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Introduction

The first half of the nineteenth century saw a revolution in the understanding of the structure and function of the nervous system and during it anatomical and physiological ideas that had long been widely accepted were overthrown. In this book we shall be particularly concerned with those ideas formulated by Galen (A.D. 129–199) in classical antiquity and by Albrecht von Haller (1708–1777) in the eighteenth century. These outmoded ideas were replaced by new concepts of the nervous system, which have survived in modified form to the present day, and it is of great interest to note how many basic neuroscientific concepts were established during this brief half-century. We can, in fact, claim that by 1850 the foundations of modern neuroscience had been laid. There is, however, one exception to this generalization. The notion of brain localization, although adumbrated early in the century, did not achieve full expression and approval until the 1870s. We shall consider the reasons for this delay in chapter 6.

During the early nineteenth century, advancement in the neurosciences depended, as in all fields of science, upon conceptual and technological innovations. In the following pages we are primarily concerned with the genesis of revolutionary ideas, although we also take cognizance of others of less lasting importance. Above all, we have tried to show that the pattern of neuroscientific thought cannot be understood in isolation: it must be set against the background of wider trends in the sciences and in the philosophy of the time.

In particular, we argue that changes in ideas of the function and structure of the nervous system during this period were stimulated by the romantic philosophy of nature that exerted a major influence upon biological thought in the first half of the nineteenth century. The late eighteenth century saw the beginnings of a trend to search for synthesis, unity, and general laws in the life sciences rather than to concentrate solely upon narrowly conceived empirical studies and the accumulation of data for its own sake.[1] Above all there was a growing conviction among scientists of this period that the human organism could not be understood in isolation, but that its relations to the rest of the organic world and even with inorganic nature must be discovered if knowledge was to advance.

This wide-ranging and ambitious program for the life sciences found proponents in Britain and France. But it achieved its fullest expression in the German-speaking states. There the goal of a comprehensive science of life which would itself be part of a general philosophy of nature and man was pursued with the most energy.

The strongest version of this course of study was the school of *romantische Naturphilosophie* inspired by the writings of Friedrich Wilhelm Joseph von Schelling (1775–1854).[2] The school of *Naturphilosophie* has generally received a harsh judgment from historians.[3] If *Naturphilosophie* is allowed any influence upon the medical sciences, it is a purely negative one. We believe that this opinion must be revised in the light of our discussion of concepts and strategies drawn from *Naturphilosophie* in the work of such major figures as Jan Evangelista Purkyně (1787–1869) and Gustav Gabriel Valentin (1810–1883) (see chap. 3.2–4).

Many of the individuals whom we will discuss were, however, only fleetingly—if at all—committed to the full-blown doctrines of *Naturphilosophie;* they can nevertheless justly be described as exponents of romantic biology. Various strands of thought and research traditions within Germany can be discerned at this period. The *Naturphilosophen* themselves were a far from homogeneous group. Further, Dietrich von Engelhardt has pointed out that Georg Wilhelm Friedrich Hegel (1770–1831) insisted upon a distinction between his "speculative" philosophy of nature and the products of such romantics as Heinrich Steffens (1773–1845) and Lorenz Oken (1779–1851).[4] Timothy Lenoir, meanwhile, has argued that the influence of *romantische Naturphilosophie* pales into insignificance in comparison with the impact upon German biology of the research tradition that emerged in Göttingen at the end of the eighteenth century, a research tradition that drew inspiration from the philosophy of Immanuel Kant (1724–1804) rather than from Schelling.[5]

If one looks beyond Germany, different national styles in science must also be acknowledged. As E. S. Russell points out, there were significant differences between the work of the *Naturphilosophen* and that of the French school of transcendental or philosophical anatomy led by Étienne Geoffroy Saint Hilaire (1772–1844),[6] who declared that this type of anatomical study comprised the most profound principles of the science. These principles were to be discerned by reasoning a priori, and because they were themselves part of a reasoning process, they transcended sense experience. Thus, he believed that enlightenment could be achieved by means of acute intellectual intuition, which therefore transcended physical appearances and permitted spiritual and nonmaterial causes to be just as acceptable as material ones. In Britain both the German and the French version of transcendentalism were widely disseminated and combined in an eclectic manner.[7]

