The Göttingen School and the Development of Transcendental Naturphilosophie in the Romantic Era

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A problem, tantalizing in its possible implications, that has persistently thwarted the efforts of historians is the relationship between empirical science and the speculative movement in philosophy and literature at the beginning of the nineteenth century, known as *Naturphilosophie*. While some scholars have regarded Naturphilosophie as a skeleton in the closet of nineteenth-century science,[1] others have indicated that it may have had a positive influence on several major discoveries.[2] There have been severe difficulties in interpreting the substantive contribution of Naturphilosophie to the development of science, however. One central difficulty in explaining how naturphilosophic systems were able to reign supreme in the German scientific community from 1800 to 1830 lies, of course, in deciphering the actual scientific content of the philosophies of nature proposed by the likes of Schelling, Oken, Hegel, and Carus, and the extent to which they incorporated a careful consideration of the contemporary scientific literature. The verdict on this issue has by no means been unambiguous: Some investigators have argued that in their disdain for empirical research the Naturphilosophen

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were attempting to return science to a simpler age.[3] Others have argued that the heart and soul of Naturphilosophie lay in empirical research. Those who defend this latter interpretation—an interpretation that is in rapid ascendance in the literature—point out that while Romantics such as Novalis, who had been trained in the sciences at the Bergakademie in Frieberg under Werner, demonstrated a strong scientific bent, other Naturphilosophen such as Goethe, Ritter, Oken, and Carus conducted extensive empirical researches themselves.[4] The potential sources of confusion in assessing this issue emerge clearly in the work of Hegel; for while he defended a conception of matter based on the four elements, earth, air, fire, and water, it is clear that he was deeply immersed in the chemical literature of the day and that he understood it well.[5]

Another problem in assessing the relationship of Naturphilosophie to science is rooted in the fact that no single system of natural philosophy is characteristic of the entire Romantic period. From its first appearance and throughout its stormy career, for instance, the Naturphilosophie of Schelling and his school was severely criticized.[6] When we turn to the writings of these critics, however, we discover many of the same conceptual elements and almost invariably refer to the same empirical data.[7] Concern is quite naturally generated about identifying the real substance of the issues being debated. Rather than a single systematic approach to nature, it seems more appropriate to regard the science of this era as having been formed from a common fund of scientific concepts and methods, metaphysical predispositions and epistemological concerns which received differing emphases in the various approaches to natural philosophy of the period. In order to assess the bases for these different styles of Naturphilosophie consideration will have to be given to the role not only of substantive philosophical and scientific issues but of personal factors as well. But a full understanding of these complex issues may ultimately await the exploration of broadly based trends in the popular culture of the period as well as the roles of social and political movements in shaping preferences for organizing and interpreting this common fund of concepts.

A better understanding of this period has resulted from recent progress in dispelling the myth of a monolithic Romantic science, and in laying bare the outlines of different traditions of natural philosophy practiced in Germany between 1790 and 1830. This has been achieved chiefly through the efforts of Reinhard Löw, H. A. M. Snelders, and Dietrich von Englehardt. Von Englehardt has argued that three different traditions characterize the science of the Romantic era.

One tradition, which he identifies as Kantian, is *transcendental Naturphilosophie*. In the spirit of Kant's critical writings this tradition views the role of philosophy as examining the logical and epistemological foundations of science by establishing the subjective contribution to experience, the a priori forms in terms of which empirical judgments are constituted, and the constraints on reason in constructing an interpretation of nature. The object of transcendental Naturphilosophie was not to explicate the proper method for abstracting lawlike generalizations from nature as given in experience. Rather, it aimed at "determining the *a priori* conditions for the possibility of experience, which is to provide the source from which general laws of nature are to be deduced."[8] Characteristic of this program is Kant's determination of the concept of matter in his *Metaphysische Anfangsgründe der Naturwissenschaft*. There, applying the categorical theory of his *Kritik der reinen Vernunft,* Kant argued that the concept of matter that must underlie mechanics cannot employ irreducible atoms but rather must invoke a dynamic interaction of attractive and repulsive forces emanating from nonmaterial points. This dynamic theory of matter, which had been proposed by Boscovich, became one of the central organizing concepts representative of the Kantian tradition of Naturphilosophie, and it was especially significant for the view of organic nature.

A second tradition of Naturphilosophie removed the boundaries of possible a priori knowledge of nature considered legitimate by transcendental Naturphilosophie. This second tradition is linked most closely with Schelling and is termed speculative or romantic Naturphilosophie by von Engelhardt. According to the speculative Romantics nature is a fundamental unity of matter, process, and spirit. The object of the philosophy of nature, according to this approach, is to construct the entire material system of nature from a single all-embracing unity, to establish the unfolding of the inorganic, organic, and finally the social and moral realms as the final objectification of potencies present in this original unity, which Schelling characterized alternately as the *Weltseele, Gott* or the *Absolut.* Characteristic of speculative thought is its claim that the dichotomy between empirical knowledge claims and the world of things in themselves crucial to Kantian or transcendental Naturphilosophie can be overcome in the act of "intellectual intuition," an empirical intuition in which the logical structure of appearances is also manifest. Also characteristic of this approach is its reliance upon polarity as the motive agent in the process of differentiating and objectifying the primitive unity at the basis of nature. Equally characteristic is the notion that the plant and animal kingdoms are each constituted from the metamorphosis of a fundamental unitary type, or *Urtyp,* and accordingly that organic nature can be perceived as a chain of beings. Perhaps most characteristic of speculative Naturphilosophie is the view that since nature is the manifestation of spirit, man must stand at the top of the chain of being.

Although it was not always clearly distinguished during the Romantic era, there was a third tradition of Naturphilosophie. This type, which von

Engelhardt calls metaphysical Naturphilosophie, was closely allied to the romantic or speculative tradition. Hegel, who was the main theoretician of this line of thought, in fact regarded the position developed by the young Schelling in his *Ideen zu einer Naturphilosophie* (1797) and in his *Von der Weltseele* (1798) as in fundamental agreement with the main lines of metaphysical Naturphilosophie; but there were certain tendencies in Schelling's thought that had been developed in an absurdly unphilosophical manner, with little knowledge of or concern for the empirical content of the sciences, by some of Schelling's most ardent followers, particularly Windischmann, Görres, and Steffens. In 1806 the differences in their outlooks led to a split between Hegel and Schelling. Principally, Hegel objected to the presence of mystical and irrational elements in Schelling's system, the so-called philosophy of identity. Moreover Schelling's attempt to deduce the material world completely from the self-activity of the Ego in terms of purely formal principles such as polarity, potential, and analogy, was objectionable in Hegel's view. Naturphilosophie could not possibly deduce the genesis of natural forms; its sole task consisted in bringing to the fore the logical structure of the system of nature and for that Naturphilosophie had to begin with the material provided by the sciences: "not only must philosophy be in accord with experience, the origin and development of scientific philosophy necessarily presupposes and is conditioned by empirical physics."[9] On the other hand, while Hegel did not regard the task of Naturphilosophie as an a priori constitutive determination of empirical science, neither did he regard it as the simple collection and categorization of scientific principles. In Hegel's view the phenomena of nature and the principles of the sciences are tied to one another through immanent connections: that is, they follow from one another by necessity. This is made possible by the fact that, according to Hegel, the categories of logic are not only the structure of human language and consciousness, and thereby sources for the structure of scientific theories, but they are simultaneously the structure of the historical world. Nature is intelligible not because it submits silently to the imposition of an arbitrarily fashioned logical framework, but rather because it is grounded in a concrete logical structure immanently present in the material world. The object of natural science is to reflect that logical structure, while that of the philosophy of nature is to grasp it and raise it to the level of consciousness.

The identification of three traditions of Naturphilosophie opens up fruitful possibilities for exploring science during the Romantic era. Von Englehardt, Snelders, and Löw have already made major contributions to our understanding of the role of each of these traditions in the development of chemistry.[10] An examination of the biological and medical thought of the Romantic era also reveals the presence of these three traditions. In the biological sciences, however, particularly natural history, comparative anatomy, and physiology, two of these traditions were predominant. One tradition was underpinned by the view of nature characterized above as transcendental Naturphilosophie; the other major tradition espoused the metaphysical style and was graced by Hegel's own systematic Naturphilosophie and by the works of Oken, Goethe, and Carus. Speculative Naturphilosophie after 1800 tended, by contrast, to be more confined to medical theory and practice.[11] The aim of the present study is to identify the major practitioners of one of these two schools of biological thought and the characteristic features of its approach to organic nature.

