyone knows that from the start and until the end of his life Müller was a resolute vitalist. . . .
>
> Müller adopted the idea of an integrated *Lebenskraft* which, although distinguished from physical and chemical forces, comes into conflict with these forces and acts in organisms as cause and uppermost guardian according to a determined plan. All the puzzles of physics and chemistry bow down before this force. In death it vanishes without a corresponding action in its place. . . .[10]

[9] Estelle Du Bois-Reymond, *Reden*, #VI, 135–136.

[10] Estelle Du Bois-Reymond, *Reden* #VI, 205–206. "Ueber die Lebenskraft," *Reden* #I (1848) (1–26) provides an earlier exposé of the *Lebenskraft* doctrine.

Du Bois-Reymond's mid-century evaluation of Johannes Müller's role in the development of modern biology and physiology is one that historians of the life sciences have continued to belabor. It rests upon the assumption that Müller, presumably, was the last individual of his generation to have been in command of the whole of biological knowledge – this in addition to being regarded as a pioneer in various sub-branches of the life sciences that were the purview of his and his student's experimental research. Many years later, in a lecture presented to the Physical Society in Berlin and commemorating the 50th anniversary of Helmholtz's doctorate, Du Bois-Reymond referred to physiology as the "queen of the sciences."[11] In the estimation of persons such as Du Bois-Reymond and Helmholtz, who counted themselves as among the earliest pioneers of the new science of physiology, it was the dominance of the physical and the mechanical-mathematical approach that by the end of the century had given physiology its essential modern character. A prominent historian of biology has remarked, in reference to the mechanistic approach and accomplishments of the Müller circle scientists, that from the 1840s onward German physiology travelled a path that took the discipline from being "a playground for dilettantism to a scientific physiology."[12]

The mechanistically conceived theoretical ideas and physical methods that were being put in practice led not only to an abundance of new discoveries in medicine and physiology but gave the discipline and its practitioners a new profile. The Müllerites had made no attempt to define life or clarify what meaning might be given to life's vital forces. Rather, the functioning of living processes was expressed and explained solely in the terms of physics and chemistry. By the end of the century the new physiology was firmly established in Vienna, Leipzig, Heidelberg, and Berlin. The school of physiology and its laboratory in Vienna had become world renowned. Brücke and his students had demonstrated, in experiments on the electric stimulus of muscles, that the magnitude of the stimulus effect was caused not solely by the amount of current applied, as Du Bois-Reymond had claimed, but was governed as well by a time factor. In Leipzig Carl Ludwig had established a research programme to clarify physiological problems by correlating study of the anatomy of a particular organ with the physiochemical changes that occur in its functioning. To achieve this end he had created physical, chemical, and anatomical divisions in the laboratory and set his sights on the design and refinement of instruments that provide the information he was looking for. Together with his students he devised a mercurial blood pump to study circulation, opened up the new field of investigations on the process of diffusion and osmosis through body membranes, and set up experimental methods to study salivary and renal secretions and respiration.

[11] Estelle Du Bois-Reymond, *Reden*, No. XVII (1892), 643–648.

[12] K. E. Rothschuh, *Physiologie im Werden*, Stuttgart, 1969, p. 167. "So wird aus einem Tummelplatz des Dilettantismus eine naturwissenschaftliche Physiologie." See, in particular, Rothschuh's last chapter entitled: "Ursprünge und Wandlungen der physiologischen Denkweise im 19. Jahrhundert."

In a lecture to the Berlin Academy of Sciences on the occasion of a Leibniz Anniversary celebration Du Bois-Reymond seized the opportunity to reflect once more on matters he had dealt with almost 40 years earlier in the memorial address for Johannes Müller.[13] The interim years had given Du Bois-Reymond the retrospective credentials to revisit and reevaluate the determinative factors that had paved the way for the accomplishments of the Müller group during the Berlin years and beyond. How had it come about that Müller, proponent of the *Lebenskraft* idea, had provided so fertile an intellectual and academic haven to pursue the mechanistic line of thought in physiology? How had Müller's students become such enthusiastic supporters and successful practitioners of the mechanistic outlook on living phenomena while rejecting their scientific mentor's *Lebenskraft* doctrine? Du Bois-Reymond sought, these many years later, to shed new light on such questions. He felt that it was important to recognize that Müller not only was the leading physiologist of Germany at the time but that he also was a skillful and influential expositor and writer. Du Bois-Reymond inferred that when Müller wrote on the subject of *Lebenskraft* he had laid out its essence and implications with such clarity, and so forthrightly and transparently, that it became relatively straightforward, especially for persons who were knowledgeable about physiology and adept at using analytical tools and sharp arguments, to show that the *Lebenskraft* doctrine rested on an illusion (*Trugbild*) that readily could be exposed. Accordingly, Müllers's vitalism was openly challenged. He had listened to his students' arguments but stood his ground. They had listened to his arguments and stood their ground. Mutual tolerance and respect were taken for granted.[14]

A related issue that Du Bois-Reymond chose to dwell on in the 1894 *Festrede* was that the task of demonstrating the sterility of the *Lebenskraft* doctrine in the biological sciences – a task approached resolutely out of respect for Müller – had led to raising questions and invoking analytical reasoning that, as by-product, opened up new trajectories for strengthening the physicalist point of view. The cardinal fault of the vitalists, as Du Bois-Reymond emphasized, was embodied in positing an erroneous conception of force (*Kraft*), but force is not, as the vitalist had conceived, associated with matter as an essence that exists separate from matter. Rather, force is a conceptual notion invoked to explain observed changes in matter. As Newton had shown, force is a mathematical concept. When associated with living matter it becomes a conceptually empty notion that serves no function in the life sciences.[15]

The focus of this study is Helmholtz (1821–1894). He was the youngest among the four members of the Johannes Müller (1801–1858) circle whose new directions in physiology developed into a scientific discipline whose early history we are exploring. He began his academic studies at the *Pepinière*, an institute for the

[13] Emil Du Bois-Reymond, "Festrede zur Feier des Leibnizschen Jahrestages," *Sitzungsberichte der königlichen Preussischen Akademie der Wissenschaften zu Berlin*, 1894, 623–641.