It is necessary to recognize this diversity if the nuances of the life sciences of this period are to be understood. However, an emphasis upon the divergent paths that the quest for a unified science of life took must not obscure the extent of concensus even among apparently disparate individuals over the goals and methods proper to biology. Lenoir, for example, noted that most of his vital materialists "always did have and continued to have much in common with *romantische Naturphilosophie.* Indeed both traditions had the same goal of constructing a dynamical morphology, and 'organic physics' as it was termed." Where they diverged, he adds, was in their opinion of how much pure speculation could contribute to this endeavor.[8]

Relatedly, Russell notes that certain key concepts were common to both the French and the German transcendentalists: "the fundamental concept that there exists a unique plan of structure, the idea of the scale of beings, the notion of the parallelism between the development of the individual and the evolution of the race."[9] Such concepts played a central role in the writings of the *Naturphilosophen;* but they were also important to a much larger body of workers who were striving to achieve a comprehensive scientific understanding of vital processes and structures. Moreover, whereas *Naturphilosophie* enjoyed a relatively brief vogue followed by a rapid decline,[10] the more general movement of a romantic biology pursuing this end with these means persisted until the mid-nineteenth century and beyond.

It is easy to ridicule the more egregious speculations of the *Naturphilosophen.* It is also likely that the wide dissemination of the tenets of romantic biology led many other scientists into false analogies and faulty reasoning. For example, the tendency among experimenters of this period to ignore species differences and to assume that phenomena observed in one animal must exist for all may well have been a product of an uncritical acceptance of the "unity of organization" principle. We will argue, however, that the endeavors of scientists working within the framework of and employing the concepts of romantic biology were of great importance in the transformation of neuroscientific thought with which we are concerned. Other factors were, of course, at work; but we have stressed the role of romantic biology because we consider this to be one of the most original results of our study.

Although our emphasis is on the conceptual side of the science of the period, the practical methods employed to verify or disprove hypotheses must also figure in our discussion. These methods will be discussed as we proceed; but this opening chapter will consider in general terms the various sources and techniques resorted to in attempts to explore the form and function of the nervous system in humans and animals. Such investigations formed a major, indeed a predominant, part of the physiology and anatomy of the period; and it is necessary first of all to account for this predilection.

1.1. THE PRIMACY OF THE NERVOUS SYSTEM

In 1835, Antoine Jacques Louis Jourdan (1788–1848) remarked that the nervous system occupied the premier place in the researches conducted by physiologists in the first few decades of the nineteenth century,[11] but a keen interest in the phenomena displayed by this system was by no means peculiar to the nineteenth century. Thus, the reasons for this preoccupation supplied by Thomas Willis (1621–1675) in 1664 also apply in our period. He wrote that

> the anatomy of the nerves [that is, the nervous system] provides more pleasant and profitable speculations than the theory concerning any other part of the animal body: for by means of it, are revealed the true and genuine reasons for very many of the actions and passions that take place in our body, which otherwise seem most difficult to explain: and from this fountain, no less than the hidden causes of diseases and symptoms, which are commonly ascribed to the incantations of witches, may be discovered and satisfactorily explained.[12]