The subject of the present study is to explore the origins and development of the Göttingen School of biology, for it was at Göttingen that transcendental Naturphilosophie had its most significant impact on biology. The distinctive approach to biology practiced by Göttingen biologists derived from ideas fashioned principally by Johann Friedrich Blumenbach during the 1780s and 1790s. Blumenbach's most significant achievement, from our point of view, was to synthesize some of the best elements of Enlightenment thought on biology, particularly aspects of the works of Buffon, Linnaeus, and Haller, in terms of a view of biological organization that he found in the writings of Kant. After discussing the background and evolution of Blumenbach's ideas, I will turn to the further development of this Kantian biological tradition in the writings of several of Blumenbach's students and colleagues, among them Carl Friedrich Kielmeyer, Alexander von Humboldt, and Gottfried Reinhold Treviranus.

The Göttingen School

Although the most important stages in the development of the research tradition that I have identified with transcendental Naturphilosophie were formed in the late 1780s and early 1790s, those developments were prepared in part by institutional arrangements established at Göttingen several years earlier. Not the least significant of these was the organizational planning of the University itself; for unlike other contemporary German (and European) universities that treated the science faculty as a necessary but by no means central part of the university, Göttingen was from the beginning organized around its science faculty, and in the early days around the medical faculty in particular. One simply cannot compare Göttingen with other European universities in the eighteenth century without perceiving the predominant role of the empirical and mathematical sciences at that institution. The reason for this lay partly in the fact that the University did not come into formal existence until 1737, a time at which the sciences were becoming regarded as the necessary basis for the rational and enlightened construction of society.

Perhaps the most important factor in shaping the scientific orientation of Göttingen was the educational vision of its founder and first currator Gerlach Adolph von Münchausen (1698-1770). Von Münchausen was a minister in the Hannoverian regime of George II. Whereas other princes such as Friedrich II had established scientific academies primarily as a personal ornament attesting to their enlightened spirits, von Münchausen had another idea. While he certainly did conceive of the University as an embellishment for Hannover, von Münchausen saw in the formation of Göttingen a means of establishing important political connections and spheres of influence among continental principalities for the fledgling Electorate of Hannover, which had only itself come into existence in 1692. What von Münchausen sought was to create a university that would quickly surpass all others in its reputation for scholarly excellence. The sons of princes and nobility would be attracted to such an institution; it would also serve as a training ground for diplomats and an obvious means for laying the groundwork for future political ties.[12]

There were two important aspects of the plan for catapulting Göttingen into the forefront of European universities. The first entailed a radical new conception of the university and the role of its professoriate. In the prevailing eighteenth-century view, the role of the university professor was simply to provide instruction in the various disciplines. He was expected to be a master of the doctrines in his field, but he was not expected to do research. In a letter to a friend, Johann Mosheim, who later became the first chancellor at Göttingen, provides a description of the typical university professor of his day:

> One hour of conversation with a reasonable friend contributes more in my opinion to the advancement of true science than several days lecturing. Moreover there is almost no one here [Helmstadt] with whom I can talk concerning my current research interests. If anyone were to ask the majority of us, what is a professor?, he would be described as a man who is paid for lecturing to young people a couple of hours a day, and who afterwards enjoys himself with friends. Everything centers on sensual pleasure, and that which goes by the name of scholarship is considered secondary and external to the work at hand.[13]

The persons consulted by Münchausen in setting up the general orientation and curriculum of the new university were opposed to this view of things. As a result a university came into being at which the professors had a twofold *official duty;* namely, teaching and research.

In addition to the new research responsibility of the faculty, there was also a shift in the sort of research to be supported by the state. Throughout the Enlightenment, the typical pattern of state-supported research was practical or applied. Science was to be the handmaiden to technology and industry and therein lay its potential contribution to society. Because scientific theory was linked so closely with systematic world-views and theological orientations in the eighteenth century, any attempt to encourage the development of theory ran the risk of supporting a sectarian position.[14] While the founders of the Göttingen educational program certainly were sensitive to this problem, and while they were above all interested in the improvement of society through the practical application of science, they were also strongly committed to the support of pure scientific research.[15] In order to promote research among the faculty members, as well as for the purpose of establishing links to other scientific societies, the *Königliche wissenschaftliche Societät zu Göttingen* was planned as an integral part of the new university from its inception. Members of this prestigious society were required to contribute papers annually. One need only look at the prize questions for the "Historische Classe" to get a sense of the new emphasis on pure research at Göttingen. While other German scientific societies were still promoting the usefulness of historical studies for the questions of legal right and especially for encouraging patriotism, the *Königliche Societät* at Göttingen promoted the study of history for its own sake without reference to its potential use.[16]

Mention was made above of the fact that Münchausen's plan for Göttingen contained two important new aspects. The first was the new role of the professor as researching-teacher. The second concerned the importance of empirical science in the university curriculum. A truly enlightened spirit, Münchausen believed that the persons best qualified to attend to the practical matters of state were those who had developed the skills of logic and a keen sense of observation.[17] The effect this point of view had on shaping the curriculum is unmistakable, for there was a strong empirical component in each of the areas of study. Under the strong influence of Mosheim, courses in history, for example, stressed the use of numismatics and the careful use of archival material.[18] Christian Gottlob Heyne's lectures on Greek literature stressed the importance of archaeological studies for grasping the content and development of Greek mythology.[19]

Perhaps the most important consequence of this emphasis on empiricism for the future development of Göttingen as a center for research was the establishment of the medical curriculum. The decision to exclude all medical theory based on uncertain speculation in favor of doctrines resting on the *terra firma* of careful observation and experimentation led to the formation of a curriculum based on the medical theories of Hermann Boerhaave.[20] In order to strengthen this orientation Werlhof, whose task it was to assemble the medical faculty, sought to attract Boerhaave's most illustrious student, Albrecht Haller, to the University. Haller joined the faculty in 1737.

The specifics of Haller's incredible fifteen-year career at Göttingen need not be recounted here. It suffices to mention that along with his prodigious scientific productivity he was also a crucial figure in establishing links with the rest of the scientific community through the construction of the general organizational plan of the *Königliche Societät der Wissenschaften,* of which he was the first president (1751), and through the establishment of the *Göttingische Anzeigen der Gelehrten Sachen,* to which he contributed at least two hundred review articles annually. It was through the organizational efforts first of Münchausen and later Haller that a new approach to natural philosophy was provided with the institutional structure that it needed in order to develop, a point that will become evident when we consider the effects of Haller's work in Göttingen.

At an institution conceived to foster an interest in pure scientific research, it was not unlikely that in such a supportive environment a new orientation toward the role of hypotheses in theory construction would develop, and indeed such an orientation was first made manifest in the works of Albrecht von Haller, particularly in his thought concerning natural history. Haller set forth his views on hypotheses in science in the introduction to the first volume of the German translation of Buffon's *Histoire Naturelle* in 1750. This essay was printed separately in Haller's *Vermischte Schriften* and was cited in the German literature under the title, "Vom Nutzen der Hypothesen."

Haller did not support Buffon's general plan of natural history. It was far too speculative for his taste. Haller preferred to attempt the provisional construction of systems of nature only after the difficult task of collecting data and constructing experiments was well in progress. Buffon was premature in this regard. Moreover, Haller had grave doubts about the cornerstone of Buffon's entire plan, namely the theory of generation. Nevertheless, even if somewhat tongue-in-cheek, he did see some utility in Buffon's work, particularly since it attempted to bring all of natural history into a single framework. Even if false, such an attempt could lead to a consideration of the real links between scattered areas of research and ultimately to a genuine understanding of the system of nature.

While he regarded the speculative use of hypotheses characteristic of Cartesian science as inimical to scientific progress, Haller did nonetheless see a legitimate role for hypothesis in theory construction. He sided with Linnaeus in considering the distinguishing characteristic of man to be his ambition to master nature, and the tool that enabled him to do so, he argued, was theoretical knowledge.[21] Accordingly, Haller was opposed to the reigning philosophy of science which attempted to ban all use of hypothesis in science.