[14] Emil Du Bois-Reymond, 1894, "Festrede..." 626–627.

[15] Emil Du Bois-Reymond, "Festrede..." 1894, 628–629.

training of medical doctors. At the same time he attended lectures on physiology at the University of Berlin. Many years later Helmholtz recalled:

> With this study I came directly under the influence of a sensitive teacher [*eines tiefsinnigen Lehrers*], the physiologist Johannes Müller, who at the same time had led Du Bois-Reymond, Brücke, Ludwig and Virchow into physiology and anatomy. Johannes Müller still was struggling with puzzling questions concerning the nature of life – questions that essentially were metaphysical, and also questions concerning the newly developing scientific outlook on the nature of life. However, the conviction that the knowledge of facts cannot be replaced by anything else was developing in him with steady firmness. That he himself still was struggling [in this way] probably made his influence on students all the greater.[16]

Working with Müller at the University of Berlin, Helmholtz completed his doctoral dissertation on the structure of the nervous system in invertebrates in 1842.[17] To the extent that freedom from medical studies and other assignments permitted, Helmholtz simultaneously immersed himself in the classic works of eighteenth-century mathematician-physicists such as Leonhard Euler (1707–1783), Daniel Bernoulli (1700–1782), Jean le Rond d'Alembert (1717–1783), and Joseph Louis Lagrange (1736–1813). His secret love [*Lieblingsthema*] from the days of his youth had been physics. When Du Bois-Reymond first met Helmholtz in 1845 he wrote to his friend Eduard Hallmann (1813–1855), who at the time was Müller's assistant,

> In the meantime an acquaintance with Helmholtz has given me much pleasure. This, according to Brücke and little me [*sauf la modestie*], is the third organic physicist in our league. He is a fellow who has devoured [*gefressen*] chemistry, physics, and mathematics with spoons; he stands entirely with us on our *Weltanschauung*, and is rich with ideas and new ways of looking at things.[18]

References

Du Bois-Reymond, Emil. 1894a. Festrede zur Feier des Leibnizschen Jahrestages. In *Sitzungsberichte der königlichen Preussischen Akademie der Wissenschaften zu Berlin*, 625–628. Berlin: The Academy.

Du Bois-Reymond, Emil. 1894b. Festrede zur Feier des Leibnizschen Jahrestages. In *Sitzungsberichte der königlichen Preussischen Akademie der Wissenschaften zu Berlin*, 623–641. Berlin: The Academy.

Du Bois-Reymond, Estelle, ed. 1912a. *Reden von Emil Du Bois-Reymond*, I–XXII, 2 vols. Leipzig: Verlag Von Veit.

[16] Helmholtz, "Erinnerungen," Tischrede gehalten bei der Feier des 70. Geburtstages, Berlin, 1891, *Vorträge und Reden*, 5th ed. 1903, vol. 1, 9.

[17] Arminius Helmholtz, *De fabrica systematis nervosi evertebratorum*, Berlin, 1842.

[18] Estelle Du Bois-Reymond (ed.), *Jugendbriefe von Emil Du Bois-Reymond und Eduard Hallmann*, Berlin, 1918, 122–123.

Du Bois-Reymond, Emil. 1912b. Gedächtnisrede auf Johannes Müller. In *Gehalten an der Leibniz-Sitzung der Akademie der Wissenschaften*, 1858, Reden #VI, 135–317. Leipzig: Veit & Co.

Du Bois-Reymond, Estelle (ed.). 1918. *Jugendbriefe von Emil Du Bois-Reymond und Eduard Hallmann*, 122–123. Berlin: Reimer.

Helmholtz, Arminius. 1842. *De fabrica systematis nervosi evertebratorum*. Berlin: Berolini, Nietackian.

Helmholtz. 1891. Erinnerungen. In *Tischrede gehalten bei der Feier des 70*. Geburtstages, Berlin, 1891, *Vorträge und Reden*, 5th ed. 1903, vol. 1, 9.

Lesky, Erna. 1970. Ernst Brücke. *DSB* 2: 530–532.

Rosen, George. 1973. Karl Ludwig. *DSB* 8: 540–542.

Rothschuh, K.E. 1969. *Physiologie im Werden*, 167. Stuttgart: Fischer.

Rothschuh, K.E. 1971. Emil Heinrich Du Bois-Reymond. *DSB* 4: 200–205.

Steudel, Johannes. 1974. Johannes Müller. *DSB* 9: 567–574.

Steven Turner, R. 1972. Hermann Helmholtz. *DSB* 6: 241–253.

http://www.springer.com/978-3-319-06601-1

The Helmholtz Legacy in Physiological Acoustics
Hiebert, E.
2014, XXIII, 269 p. 12 illus., Hardcover
ISBN: 978-3-319-06601-1