One of the reasons why the nervous system exerted a fascination upon late eighteenth- and early nineteenth-century investigators, as it did upon those of other epochs, was its intimate association with the phenomena of mind. As we shall see below, the precise "seat" of the soul in the nervous system, and the nature of the relation between this organ and the mind, remained highly contentious. Nevertheless, it was generally recognized that the nervous system did represent an interface between the material and psychic realms and was, therefore, an object of unique interest.[13] In chapter 6, we shall learn how Franz Joseph Gall (1758–1828),[14] at the turn of the nineteenth century, insisted that the mind was situated in the brain, to us a very obvious conclusion, but by no means universally accepted in the early nineteenth century.[15] His advocacy of this neuroscientific principle, his application of it to a cult of psychological testing called organology and later known as phrenology (see chap. 6.3), his widespread teaching, and his skillfully executed and publicized dissections of the brain, together with the labors of his colleague, Johann Caspar Spurzheim (1776–1832), all helped to focus the attention of the layman as well as the scientist on the nervous system and, in particular, on the brain. Gall's eminent contemporary, François Magendie (1783–1855), who was one of the greatest physiologists of his age, also agreed that it was necessary to regard strictly the phenomena of the human intellect as "the result of brain action and not in any measure to distinguish them from other phenomena which depend upon organic actions."[16]

J. E. Lesch has examined the various reasons why Magendie's main research interests concerned the nervous system, and we can take him to be representative of others, who, on account of similar motives, elected neurophysiology as their chosen field of scientific study.[17] In his case, there was, first of all, the profound influence of the celebrated French comparative anatomist, Georges Cuvier (1769–1832), whose classical investigations led him to insist upon the primary functional importance of the nervous system.[18] The provocative theories of Gall and Spurzheim on the properties of the brain referred to above also drew attention to it, just as the researches of Charles Bell (1774–1842) highlighted the specific properties of the spinal cord roots, as we shall see below.[19] In addition, the contributions of clinicopathological correlation to the elucidation of neurophysiological problems, or "pathological physiology" as Magendie named it, seemed to him most rewarding. We shall discuss this topic in more detail shortly. Finally, the experiments on drugs that affected the nervous system carried out early in his career made a deep impression on Magendie,[20] as they did on others.

Another reason for the primacy of the nervous system in physiological research was that many considered it to be, in fact, the most "noble," or in the words of Gottfried Reinhold Treviranus (1776–1837) in 1821, "the first" of the organ systems of the body; and for this reason especially demanding of attention.[21] To say that the nervous system was the "first" of the bodily systems could imply various claims. Treviranus probably referred to hierarchical ideas of nature, popular especially among those influenced by the *Naturphilosophie* of the early nineteenth century, which saw animate nature advancing through progressively more elaborate and elevated stages toward a preconceived goal. This pinnacle of perfection was the human body, but there was also hierarchy within the human frame. On these assumptions, the nervous system represented the apogee of organic evolution; the point to which nature was striving, and to which all other systems of the body were subsidiary and preparatory.

The popularity of the nervous system in the physiological investigation of the body's systems may have been due in part to the paucity of experimental techniques available in the early nineteenth century. Those that existed were suited to neurological research, as we shall see, but not to the more intimate study of respiratory, gastrointestinal, endocrinological, and renal functions, where elucidation depended, as we now know, on more sophisticated chemistry than was then at the disposal of the physiologist, and was not to be available until later in the century.

Other possible stimuli encouraging interest in the nervous system, were the several disputes over priority of discovery that erupted in the first half of the nineteenth century and will be discussed in subsequent chapters of this book.[22] The best-known controversy was between Bell and Magendie concerning the functions of the spinal cord roots[23] (chap. 4.3), and the others included Luigi Rolando (1773–1831)[24] versus Marie Jean Pierre Flourens (1794–1867)[25] on cerebral and cerebellar functions (chap. 6.4,6) and Marshall Hall (1790–1857)[26] versus several opponents, who accused him of plagiarism in his research on reflex physiology (chap. 4.4). There was also an ongoing debate throughout our selected period between those like Hall, for example, who advocated a materialistic interpretation of neuroscientific phenomena and those who preferred to invoke vitalistic principles.[27] The problem of the location of the mind also generated a great deal of contention, and because it spread into nonscientific disciplines such as philosophy and theology, the nervous system received much more publicity than the other systems of the body. As in any field of human endeavor, disagreement bred action either in defense of an opinion or in an attempt to refute it. Thus, the various polemics involving the nervous system evoked concern with, and investigation of, its form and function.