> The new wisdom has it that at some future date all arbitrary opinions, all hypotheses, will be completely banned. . . . [The reason for this restriction] is the assumption that man is prevented from grasping the inner nature of things, that he can at best hope for perceptions of the phenomena, and that the Truth lies beyond a chasm over which he has no bridge.[22]

Unlike most of his contemporaries, Haller did not think that the truth lay forever inaccessible to human reason, but he also felt that it was an illusion to think that empirical knowledge could ever be free from all hypothetical components. He regarded this tendency to eliminate hypothesis from empirical knowledge as an attempt to force a mathematical conception of rigor in a domain where it was not applicable. Furthermore he pointed out that even in recent mathematics, progress rested upon hypothetical foundations regarding the infinite for which no rigorous justification could be given.[23] He observed that some of the most important recent advances in empirical science had been made through the exploration of Newton's hypotheses regarding the aether.[24]

What then was the true use of hypotheses? According to Haller:

> They are short of the Truth, but they lead one to it; and I say moreover, man has yet to find a better path, and I can think of no discoverer, who has not himself made use of it. When Kepler wanted to determine the laws of planetary motion, he constructed an hypothesis, an improbable one at that, whose falsity has now been demonstrated; and yet this hypothesis led him to the most wonderful law . . . concerning the periodic times . . . which was firm enough for Newton to build upon.[25]

Thus, "[hypotheses] pose questions whose answers demand experiences which would not have occurred to us otherwise; an effect with untold advantages for science."[26]

This discussion served as an introduction to Buffon's *Histoire naturelle.* Although he disagreed with many of the hypotheses upon which Buffon's natural history was constructed, particularly the theory of generation, Haller felt nonetheless that Buffon's theory raised a number of interesting questions worthy of further exploration by German scientists.

There was a second reason for Haller's encouragement of exploration of the questions raised by Buffon that also related to his philosophy of science. Since hypotheses led to the discovery of different aspects of nature, the most profitable path for science was to develop as many complete systems of nature as possible; for out of the unification of these different viewpoints a theory that approximated nature more closely would emerge. This idea that the path toward constructing the true system of nature lay in unifying the greatest multiplicity of different theoretical perspectives became a central feature of later discussions on the philosophy of nature at Göttingen.

Whatever Haller's own reasons for encouraging the study of Buffon's work, the fact of the matter is that a number of aspects of Buffon's *Histoire* were explored by subsequent generations of students at Göttingen. Widespread dissent may have been registered to some of his specific conclusions, but Buffon's *Histoire* was regarded nonetheless as an intellectual *tour de force.*

In his lectures on natural history, for instance, Blumenbach ranked Buffon along with Aristotle, Harvey, Linnaeus, and Haller as one of the major theoretical minds of the subject. One aspect of Buffon's work central to later developments at Göttingen was the insistence on a pluralistic approach in constructing a natural system. Buffon's views on this matter were developed in his criticisms of the systems of Linnaeus and Tournefort, which, he argued, had been based on arbitrarily chosen single characteristics.

Like Haller, Buffon argued that the object of scientific knowledge, though unattainable at present, was to grasp the inner nature of things. Yet this was a knowledge that extended only to the general outlines of nature.

> One does not envision that with time we can go so far as to grasp each and every individual thing not only according to its form but also to understand everything that belongs to its birth and genesis, to its internal structure . . . in a word everything that belongs to the natural history of each individual in particular.[27]

Because the natural scientist has no direct intuition of the internal nature of things—or as Kant would phrase it later, because Reason cannot claim to know things in themselves—the only path to knowledge is to construct the *general system* of nature through a comparative analysis.

> Insofar as we have no other means to acquire a knowledge of natural things, we must pursue this path as far as it leads us: We must take all things together and gather information concerning their similarities which is useful to us in distinguishing them more clearly and knowing them better.[28]

Latent in Buffon's position was a tension over which the transcendental and romantic Naturphilosophen would later split. Strongly influenced by Leibniz, Buffon believed that once a system had been constructed that harmonized all its elements into a unified view of nature, that system would in fact reflect the real constitutive relations of nature. Certainty regarding the correspondence of this system with nature would be imparted through a kind of intellectual intuition that would emerge through an aesthetic sensitivity to the natural liaison of phenomena thus organized. Kant, by contrast, always insisted that the necessity of seeking systematic unity among theoretical aspects of nature is the paramount demand of reason; but it is a subjective demand that cannot be accorded objective reference. Moreover, only God in Kant's view is capable of the sort of intellectual intuition demanded by Buffon and Leibniz. The human faculty of intuition is sensuous and discursive according to Kant; it can never be intellectual.

Two features of Buffon's comparative method were radical departures from contemporary thought on taxonomy and systematics. The first was his insistence that arbitrarily selected single characteristics such as leaf shape, flowers, or, in the case of the vertebrates, single anatomical characteristics such as claws or teeth, were insufficient means for distinguishing organisms into groups, orders, classes, genera, and species. Such classifications might indeed be useful for certain purposes, but there was no guarantee that they corresponded to natural divisions. The only means of approximating a natural classification was in terms of a system based on multiple characteristics:

> One intentionally renounces the greatest advantages which nature offers us unless he makes use of every part of the thing being observed. . . . This is the methodical ordering which must be followed in the classification of natural things: It is important to realize that the similarities and dissimilarities of things are not to be taken from single parts; rather that the descriptive method must be based on the shape, size, and external appearance of various parts, on their number and position, and even on [the chemical constitution of] the material constituting them.[29]

This passage emphasized a major feature of Buffon's approach, later developed more fully by the Göttingen School, namely that the construction of the natural system demanded a classification based not only on multiple morphological criteria but also on systemic physiological critera as well as knowledge of the specific chemical composition of the organism. As we shall see, Blumenbach, Kielmeyer, and Treviranus regarded these different classificatory levels, which they called *Struktur, Textur,* and *Mischung,* as essential to the construction of the natural system. Moreover, a point not evident in the passage quoted above but equally important for his view, Buffon emphasized that a theory of the internal principles of organization must be conjoined with a consideration of the relationship of organisms to their environment as well as to other organisms. This too became the hallmark of the Göttingen program. But it should be noted that by "internal principles" Buffon had something much grander in mind than even the formidable systematic correlation of organic phenomena just mentioned; for in a philosophical sense even these might still be considered "external" characters. What Buffon sought was the essence of animal form itself, the productive source of all these different levels of "external" characters. It was this essentialist dimension of his thought that the Newtonian physiologist Haller had found objectionable, and it was this essentialist dimension of Buffon's philosophy of nature that the Göttingen School rejected. The inheritors of this dimension of Buffon's thought were the metaphysical Naturphilosophen.

This method would produce a series of different classifications just as the so-called "artificial" systems of Linnaeus and Tournefort had done, but this would only be a temporary system subject to constant revision. All systems in Buffon's opinion were necessarily artificial in that they represented at best a series of correlations between *external* characteristics. The object of scientific knowledge, however, was to grasp the essence of the individual. Accordingly, Buffon argued that the various divisions in even the most extensive classification scheme did not refer to things existing in nature: only individuals exist in nature. In order to catch these individuals the natural historian must cast out a net with ever finer systematic gradations. "The more one multiplies the divisions [Einteilungen] among natural beings, the closer he comes to the Truth, because nothing actually exists in nature except individuals. Genera [Arten], classes, and orders exists only in our imaginations."[30]

This distinction between the artificial character of the products of reason on the one hand as opposed to the multiplicity of real individuals existing in nature on the other was a distinction that traced its origin to Buffon's views on epistemology,[31] but it gave rise to a second distinguishing feature of his philosophy of nature. While reason could not immediately attain to an intuition of things in themselves it could nonetheless acquire a dim intimation of what they are like by grasping in a single unified system all the external characteristics of things:

> . . . the construction of a general theory requires that everything should be contained within it.[32]
>
> . . . the only true method is nothing other than a complete and correct description of every individual in particular.[33]

As we shall see, two ideas dominated discussions on the construction of a natural system in the works of scientists at Göttingen in the latter half of the eighteenth century. The first was the notion that the only means for attaining a natural system was through a unification of a multitude of "artificially" constructed systems under a single idea; and the second was the related idea that only a complete description of nature [eine vollständige Naturbeschreibung] that united under a single plan the laws of the phenomena from all the various domains could succeed in grasping nature as it is in itself.[34] These were ideas central to Buffon's *Histoire* and while it cannot be said that Buffon was the only source for such ideas,[35] it was through the sponsorship of his work by Albrecht von Haller and others at Göttingen that they occupied a focal position in scientific discussions there.

There was another feature of Buffon's work that became central for later developments at Göttingen, but it concerned an issue over which Haller differed sharply with Buffon. As we have seen in our consideration of the views presented by Buffon in the introduction to his work, a true understanding of individuals contained in a complete descriptive system depended upon grasping the process through which they came into being. Consequently a theory of generation was an essential feature of the natural system. As Buffon saw it, the essential problem was to explain how individuals of the same species reproduce their own kind. That Haller defended a preformationist theory of generation while Buffon proposed an epigeneticist account is well enough known not to require elaboration here. Two features of Buffon's model deserve special consideration, however, for they were important for later developments at Göttingen.