An ascription of preeminence to the nervous system might also imply that it exercised a dominant role in the functioning of the body in general, as Willis had inferred in 1664. In addition to the intellectual and somatic functions, the nervous system was also held to be involved in such operations as nutrition and secretion,[28] and we shall observe in chapter 7 how physiologists came to maintain that the vegetative (autonomic) nervous system brought about these and other autonomic functions by means of nervous control. Moreover, it followed that because all bodily properties thus derived from the nervous system, then dysfunction must likewise arise from the same source.

The conviction that all, or almost all, diseases had their ultimate seat in the nervous system was another potent factor in drawing the minds of nineteeth-century investigators in that direction. Early in the eighteenth century, Friedrich Hoffmann (1660–1742)[29] adopted and modified by further conjecture an ancient Greek idea that the brain produced a special substance, which circulated in the nerves,[30] and, together with the circulating blood, controlled the body's vital activities. It was also the source of all diseases. There were other components of Hoffmann's system, but his neurogenic concept of disease etiology gained great prominence toward the end of the century, despite competition from similar theories, as Rath has shown.[31] The most striking and original application of Hoffmann's speculation was by the Scottish physician, William Cullen (1710–1790).[32] The theory of disease causation that he formulated appeared first in 1772 and it survived, at least in Germany, until the middle of the nineteenth century. Like other eighteenth-century physicians, he was attempting, unsuccessfully as it turned out, to provide clinical medicine with scientific foundations and to simplify the genesis of disease by incriminating only one universal etiological agent. The latter was a nervous "power" or "property,"[33] and like Hoffmann's substance, it was responsible for all pathological as well as physiological phenomena in the body.[34] It emanated from the brain and traveled through the nerves to maintain the tissues' tone.[35] Thus, Cullen was able to account for all disease states and also to suggest appropriate medication for them. It followed that if the nervous system was omnipotent in the economy of the body, it was worthy of close attention: "The nervous system, as an organ of sense and motion, is connected with so many functions of the animal oeconomy, that the study of it must be of the utmost importance, and a fundamental part of the study of the whole oeconomy."[36]

Cullen, unlike most of his predecessors, succeeded in popularizing his hypothesis, which eventually became known as the theory of "neuropathology." For obvious reasons, historians now prefer to call it "neural pathology."[37] In the early nineteenth century, its acceptance was greatest in the German-speaking nations, mainly because it invoked a generalized life force or "vital principle" and therefore appealed to adherents of *Naturphilosophie,* a cardinal tenet of which was the existence of a universal vital power. It continued to receive attention there until it was demolished in 1858 by Rudolf Virchow (1821–1902) with his theory of cellular pathology, which forms the foundation of present day morbid anatomy.[38] Outstanding medical scientists had subscribed to neural pathology, and these included the renowned Friedrich Gustav Jakob Henle (1809–1885).[39]

Meanwhile, in France, from the beginning of the century, a very different approach to disease etiology was emerging.[40] This was the notion of clinicopathological correlation based on morbid anatomy that would become the basis of modern medicine. It would eventually destroy not only neural pathology[41] but all other eighteenth-century concepts of disease causation except homeopathy. There were, however, some in France who preferred Cullen's doctrine and among them was Jean Georges Chrétien Frédéric Martin Lobstein (1777–1835) of Strasbourg who, in 1821, addressed medical students on the preeminence of the nervous system.[42] He will be encountered later because he contributed importantly to the study of the autonomic nervous system (chap. 7.6). He pointed out the paramount role of nervous system function in the healthy state. "Thus," he declared, "in all vital actions and in the case of those that demonstrate the principle on which life depends, nervous action is constantly recognized as the primary factor."[43] The nerves were of fundamental importance, because they carried morbid impressions to the brain and solar plexus (see chap. 7.7.3), and also controlled the blood vessels, which as in Hoffmann's scheme shared with the nervous system the responsibility for both the healthy and diseased body. Thus, "[I]n the vast field of pathology we constantly find the nervous system in the forefront,"[44] and it was "the premier source of all pathological affections."[45] Following Cullen, Lobstein used this knowledge in attempts to contrive specific treatments aimed at neural structures and exhorted his audience to familiarize themselves with the nervous system. Echoing Cullen's words of 1785, he insisted:

> It remains incontestable that a most perfect analysis of the nervous system and a most precise determination of the role that it plays in the state of health as well as in disease is an object most worthy of the physician's attention.[46]

If they did so they would walk "on the road that leads to the perfection of which medicine is capable."[47] There can be little doubt that this kind of persuasion from respected medical men, at a time when various rival theories of a vital principle and doctrines of disease etiology were still competing for cognizance, must have drawn considerable attention to the nervous system, and may have inspired some individuals to investigate its properties, either morphological or physiological.

A British commentator noted in 1824 that "[N]o subject has excited deeper and more universal interest among the present physiologists of France, than the Properties and Functions of the Nervous System,"[48] and he adduced a peculiar reason for this. Whereas in Britain, he explained, it was understood among the scientific community that when a man discovered and pursued a new and profitable line of research others did not disturb his progress nor encroach upon his preserves, this was not the case in France where ethics were different and a new and fertile field of discovery could be invaded by the pioneer's scientific brethren. This development, the writer thought, must benefit science by allowing more rapid advancement in the area, because of the labors of several rather than one investigator, and also by providing the benefits derived from the possibility of comparing and contrasting their individual results. Such an outcome had, he pointed out, taken place in France in the case of neuroscientific research, as was evidenced by no less than six important publications describing and assessing new and novel studies on the nervous system that had all appeared in 1822, and which he proceeded to review.[49] This special interest extended beyond the period we are dealing with, because the American physiologist, John Coll Dalton (1825–1889) in 1875 explained that concerning the nervous system "[T]his department of medicine is now so extensive, both in its physiology and its pathology, that few subjects can be said to have received greater attention."[50] And seven years later this "special activity of growth"[51] was still continuing.

1.2. METHODS OF RESEARCH

We possess several contemporary accounts of the avenues open to students of the nervous system. For example, Amariah Brigham (1798–1849) in 1840 listed seven methods for determining the functions of the brain: "(1) chemical analysis; (2) dissection of the brain; (3) experiments on living animals; (4) comparative anatomy; (5) the foetal condition and growth of the brain; (6) pathological observations; and (7) external examination of the cranium."[52] The last of these is a reference to Gall and Spurzheim's organology or phrenology, a cult based on an unproven hypothesis that psychological and moral propensities could be assessed by palpating the skull (see chap. 6.3). Although it is mainly of interest to historians of the phrenological movement, and will be considered in detail later, it can for our present purpose be ignored. Chemical analysis likewise has no role to play in our present discussions, but for different reasons. It had revealed, in a crude way, the basic constituents of brain tissue, but as Brigham confessed, "nothing has been learned by analysing the brain that has added to our knowledge of its functions."[53] In general, it is true to say that chemistry contributed little to the neurosciences during this period for the same reason that it could not contribute to an understanding of such functions as respiration, nutrition, and secretion; chemistry was still in a relatively primitive state and quite unable to answer the questions asked of it.[54] Its application to the problems of nerve function in the late eighteenth and early nineteenth century will be discussed in chapter 5.2.3, but it provided little or no elucidation at that time. Similarly, chemical substances were widely used to stimulate nervous tissue along with mechanical and electrical irritation, but their mode of action was quite unknown. We should, however, note that a topic related to chemistry, experimental pharmacology as we now term it, had an indirect influence on neurophysiological research. It was applied to the elucidation of nervous system function, and the most outstanding proponent of the method during our period was Magendie. His classic experiments on living animals revealed that certain drugs, for example, those of the *strychnos* family, acted on the nervous system,[55] and this finding, as we noted above, profoundly influenced Magendie in his contention that this system was central to the animal economy. However, the contribution to neurophysiology per se was small, as was also true in the case of Flourens's investigations in 1847 of the excitability of the spinal cord and other nervous centers during ether anesthesia.[56]

The five remaining methods listed by Brigham constitute the chief means by which scientists in the first half of the nineteenth century sought to expand their understanding of the nervous system. We should add microscopy to this list which, from the 1830s onward, provided an important additional resource. Some investigators pursued their research almost exclusively by only one of these techniques; others used two or more of them. We shall attempt to illustrate the potentials and limitations inherent in each of these approaches to the nervous system by discussing the work of certain exemplars whose labors figure prominently in the following chapters.