In order to account for the special nature of organic development Buffon postulated the existence of certain elementary organic particles, which he imagined as being probably spherical in shape. The similarities between Buffon's corpuscles and the monads of Leibniz are striking:

> It appears highly probable to me that in nature there are innumerable small organic beings that are similar to the large organisms which are manifest [to our sense], and furthermore that these smaller organisms consist of living organic particles which are common to both plant and animal life. These organic particles are elementary and indestructible. A collection of such particles make up the organisms of which we are aware. Consequently generation is merely a change of shape which takes place through the addition of these similar particles just as dissolution of their [spatial] arrangement destroys the whole.[36]

In order to explain how these organic "elements" were shaped into the multiplicity of structures present in nature Buffon took refuge in a construct which he called the *moule intérieur.* The *moule intérieur* was conceived as a kind of structuring force responsible for reproduction, growth, and development, but the mechanism in terms of which it functioned remained unexplained in Buffon's work. In fact Buffon argued that a full understanding of the operation of the *moule intérieur* was not possible. "We will never have a complete correct conception of the characteristics [of the *moule intérieur*], because . . . they are not external characteristics and consequently do not fall within the domain of our senses."[37] For Buffon the *moule intérieur* was the essence of the animal productive of but never grasped in the phenomena to which it gave rise. The only means of incorporating it into an empirical scientific theory was to follow the lead of Newton. Buffon compared the structuring force of the *moule intérieur* to Newton's conception of universal gravitation: in the same way that we must assume that all bodies attract each other in terms of a force whose effects only can be perceived, so must we assume that the *moule intérieur* exists though we may never be able to provide a mechanism that accounts for its effects.

Although Haller left Göttingen in 1753, he continued to exert a strong influence on the development of science there not only through his many personal contacts but also through numerous editions of his works prepared by former colleagues and students, which formed part of the core curriculum at Göttingen.

Four of Haller's former colleagues and immediate successors at Göttingen were instrumental in developing the philosophy of nature found in Haller's own works as well as elaborating some of the themes found in Buffon's

Histoire. One person significant in bringing about further discussion of the philosophical issues raised in the Haller-Buffon controversies was Abraham Gotthelf Kaestner, whose influence in German scientific circles at the time was second only to that of Euler. Kaestner is primarily remembered for his work as a mathematician, particularly in the area of analysis, as well as for having initiated discussion on the provability of Euclid's parallel postulate. Before he came to Göttingen in 1756, however, Kaestner had been the translator of the first three volumes of Buffon's *Histoire,* and in his *Anmerkungen* to Buffon's text Kaestner raised some of the key issues explored later by the Göttingen School.

While openly a strong supporter of the Linnaean method of classification, Kaestner acknowledged that there were unavoidable deficiencies in the so-called artificial system.[38] While he found Buffon's theory of the *moule intérieur* an interesting speculation, he sided with Haller in pointing out that the manner of its functioning remained dark and in need of further clarification.[39]

Kaestner did not teach courses in natural history at Göttingen. His primary teaching activities were in mathematics and physics. Nevertheless it is clear that he continued to exert an influence on questions regarding natural history and on a related topic of increasing interest at Göttingen, *allgemeine Naturlehre.* That Kaestner exerted such an influence is evidenced by his students. Although he wrote his dissertation under Kaestner on matters concerning Euclid's parallel postulate, Georg Simon Klugel later composed a work entitled *Anfangsgründe der Naturlehre,* which falls in the area of philosophy of nature. Stronger evidence of Kaestner's influence is provided by the works of his two most illustrious students, Lichtenberg and Blumenbach. Both of these men acknowledged their debt to Kaestner, and, as we shall see explicitly in the case of Blumenbach, both explored questions raised by Kaestner in his *Anmerkungen* to Buffon's text.

A colleague of Kaestner who taught courses supportive of the general orientation toward the philosophy of nature we have been exploring was David Sigismund Büttner (1724-1768). Büttner's path to Göttingen was indeed an interesting one. Having lost his father at the age of four, Büttner was reared in the home of Georg Ernst Stahl from 1728 to 1735, an experience that may have influenced his scientific orientation considerably. Büttner studied with Haller for one year during 1745 and then moved on to study in Leiden for two years. After teaching chemistry at the Akademie in Berlin for several years, Büttner came to Göttingen in 1760 highly recommended by Leonhard Euler.[40]

Despite the bad press that Stahl has received in historical literature on the development of eighteenth-century medical theory, there is a remarkable affinity between the organic philosophy of nature presented in the lengthy (and repetitive) introduction to his *Theoria medica vera* (Halle, 1708) and the views of the Göttingen School. In that work Stahl set forth a theme we have already encountered in the works of Buffon.

> There are two ways in which things can be made the object of research: one can observe them either in their *being* or one can consider them in their process of *becoming;* and with respect to the latter, consideration is to be given to the conditions under which it must occur.[41]

While the first method was purely descriptive in focusing on external characteristics such as size, shape, and quantitative aspects, the second approach concerned itself with the internal nature of the things themselves. Rather than constructing a general conceptual framework of nature, Stahl claimed that the true task of science is to grasp the particular properties of individuals.[42] Such an understanding of things would only be forthcoming, however, with a complete cosmology that demonstrated the nexus of relations linking all individuals.

> We do not want to hunt hastily for the universal and final goal according to which all things are constructed and ordered, . . . much less do we want to deceive ourselves through arbitrary fantasies. In order to protect ourselves from all self-deception we ought to consider the teleological relationships in which individual things stand to one another, and accordingly we should concentrate on an historical consideration of these relations through the proper use of the understanding.[43]

Stahl, who was strongly opposed to the tendencies of the mechanical philosophy, proposed a return to an Aristotelian organic philosophy of nature that took as its fundamental datum the unmistakable fact that nature strikes us as *organized,* as constituting a structured whole or Cosmos. According to Stahl's holistic philosophy, the laws of mechanics should be considered a subset of the laws of organic nature.[44]

That Stahl's views were taken seriously at Göttingen in spite of Haller's opposition is evidenced in the works of Blumenbach, who regarded Stahl as "one of the deepest thinking physiologists."[45] The extent to which Stahl's organic philosophy of nature entered Göttingen through Büttner's influence is difficult to determine, however, for Büttner died at an early age having left as his only publication a work on the polyp, which appeared in the *Proceedings of the Royal Society* in 1752. There is some evidence of his teaching activity at Göttingen between 1760 and 1761, however, which sheds some light on his general intellectual orientation. In his history of the university, Johann Stephen Pütter described the teaching activities of his young colleague. Büttner normally taught courses on chemistry and Materia medica, but in the summers he taught a special course

> devoted to the medicinal plants which he ordered according to their natural affinities, . . . since then the powers of such plants and their effects on the human body could be explained. He makes a special effort to predetermine the inner essences [innerliche unsichtbar Kraftwesen] of these plants merely from botanical similarities and relationships [verwandtschaften] of the plants among one another as well as from their external characteristics which immediately strike the senses.[46]

While such a course need not have been the special preserve of one committed to an organicist philosophy of nature it did contain a number of features in common with the philosophies of nature of Stahl and Buffon. There was a concern for grasping the inner essence of the things themselves coupled with a methodological prescription that this could only be accomplished through a complete description of all the external characteristics of the plant under consideration and its relationship to the rest of nature. As a first step in grasping the *innerliche Kraftwesen* a classification of external characters was to be constructed.

A similar orientation was manifest in the work of Christian Wilhelm Büttner, a colleague not related to David Sigismund Büttner. C. W. Büttner was active at Göttingen for twenty-five years from 1758 to 1783. He taught a variety of courses including natural history and chemistry. His natural history collection, which had been begun by his grandfather, Ulrich Büttner, was famous throughout Germany. Part of it served as the basis for the Museum of Natural History at Göttingen, although Büttner later (1783) gave the major portion of the collection to the University of Jena in exchange for a sinecure.