1.2.1. Gross Anatomy

The pure, gross anatomical approach is exemplified by Charles Bell. He used this approach in his attempts to bring order to the chaotic state of contemporary knowledge of the nervous system. His statement of 1821 illustrates vividly the situation he and others faced:

> The endless confusion of the subject induces the physician, instead of taking the nervous system as the secure ground of his practice, to dismiss it from his course of study, as a subject presenting too great irregularity for legitimate investigation or reliance.[57]

Relying almost entirely on anatomical investigations, Bell set about formulating his *Idea of a New Anatomy*[58] hoping to establish "grand divisions" of the nervous system anatomically defined and functionally distinct. He failed to achieve his objective, and a similar fate befell a second enterprise aimed at creating a new arrangement of the nervous system, with special reference to the nerves of the face. Nevertheless, his studies revealed originality, talent, and ingenuity, and they contained much that was of permanent value to the neurosciences.

The main reason for Bell's failures lay in his belief that deductions must, in the first place, be made from a meticulous study of anatomical structure, relegating other methods to a subordinate status. He was first and foremost an anatomist carrying on the Hunterian tradition; but unlike John Hunter (1728–1793), he had no faith in experimentation as a source of knowledge. Whether this was due primarily to his aversion to experiments on living animals (which he shared with Gall and many other scientists of the period) is not known. Unlike devout experimental physiologists such as Magendie and Flourens, Bell judged vivisection procedures to be of secondary value, only employing them after his anatomical conclusions had been formulated—and then only to confirm them or to impress his opinions on others. The few experiments he carried out were intended only to verify the fundamental principles upon which his systems of the brain and nerves were established. Moreover, he believed that the anatomical method could also solve problems of function, but it is ironic that the results of the few physiological experiments he conducted, and upon which he placed the least reliance, have turned out to be partially correct, whereas his proposed classifications of the nervous system have long since disappeared.

There was another reason for Bell's lack of success in these endeavors. Although a talented artist, and therefore able to portray his anatomical discoveries superbly, paradoxically he exhibited a curious obscurity of expression in his scientific writings. Numerous opaque passages can be cited and his research protocols lacked the precise and terse style characteristic of Flourens and Magendie so that doubts and uncertainties must have arisen in the minds of his readers. At a time when a scientific language was evolving and photography unknown, a simple yet accurate literary style was essential, not only for the sake of comprehension, but also to allow others to repeat an author's dissections or experiments and thus to compare results.

Another early nineteenth-century medical scientist who used anatomy in a way that we regard as very strange was Gall. His method was the reverse of Bell's because he began by erecting physiological hypotheses collected from clinical and pathological observations, analogy, and speculation, but few vivisections, and then verifying them to his satisfaction by dissecting the brain and spinal cord. We shall study more closely this unusual approach to brain function in chapters 2 and 6. We can note here, however, that he claimed in 1825 that "the anatomy of the brain serves only as confirmation of physiological discoveries."[59] This was three years before his death, indicating that his life's experience and that of others had not altered a belief he had accepted in the 1790s. Gall must not be dismissed for this inverted research method, because he not only helped to establish the notion of punctate brain localization (see chap. 6.3.4), but he also made a number of important anatomical discoveries (chap. 2.1), and he did not hesitate to attribute the credit for them to his research method:

> I owe almost all my anatomical discoveries to my physiological and pathological conceptions; and it is only from these, that I have been able to convince myself of the perfect agreement of moral and intellectual phenomena, with the material circumstances [that is, morphology] of [that is, underlying] their manifestations.[60]