A number of his students, including Blumenbach,[47] acknowledged C. W. Büttner as having exercised a formative influence on their thought. Two aspects of his orientation toward natural philosophy seem to have been especially important. Like others in the tradition emerging at Göttingen, Büttner considered the true path to knowledge to consist in grasping the "inner nature" of things. Pütter, for example, reports that "in his chemical lectures Chr. Wil. Büttner seeks to show in particular that chemistry can serve as a key to the knowledge of the innermost nature of things themselves."[48]

Along with the interest in grasping the nature of individuals, we have seen a developing interest in extracting a general system from a catalogue of phenomenal relations and characteristics. Büttner's work manifests a similar tendency. A special feature of his course on natural history was the inclusion of man as an object of study. Büttner was particularly interested in the development of civilizations and he focused on the study of language as a primary indicator of development. Though obscurely formulated in his writings, Büttner advocated a method that later became a central feature of the work of another Göttingen student with strong leanings toward metaphysical Naturphilosophie, Wilhelm von Humboldt. Büttner proposed that the languages of various cultures all be considered as manifestations of a single *Urform* that had been expressed differently under different environmental conditions.[49] Of course, such ideas had a long tradition stretching back to the Hippocratic work, *Airs, Waters, and Places,* but the need for constructing an *Urbild* or Ideal Type was typical of works at Göttingen during this period that explored the issues surrounding Buffon's *Histoire naturelle.*[50]

The notion of an *Urbild,* or *Urtyp,* played a central role in the work of another Göttingen professor, Christian Gottlob Heyne, who was the teacher of Blumenbach as well as a number of prominent Naturphilosophen. A theory of art criticism bearing the marks of views expounded by Winkelmann, but more importantly by Diderot in his *Essais sur le peinture,* formed the core of Heyne's course of lectures on archaeology at Göttingen.[51] In Heyne's view the central task of archaeology is to analyze the artistic creations of the ancient world. In order to do this he recommended that the student must ultimately immerse himself in what he called the *total habitus* of the civilization under consideration. To grasp the significance of some artistic production within a culture, a statue of Apollo for example, the archaeologist must be exposed to every empirical aspect of the culture, including the climatic variations of the region, in order to penetrate the true spirit of that civilization. Having been so prepared, he must finally construct an ideal type.

> The artist can take numerous paths in order to construct the ideal. He can do it through the imagination or through the interrelation of individual parts into a whole. The parts of this ideal form will never be found in nature itself, rather they will be scattered here and there.[52]

As in the works of other Göttingen professors we have examined there was an emphasis on grasping the individuals encountered in experience under the unity of a single plan. This plan emerged from a thorough immersion in all the relationships between individuals in the total habitus. In Heyne's theory, reason grasped the *Urbild,* or ideal type, in the same way that Buffon had argued that it grasps the *moule intérieur,* and in the same way that Diderot argued that it grasps the "*beau ideal*" in art: namely through an intuitive act of the imagination that gives rise to a perception of a "secret liaison," a necessary connection in all the differences between individuals.[53]

From the preceding discussion we can see that at Göttingen in the 1750s and 1760s the elements of a distinctive philosophy of nature were beginning to form. As yet no clear statement of that philosophy had been put forward, but in the series of questions surrounding Buffon's work and in the general intellectual orientation of key figures at Göttingen during this period the outlines of what would emerge as a fully articulated system in the late 1780s and early 1790s can be seen.

The issues from which the new philosophy of nature would develop centered on natural history, and in particular on the construction of a natural system. At the heart of discussions of the natural system was the belief that only a theory that comprehended all existing individuals under the unity of a single plan would suffice. Such a theory would depend necessarily upon a grasp of the "internal nature" of things, on the *Urform* that underpinned their phenomenal existence, and on the environmental conditions responsible for its particular manifestation. As the problem came to be formulated in Göttingen scientific circles such a theory would show how "Alles in allem verwebt ist." In the wake of sceptical critics such as Descartes, Locke, and Newton, and in the mounting onslaught of Berkeley and Hume, such a philosophy of nature stood in desperate need of an epistemological critique that solved the riddle of how human reason, confined in its operation to the combination of "external" characteristics derived through sense perceptions, could ever penetrate the *innerliche Kraftwesen* of things. One potential solution visible in the early writings of Göttingen natural philosophers such as Kaestner was to argue that reason simply does not have access to such internal unities. The best it can do is seek out laws governing different aspects of organic phenomena and then seek to relate them into a synthetic whole, perhaps through establishing systematic interconnections in terms of a single natural force or small set of mutually dependent forces. This was the approach ultimately developed by the Göttingen School as a result of the influence of Blumenbach and his acceptance of Kant's views. Another potential solution to this problem, also visible in the writings of the Göttingen professoriate, was to seek a theory of mental activity, at once sensuous but also intellectual, that permitted access to the source of the "secret liaisons" of phenomena. This approach was favored by those who, like Diderot, saw in aesthetic theory a solution to some of the most difficult epistemological questions confronting the investigation of nature. This latter approach was explored by the Romantic Naturphilosophen.

Laying the Theoretical Foundations of the Göttingen School: The Union of the Teleological and Mechanical Systems of Nature in the Works of Kant and Blumenbach

Although there was a common set of themes in what I have attempted to describe as a shared general orientation to natural philosophy developing in the courses and writings of several Göttingen professors in the period after Haller's departure, there was, as yet, no attempt made to synthesize the various elements of this "orientation" into a coherent view of nature. Such a synthesis was first approached in the work of Johann Friedrich Blumenbach (1752-1840). Blumenbach began his studies at Jena, but was encouraged by his father, who was a close friend of Christian Gottlob Heyne, to move on to Göttingen. Blumenbach matriculated at Göttingen in 1772.[54] He studied under both Heyne and C. W. Büttner, both of whom he acknowledged fondly in his dissertation *De generis varietate humani nativa* of 1775. Blumenbach was appointed to the faculty in 1776 and became professor of medicine in 1778. Through his incredible scientific productivity, nearly equal to that of Haller and Kaestner, and through a long and active teaching career extending over nearly half a century, Blumenbach became one of the most influential German theoreticians on questions of natural history in the late eighteenth and early nineteenth centuries.

In his dissertation *De generis varietate humani nativa* Blumenbach was already at work synthesizing themes from the discussions of his predecessors at Göttingen that would form the basis of the philosophy of nature that emerged in the late 1780s. While most writers on the subject regarded the different varieties of man as clearly distinct species, the aim of Blumenbach's dissertation was to show that there exists only one human species and that the various races are "degenerations" of a primary species or Stammgattung.[55]

At the heart of the problem of determining the characteristics of the Stammgattung was the thorny issue of identifying true species and distinguishing them from races. As Blumenbach noted this was no simple matter:

> What is *species*? We say that animals belong to one and the same species if they agree so well in form and constitution that those things in which they differ may have arisen from degeneration. . . . Now we come to the real difficulty, which is to set forth the characters by which *in the natural world* we may distinguish mere varieties from genuine species.[56]

Two paths lay open to him: that of Linnaeus and that of Buffon. As the definition above indicates he preferred the Linnaean method of referring to morphological characters in determining species. Blumenbach argued that a determination based on the capacity to interbreed and produce fertile offspring, while undeniably a true criterion for distinguishing species, was insufficient for the purposes of empirical investigation. Although wild species do indeed reproduce fertile offspring only with members of the same species, Blumenbach reasoned that the application of this as a criterion for distinguishing species was possible for only a few cases. One would like to know, for example, whether the Indian and African elephants are races of the same species. Answers to such questions could in practice only be given by an anatomical investigation.[57]

Blumenbach's rejection of Buffon's breeding definition for species did not imply an unconditioned acceptance of Linnaean principles of taxonomy, however. Rather, Blumenbach followed the lead of others at Göttingen who had agreed with Buffon's arguments in the General Introduction to the

Histoire naturelle which stressed the importance of multicharacters for determining the natural system.[58]

Blumenbach proposed to construct a system based on the *total habitus* of the organism under consideration. This would include not only a determination based on multiple anatomical characters but would also include the relationship of particular forms to the environment. Once the stem for each species had been identified Blumenbach intended to provide a theory accounting for the causes of their variations. And in setting out this theory he vowed to follow Newton's rules for philosophizing about nature:

As we enter upon this path we ought always to have before our eyes the two golden rules which the great Newton has laid down for philosophizing. First that the same causes should always be assigned to account for natural effects of the same kind. We must therefore assign the same causes for the bodily diversity of the races of mankind to which we assign a similar diversity of body in the other domestic animals which are widely scattered over the world. Secondly, that we ought not to admit more causes of natural things than what are sufficient to explain the phenomena. If therefore it shall appear that the causes of degeneration are sufficient to explain the phenomena of the corporeal diversity of mankind, we ought not to admit anything else deduced from the idea of the plurality of the human species.[59]

Having adopted this methodology Blumenbach addressed the question, "What is it that produces now a better now a worse progeny, at all events different from its original progenitor?" A first attempt proposed only to be immediately and unconditionally dismissed was that degeneration could occur through fertile hybridization leading to an ultimate transformation of species.

The latter case [fertile hybridization] although rare (and that by the providence of the Supreme Being lest new species should be multiplied indefinitely) I would admit of in beings closely allied. . . . But from all this we must carefully separate the plainly fruitless unions of animals of different species. . . . There are good reasons for refusing to believe that from any incongruous attempt . . . offspring can be born or even conceived. First to consider is the unequal proportions of the genital parts in many which are providentially and carefully adopted for copulation in either sex of the same species, but in distinct genera render the entire thing impossible. [Here B. cites Haller, Physiologie, Bd. viii, p. 9] . . . Besides . . . in each species of animal there are certain periods of gestation and pregnancy of the mother, the formation and progressive development of the fetus.[60]

On the basis of the position elaborated in this passage, which he supported by extensive anatomical evidence, Blumenbach went on to conclude that the Ethiopian race could be neither a degenerate form of ape nor a hybrid simian-homosapiens form.

Having eliminated transmutation as a possible mode of degeneration Blumenbach went on to describe what he considered the true cause of the variation of species. The principal source he reckoned to be climate:

There is no diversity of the *habitus*, which may not be produced by varieties of climate. . . . Thus if European horses are transported toward the east, or to Siberia or China, in the process of time they . . . dwindle, and become smaller in body so that you would scarcely recognize them as being of the same species.[61]

European cattle, on the contrary, produce taller offspring under the same conditions. In addition to climate Blumenbach singled out mode of life and differences in the constituents of nutrition as causal agents producing variations in the original *Stammgattung*. Using this theoretical framework he went on to conclude that the Caucasian race was the original stock of the human species and that all other races were degenerations of this original.

While it would be misleading to see all of Blumenbach's later scientific concerns as having been generated by questions raised in his dissertation, still, in my opinion, it is not far from the mark to see the core elements of his later philosophy of nature in this youthful work. Blumenbach prepared two other editions of the treatise (1781, 1795), each one of which was expanded to include the latest results of his own research along with a synthesis of materials drawn from an extensive and careful search of the scientific literature. As Blumenbach noted in the introduction to each new edition of the treatise, he had raised questions in his dissertation for which he could not then provide adequate answers, and the arguments presented therein lacked a solid foundation of empirical support. Many directions of his later scientific career were aimed at providing that needed support.

One element present in the *De generis varietate humani nativa* that became an abiding feature of Blumenbach's philosophy of nature was the notion that classification must proceed by the examination of multiple characters. All twelve editions of his extremely influential *Handbuch der Naturgeschichte* (1st. ed., 1779) as well as a more speculative work, *Beyträge zur Naturgeschichte* (1st. ed. 1790, expanded in 1806–1811), contain clear statements of the importance of multiple characters for constructing a natural system. It is important to note, however, that Blumenbach considered the use of multiple characters as a methodological strategy and that the system constructed in terms of this strategem was still an *artificial* system. In this he took issue with Buffon who, according to Blumenbach, had violated the *methodological* nature of this strategem by inferring from it the *existence* of an all-encompassing network of organisms, a great chain of being:

All the beloved pictures of chains, ladders, nets etc. in nature certainly do have an unmistakable usefulness for methodology in the study of natural history, since they give the basis for the so-called *natural system* according to which all creatures are ordered according to the most numerous and most evident similarities, that is, according to the *total habitus* and the affinities based upon it. But it is a great weakness to see in such pictures the Plan for creation, that "nature makes no leaps" as the natural theologians are wont to say, simply because according to their *form* organisms follow upon one another in a finely graded series of steps [*Stufenfolge*].[62]

The chain of being, he went on to argue, is simply an artifact of the method of classification. Closer inspection reveals unmistakable gaps for which there are no imaginable bridges, as for example between the organic and mineral realms.

A further aspect of Blumenbach's theory of the natural system present in his dissertation but which became the subject for extensive subsequent development was the notion of the ideal type. In the dissertation the various races of man were all described as phenomenal manifestations of an original *Stammgattung* which had been subjected to different environmental pressures. While Blumenbach identified this original *Stamm* with one of the presently existing races, namely the caucasian race, implicit in his treatment of the problem was the idea that the *Stamm* need not exist, that it may have become extinct in one of the revolutions of the globe and that accordingly a number of different organisms might mistakenly be identified as separate species when in fact they were simply races of the same (extinct) *Stammgattung*. Here the systematist was confronted with one of those gaps in the "net" of nature, and it was his special task to provide a hypothetical reconstruction of the *Stamm*.

In order to construct the *Stamm* Blumenbach followed the lead given by Haller in comparative anatomy and physiology. By the second edition of his *Handbuch der vergleichenden Anatomie*, Blumenbach was "daily becoming more convinced that comparative anatomy is the living soul of natural history."[63] It was through comparative anatomy that the ideal type, or *Stamm*, was to be identified. Blumenbach's theory of the ideal type was identical to that found in the works of his teacher (and later father-in-law) Heyne. In his *Geschichte und Beschreibung der Knochen des menschlichen Körpers*, Blumenbach cited as two additional sources for his notion of the ideal type works by Caspar Friedrich Wolff and Denis Diderot. In his paper, *De inconstantia fabrica corporus humani* (1778), Wolff argued that the main problem confronting the naturalist is the variability encountered in comparative studies of individual anatomical parts of the human body:

I do not deny that there are conformities in the human structure and that these are perpetual, . . . but the inconstant characteristics are so mixed and confused with the constant ones that I do not believe there is anyone who can distinguish and define them.[64]

In order to solve this problem Wolff concluded: "Therefore in both the external shape of the human body as well as its inner structure it is necessary to construct a beautiful form."[65] This "beautiful form," though not to be encountered in any individual, was to be abstracted from extensive comparative anatomical studies.

In his "Essais sur la peinture" Diderot also stressed the importance of constructing through an act of the imagination a "beau ideal." While Blumenbach was convinced of the importance of constructing an ideal type, in none of his works did he support Diderot's view that it was to be arrived at through an aesthetic judgment. Instead Blumenbach was more intrigued with another aspect of Diderot's essay. While it was universally admitted that the variability in nature could only be made intelligible in terms of ideal types, Diderot argued that even in its variations nature follows definite rules:

> Nature does not do anything incorrectly. Every form whether it be beautiful or ugly has its cause, and of all the things that exist there is not one that should be otherwise than it is. Look at that woman who lost her eye during her youth. The successive increase of the orbit no longer distends the eyelids; they have retreated into the cavity hollowed out by the lack of the organ; they have become smaller . . . the alternation has affected every part of the face rendering them longer or shorter as a result of the accident.
> . . . We say that the man passing in the street is misshapen. Yes, according to our impoverished rules, but according to nature it is otherwise.[66]

What interested Blumenbach was the suggestion that one could work back to the ideal type by constructing the laws of its variation. Characteristic of Blumenbach's approach is that ideal types are theoretical constructs. They are a hypothetical synthesis of laws related to various aspects of animal organization. In applying these ideas to his own work, Blumenbach noted that there is always a homogeneous relationship between the parts of the skeleton. If a particular part of a skeleton was found to be well-formed, he claimed to have found that the other related parts would also be well-formed. Moreover, if a particularly important structure was found to be misshapen in some aspect, Blumenbach observed that the other related parts would vary from the *Muster* or *Vorbild* proportionately in the same degree. How these degrees of variation were to be measured he did not say. That he was intent upon finding a quantitative determination, however, is indicated by the fact that he called this relation the *Law of Homogeneity* and claimed that it is the anatomist's most important tool.[67] Moreover, he did not intend to leave this "law" as a mere conjecture. He undertook a study of monstrous births in order to discover the rules underlying variation from the ideal type. The study of misbirths always occupied a central role in his later investigations; he kept a special notebook[68] on the subject up until the last years of his active research (1833); and it always played a central role in the theoretical portions of his works on natural history.

Another feature of the passage quoted from Diderot above came to occupy an extremely important function not only in Blumenbach's approach to biology but it came to be characteristic of the biology of the entire Göttingen School and even of the Romantic era in general. It concerned the degree to which biological science must ultimately be grounded in a *teleological* form of explanation. What so impressed Diderot and Blumenbach is that even when it begins with partially defective materials, nature always strives to bring about the most perfect form possible. The norm followed in this instance is not some abstract concept of beauty; rather it is the production of a functional whole organism given the limitations of the materials from which it is organized and the demands placed on it by the external environment. Birth defects were of enormous importance not only because they revealed the sort of variations an organic system was capable of assuming. Blumenbach and many of his colleagues and students, such as Sömmering, Reil, J. F. Meckel, and Kielmeyer, saw in monstrous births certain definite lawlike patterns. These could not be the result of blind chance. Instead they revealed that at the basis of organic phenomena are forces that do not at all follow the same patterns of cause and effect found in the inorganic realm. They are more self-regulating, striving to achieve some definite end, even when faced with obstacles. By studying the laws of these variations, biological science would attain a fuller understanding of these forces of organization and regulation.