Historians have emphasized Gall's contributions to the anatomy of the nervous system,[61] and among them Neuburger has claimed that "[T]he work of anatomists especially of Gall is the pedestal on which the physiology of Flourens stands."[62] Gall's contemporaries were equally laudatory as, for example, Herbert Mayo (1796–1852) in 1827: "The most serviceable impulse that has been given to the study of the anatomy of the brain of later years we may attribute to the theoretical account given by Drs. Gall and Spurzheim."[63] In chapter 3.5.2 we shall discuss further this "physiological anatomy," as particularly applied to the microscopical study of nervous tissue and the relationships established between the latter and physiological concepts. Thus, scientists were attempting to elucidate function by means of microscopical structure, and, as we shall point out, this method of physiological investigation, although not as yet adequately researched by historians, was of great importance for the development of neurohistology.

But as well as Bell, Gall, and others who applied their gross anatomical research in what we consider an unusual manner, there were many neuroanatomists in the early nineteenth century who pursued a more orthodox anatomical pathway. These included Pierre Augustin Béclard (1785–1825), Marie François Xavier Bichat (1771–1802), Karl Friedrich Burdach (1776–1847), Achille Louis Foville (1799–1878), Johann Christian Reil (1759–1813), Antonio Scarpa (1752–1832), Samuel Thomas Soemmerring (1755–1830), and Benedikt Stilling (1810–1879). Their influence was felt throughout our selected period, and they will be referred to repeatedly below. Many of them contributed to new ways of examining the brain and spinal cord, but Reil's improved method of fixing neural material and Gall's technique of examining the central nervous system functionally, that is, by tracing the white matter fibers from below upwards rather than by random slicing (see chap. 2.1), were particularly rewarding. Samuel Solly (1805–1871) in 1836 judged that the older procedures superseded by Gall and Reil were "totally inadequte to impart any real information in regard to the structure of the organ [brain]," and that "this circumstance has contributed essentially to retard the diffusion of sound knowledge in regard to the anatomy and physiology of the most important system of the body."[64]

1.2.2. Physiological Experiments

Following Brigham's list we can now consider two outstanding proponents of experiments on living animals. We have already referred to Magendie and Flourens who were the second and third in a dynasty of French experimental neurophysiologists that began with Julien Jean César Legallois (1770–1814) and that led by way of them to François Achille Longet (1811–1871), Claude Bernard (1813–1878), and Charles Edouard Brown-Séquard (1817–1894). The first of these eminent men, Legallois, was concerned mainly with spinal cord function, but he also took a broader view of the application of the experimental approach to the nervous system. Thus, concerning the problem of the sympathetic trunk, he stated that "all the questions, I say, insoluble until now by means of anatomy are completely resolved by the experimental approach."[65] Unfortunately, the interpretations derived from his experimental results did not equal in quality the skills he demonstrated as a vivisector nor was his optimism reflected in his overall achievement. Nevertheless, he inspired others, and many of his contemporaries agreed that the perfection of physiology was close to hand.

However, Magendie, who was the real pioneer of the experimental movement, did not share these expectations, and in an article dated 1809, he pointed out that physiology as a subject could only advance if the eighteenth-century type of research, whereby the vital forces and powers responsible for physiological phenomena were vainly sought, was abandoned.[66] In its place there must be a relentless search for explanations. As Albury has shown, Magendie shared with Cuvier a new way of looking at life, which brought about "the elevation of functions to a status of priority over anatomical structure."[67] This revolutionary approach, the reverse of that adopted by Bell and Gall, is the one we accept today.