In Blumenbach's work what might best be characterized as a Newtonian research program for natural history was emerging from a consideration of problems surrounding classification given the immense variability in nature. Like Buffon, he was willing to admit that only individuals exist in nature; but these individuals were formed according to a plan, a definite *Urbild* lying hidden in their inner being. The problem was to get at that *Urbild* and to relate it in a system with other *Urbilder.* The goal of reconstructing the *total habitus,* although methodologically useful, did not ultimately provide a satisfactory solution to the problem, because it furnished at best a multitude of *external* characters that would always be ordered in different ways according to the intentions of the systematist. The natural system could only be constructed by penetrating the inner core of the organism, by observing its construction from the inside out, as it were. As Blumenbach told his students in the section of his lectures on comparative anatomy entitled "Allgemeine Übersicht der Geschichte der Anatomie," the true nature of an organism is given by its internal form [nach der innern Form.] [69]

The problem, however, was to get at the inner form when according to the prevailing epistemology, reason could not get at things in themselves. The answers provided by Buffon, Diderot, and Caspar Friedrich Wolff were not satisfactory. Wolff proposed that reason abstract an ideal type from the multiplicity of individuals without providing a theory of mental activity that could guarantee the results. Buffon and Diderot on the other hand seemed to attribute to Reason a mysterious power of grasping the "secret liaisons" between things. But as Blumenbach's teacher Kaestner had pointed out in his note to the section of the *Histoire* on the *moule intérieur,*

> Does not Herr Buffon simply conclude that because there are internal characteristics of bodies so must there be an internal form? And is this conclusion so convincing since he has not given a general explanation of what he calls the internal form, rather has he not left us to construct the inner form from the comparison of external characters, which he readily admits apply only to the exterior of things? Does he say, therefore, anything more than that there exist things for the inner nature of a body which are for it what its external characteristics are for us?[70]

Blumenbach believed that it was necessary to construct the *moule intérieur* in a manner that satisfied the requirements of a scientific explanation and at the same time avoided the use of a kind of mystic vision in arriving at its fundamental concepts. This he proposed to do in the manner of Newton: Reason could not penetrate the inner nature of things to provide a causal mechanism for their operations, but it could prove the existence of such beings and the modes in which they appear. The problem must be approached as one approaches problems in perturbation theory: from the observed variations in motion to determine the mass of the unobserved planet and construct its orbit. In terms of natural history this meant that each type of organism had its organizing form. In order to grasp the nature of this form one must observe the patterns in variations produced by environmental factors, in monstrous births and in hybridization. Though never accessible in itself, the inner form was to be treated as a "force" in the Newtonian sense, and the properties of that force would be revealed through the development of structure of which it was the cause.

There was a precedent in this Newtonian approach to the problem in the work of Albrect von Haller, with whom Blumenbach was in close correspondence.[71] In his theory of muscle contraction Haller had argued that the power of irritability, the ability of some parts to contract spontaneously when subjected to an external stimulus, must be considered the effect of an inborn force [*angeborene Kraft*] for which no further explanation could be given.[72] Blumenbach sought to follow the path marked out by Haller in the use of Newtonian-type forces as causal agents in physiology by constructing a force model for the *moule intérieur* that would account for the variety within species in a lawlike fashion. He called this force the *Bildungstrieb* and it was the causal agent responsible for all generation, reproduction, and nutrition.

The theory of the *Bildungstrieb* was first presented in a short paper which appeared in the *Göttingenschen Magasin der Wissenschaften* in 1780. A fuller version appeared in 1781 titled *Über den Bildungstrieb und das Zeugungsgeschäfte.* As the following passage from the *Handbuch der Naturgeschichte* indicates, Blumenbach conceived the *Bildungstrieb* as resolving questions for natural history that Buffon had raised in regard to the *moule intérieur:*

> The specific form and habitus of each individual species of organized body is maintained through the determinate, purposeful [*zweckmassige*] effect of the *Bildungstrieb* in the organic materials which are specifically suited to receive it.[73]

Blumenbach was always careful to distinguish the *Bildungstrieb* from anything resembling a soul superimposed upon matter, a *vis plastica* or the *vis essentialis* of Caspar Friedrich Wolff.

> The term *Bildungstrieb* just like all other *Lebenskräfte* such as sensibility and irritability explains nothing itself, rather it is intended to designate a particular force whose constant effect is to be recognized from the phenomena of experience, but whose cause, just like the causes of all other universally recognized natural forces, remains for us an occult quality. That does not hinder us in any way whatsoever, however, from attempting to investigate the effects of this force through empirical observations and to bring them under general laws.[74]

Fashioned in the language of the General Scholium to the *Principia,* this passage revealed Blumenbach's goal of doing for organic bodies what Newton had accomplished for inert matter. For each class of organized beings there was a specific *Bildungstrieb* that gave rise to its determinate structure. And just as Newton had succeeded in finding the universal organizing force of inert matter by constructing a model that successfully unified Kepler's laws, Galileo's law, and a host of other "observed" regularities under a single plan, so it was the task of the naturalist to reconstruct the *Bildungstrieb* for each class of organism by unifying the regularities found in reproduction, generation, and nutrition under a general law.

The treatise *Über den Bildungstrieb* proposed a solution to a problem that had been current in Göttingen scientific circles for a generation. Moreover it built firmly on ideas central to the discussions of the previous generation, particularly those of Albrecht von Haller. Indirect evidence from the treatise itself indicates that the theory presented there grew out of discussions with some of the principal figures mentioned earlier. Blumenbach explicitly acknowledged Haller's direct influence on the theory.[75] While Haller had defended the preformationist view in the 1750s in his dispute with Buffon and later with Caspar Friedrich Wolff, Blumenbach believed that he had begun to reverse his position in the 1770s in the latest edition of his *Grundriss* *der Physiologie,* and this lent great authority to Blumenbach's project. Others mentioned as having been involved in the discussion leading to the production of the theory were Büttner and Lichtenberg.

As we shall see, the treatise *Über den Bildungstrieb* not only brought together a number of key ideas from the previous generation, it also served as a central text around which the ideas on natural history of the generation of students trained by Blumenbach were organized.

The basic model for the *Bildungstrieb* grew out of Blumenbach's experiments on the polyp. What was particularly striking about that organism was not only that it could regenerate amputated parts without noticeable modification of structure but that the regenerated parts were always *smaller* than their originals.[76] Upon closer inspection this seemed to be characteristic of the reproduction of injured organic parts generally. In cases of serious flesh wounds, for example, the repaired region was never completely renewed but always contained somewhat of a depression. Such observations led to two conclusions:

> First that in all living organisms, a special inborn *Trieb* exists which is active throughout the entire life span of the organism, by means of which they receive a determinate shape originally, then maintain it, and when it is destroyed repair it where possible.
>
> Secondly that all organized bodies have a *Trieb* which is to be distinguished from the general properties of the body as a whole as well as from the particular forces characteristic of that body. This *Trieb* appears to be the primary cause of all generation, reproduction, and nutrition. And in order to distinguish it from the other forces of nature, I call it the *Bildungstrieb.*[77]

As the name indicates, the *Bildungstrieb* or "formative drive" was considered the force responsible for producing organic structure, and it was conceived to be manifest in three functions specifically associated with the production, maintainance, and repair of structure. As Blumenbach phrased it: "in other words nutrition is a general but continual, reproduction on the other hand a repeated but partial, generation."[78] This way of phrasing the problem makes it clear that the model for the *Bildungstrieb* was to be constructed from careful observations on the generation of animals.

The *Bildungstrieb* was not a blind mechanical force of expansion that produced structure by being opposed in some way; it was not a chemical force of "fermentation," nor was it a soul superimposed upon matter.[79] Rather the *Bildungstrieb* was conceived as a teleological agent with its antecedents ultimately in the inorganic realm, but which was an emergent vital force. This aspect of Blumenbach's work was its distinguishing feature, and it was in terms of this extremely important idea that German philosophers of nature saw for the first time a means of uniting the teleological and mechanical systems of nature.

That the *Bildungstrieb* was conceived as intimately linked to a material basis can be seen from the manner in which Blumenbach claimed to have been led to the idea; namely, that while the polyp always regenerates a lost part, the regenerated part is always smaller. Having lost a substantial portion of its primary generative substance, the force of the *Bildungstrieb* had been weakened. Though its force could be diminished, if it had sufficient strength it would always bring forth the whole structure associated with it.