We have indicated already the effect of contemporary philosophy on biological and medical thought, and Magendie is another example of this influence. As a young man he was connected with the ideologues, a group of intellectuals who were intent on creating a science of ideas that aimed at replacing existing metaphysical systems.[68] Temkin has traced this aspect of Magendie's background;[69] and we shall make further reference to the impact made by it and other schools of philosophy in early nineteenth-century France (see chap. 6.5). Suffice to mention here that Magendie's physiological method, in keeping with the ideologues' doctrine, was to accumulate by experiment as many new and true facts as possible, and, eschewing vague opinions and speculation, he believed that if facts were acquired in large numbers they would eventually lead to an integrated theory concerning the physiological phenomenon under scrutiny. In the chapters below we shall encounter some of his neurophysiological discoveries and observe how he typified the experimental investigator par excellence. His approach, therefore, could not have been more different from that of his contemporary and contestant, Charles Bell, as illustrated by the problem of spinal root functions.[70] Magendie denounced all forms of anatomical deduction and his general attitude is well exemplified by the following statement from his book on the functions and diseases of the nervous system:

> But concerning the nerve, what do you understand of its uses by examining its tissue? . . . There is nothing to indicate that it has one use rather than another . . . You prick it and the animal manifests pain. There, you are starting on the track of its functions; but in this case note that it is no longer a question of the scalpel or of meticulous dissections; you are in the field of experimental physiology.[71]

In effect, Magendie was finally destroying the anatomically based concepts of structure-function relationships in favor of the notion of a function as the product of several organs. The physiological systems of earlier centuries based on speculation and analogy applied to structure were to be replaced by empirically developed physiological ideas derived from systematic vivisections and accurate observations. This process was to find full expression in the many classical studies of Claude Bernard and was embodied in his equally classical book on experimental medicine.[72]

Magendie had much in common with Pierre Flourens, who was ten years his junior. Both were remarkably dexterous, perceptive, and articulate experimental physiologists, whose activities, although ranging over the whole subject, were particularly directed at the nervous system. In each, their experimental prowess owed something to the French surgical tradition that had begun in the eighteenth century, and in the case of the nervous system had shown that brain lesions could enlighten physiology, as we shall see below. Another factor responsible for their way of reasoning and their technique was the new anatomical approach to disease, founded in Paris during the early 1800s and forming the foundations for our method of clinicopathological correlation. They were also both deeply influenced by the philosophical thought of their time, and, as will be seen (chap. 6.5), in the case of Flourens, this accounts for a change of attitude to brain activity that is otherwise inexplicable. His main contribution to neurophysiology was threefold: he located the *noeud vital*, the respiratory center (chap. 6.4.1); he reached erroneous conclusions on cerebral function with immensely deleterious effects (chap. 6.4); and he identified correctly the cerebellar function of coordination (chap. 6.6). He claimed correctly that most of his success was due to a close attention to experimental method. We can also appreciate in the following passage his epigrammatic style referred to above:

> In experimental research everything depends upon the method; for it is the method that produces the results. A new method leads to new results; a rigorous method to precise results; a vague method has always led only to confused results.[73]

He repeatedly emphasized this basic principle, and he was one of the few physiologists during our period who wrote on "[T]he experimental method employed in my researches on the brain."[74] But, like Magendie, he was concerned to amass experimental data, declaring that "[T]he art of discerning simple facts is the whole art of experimentation."[75] To collect these facts, Flourens insisted that first the part of the brain under investigation should be adequately exposed; and that the ambiguous, contradictory results of his predecessors such as Haller and his school and Rolando were due to the relative crudeness of their techniques. Second, the part being studied must be ablated precisely, and it was Flourens who established this as a neurophysiological procedure of the greatest value. Third, complications must be recognized and avoided. "In physiology," he commented, "when a mistake is made, it is nearly always because all of the possible complications have not been recognized."[76] Their variety and significance will be discussed shortly. But as Young has pointed out, the quality of Flourens's surgical procedures was not equaled by his unsophisticated and limited postoperative observations on changes in behavior and by his controlled testing nor were his sweeping conclusions always warranted by the evidence he accumulated.[77] Nevertheless, we can agree with Neuburger's accurate general assessment of Flourens's contributions to neurophysiology:

> Flourens's work eclipsed that of his predecessors and contemporaries to the extent it did because of the fundamental reform in experimental physiology of the central nervous system that he brought about. He created a new method, he formulated problems in a new way, and he endeavored to substantiate his clearly defined ideas with plain facts.[78]