> No small evidence in support of the worth of this theory of the *Bildungstreib* consists in the fact that the shape and structure of organic bodies is much more determinate than either their size, length or other such qualities. . . . not only in the case of water plants but also in the case of animals and even man the size of many parts, even the most important tissues of the stomach and the brain, and the length of the intestines can vary enormously, while the variation in their structure and organization is seldomly ever encountered.[80]

The direction in which this idea would lead can be seen from a section of the copy of the *Handbuch der Naturgeschichte* that Blumenbach used for his lectures. There we find the following:

> In comparison with presently existing organisms we find many, even among the pre-Adamistic conchylien, which are identical to present forms. We find others, however, which are *similar* to present forms but which differ substantially from them in size, distinguished partly through small yet constant divergencies [*Abweichungen*] in the formation of individual parts; but also distinguished by the fact that they agree more or less with *Urbilder* that are native only in tropical regions far from the location of the fossils.[81]

When the ideas in this passage are juxtaposed with an aspect of Blumenbach's thought discussed earlier, we see the great potential of the theory of the *Bildungstrieb* for natural history. In the *De varietate generis humani nativa* Blumenbach had said that he accepted as a rare but possible occurrence fertile hybrid crosses between individuals of closely related genera [*Geschlechter*]. Central to the theory of the *Bildungstrieb* was the notion that as the vital force was diminished, smaller but *similar* structures were produced. Thus the largest forms of a particular type might flourish under a specific habitus, the tropical zone for example, while smaller organisms having the same essential structure would be the result of the activity of the *Bildungstrieb* in an environment that diminished its total effective force. Other modifications were also conceivable. By substantially altering the material constituents upon which the *Bildungstrieb* was dependent for the manifestation of its active force, effects analogous to the production of monstrous births might be introduced; there would be a structural modification among classes of forms related to an ancestral ideal functional arrangement of the forces constituting the animal. In short, species falling within a genus could be viewed as "degenerations" of an original stem produced through the agency of the environment. This alteration in the force of the *Bildungstrieb* would also account for the formation of races from the degenerations of a *Stammgattung*.

That such implications were present in the theory did not escape Blumenbach's notice. He drew explicit attention to them in Part I of the *Beiträge zur Naturgeschichte:*

> Almost every paving stone in Göttingen bears witness to the fact that species—even entire genuses—of animals must have perished. . . . The structures of an enormous number of fossils in our vicinity are so divergent from all present forms that hopefully no one will seriously attempt any longer to search for them among present forms of life.[82]

Once Blumenbach had committed himself to the view that whole systems of organic forms had been destroyed, the problem immediately thrust forward was the relationship between the forms of the *Vorwelt* and presently existing forms. Had there been several creations or was there a genetic relationship between the forms of the *Vorwelt* and presently existing forms? Had there been several creations or was there a genetic relationship between the old and new orders? Blumenbach took the side of continuity in the operations of nature: "After the organic creation of the pre-Adamistic period . . . had been destroyed by a total catastrophe . . . the Creator allowed the same natural forces to operate in bringing forth the new organic realms."[83] At first glance this move seemed to introduce more problems than it actually resolved; for if entire genuses had been destroyed in the revolutions of the globe, there would seem to be no basis for a continuity of *forms* between the old world and the new.

It was at this point that the notion of the ideal type and its associated *Bildungstrieb* entered the picture.

> In order that the formative nature reproduces organisms of a similar type to those of the *Vorwelt,* but organisms which are nonetheless more suited to the other forms in the new order of things, it is necessary that forms be permuted [*hat vertauschen müssen*] since they [are produced] by modified laws of the *Bildungstrieb.*[84]

Two features of this remarkable hypothesis are important to note. The first is that Blumenbach considered the history of nature to consist in a succession of *systems* of interrelated forms. Moreover, the interrelation between forms is a *dynamic* one, the specific characteristics of an organism depending on its relation to other organisms and to the environment. The second point to consider in this passage is that beneath the series of forms in the successive systems of nature is a substrate of permanent Types: forms that are capable of different phenomenal manifestations depending on the conditions in which they are placed. The *Bildungstrieb* associated with each of these Types and the direction it receives from the environment is responsible for the specific differences in the series of forms of the same type in the fossil record.

One further aspect of the theory is especially important to bear in mind. The Types mentioned by Blumenbach are not to be identified with "species." Species, in Blumenbach's view, can be created and destroyed, while the Types of which they are the phenomenal manifestations are permanent. The Types remain,

> only the *Bildungstrieb* is forced to take on a more or less altered direction even in the production of new species [*Gattungen*] as a result of the modification of matter arising from such a total revolution.[85]

In commenting on this aspect of his theory Blumenbach underscored that the sort of alteration of form he had in mind was not a degeneration [*Ausartung*], but rather a "modification" [*Umschaffung*] resulting from the changed direction of the *Bildungstrieb.*[86]

The mechanism for such a development was implicit in the materialistic basis of the *Bildungstrieb.* This point came forth most explicitly in Blumenbach's explanation of generation. He ushered numerous reasons for rejecting the preformationist doctrine, but the most significant fact against it in his opinion was that a considerable amount of time was required between fertilization and the appearance of any structured development. During this time even the most careful microscopic investigation could reveal no structure. Once development did begin, however, it proceeded with incredible rapidity. In fact Blumenbach attempted to state a law expressing the rate of development; to wit, that increasing development is inversely related to time.[87] The explanation offered for this phenomenon was that it took time for the seminal material contributed by both parents to "organize" and develop the inherent *Bildungstrieb* which would give rise to structured development.

> The specific time associated with the onset of development in each species . . . is explained as soon as it is assumed that the fluids contributed by each parent for generation, the raw materials of the future new organism, require a specific preparation period for their mixture and inner connection and other changes; in a word they require time for ripening before the *Bildungstreib* in them can be excited and the formation of the unstructured material can begin.[88]

The force of the *Bildungstrieb* lay somehow inextricably bound with the constituents of the generating liquid. According to the Newtonian force imagery underlying the model, the mixture of two parent stocks of very different species would cancel each other out:

> the mixture of generational fluids [*Zeugungssäften*] of two completely different kinds normally smothers and destroys any disposition for the *Bildungstrieb*

which would otherwise be excited. Consequently the possibility of hybridization [*Bastardzeugung*] is limited to very few cases due to the confusion that would necessarily accompany it.[89]

An example of successful transformation by hybridization was provided by Kohlreuter's experiments on tobacco plants. Here fertile hybrid offspring were produced because the *Zeugungssäfte* of *Nicotiana rusticana* and *Nicotiana paniculata* were so closely related. But after several generations the greater "force" of the *Bildungstrieb* associated with *paniculata* manifested itself erasing any trace of a hybrid origin.[90] The same model explained monstrous births. In this case an extremely strong external force or the mixture of two incompatible *Zeugungssäfte* diverted the *Bildungstrieb* from its normal course. Milder but continuous external pressures, however, such as gradual changes in climate either through physical alteration of the environment or through migration as well as changes in the constituents of nutrition, could divert the *Bildungstrieb* from its normal path resulting in the production of races and varieties. All classes of degeneration were thus accounted for in terms of the force produced by the generational fluids contributed by the parents.

Blumenbach had the idea of constructing an entire physiology and anatomy based on the model of the *Bildungstrieb.* The foundation of all organic structure was the force emergent from the *Zeugungssaft.* In a similar fashion more articulated structures would result from the general emergent forces that had the *Zeugungssaft* as their general basis but subsequently rendered specific through interaction with other organic or inorganic substances. Thus a hierarchy of structuring forces was conceived which, like Newton's forces of various description, had its ultimate foundation in a *Grundkraft* corresponding to a kind of Newtonian "aether" for the organic world.

An example of how Blumenbach intended to apply the *Bildungstrieb* model to anatomy and physiology is provided by his *Beschreibung und Geschichte der Knochen des menschlichen Körpers.* The structuring force of the *Bildungstrieb* was of course considered most evident in shaping the skeletal system; for as Blumenbach noted: "nature has confered upon this [part of the organism] the most powerful and active *Bildungstrieb,* since the total structure of the rest of the body depends upon it."[91] Providing the most basic structure of the organism, the skeletal system was also constructed from the most primary level of organic matter produced from the *Zeugungssaft,* to which the *Bildungstrieb* itself traced its origins. One factor indicating the primitive level of the skeletal material [*Knochensaft*] was the ease with which the organism produced it and the multiple uses it took on.

It frequently occurs that Nature uses the easily producible skeletal substance [*Knochenmasse*] to compensate for loss of the material of an organ that cannot be reproduced and makes the organ thereby at least *taliter qualiter* functional. The famous physician Morand describes a rabbit (in the *Hist. de l'Academie des Sciences de Paris,* 1770, p. 50) that had lost a foot which nature attempted to replace through a surrogate . . . by means of a foot-shaped mass of skeletal material.[92]

The base of the *Knochensaft* was an organic substance which Blumenbach called variously *Gallert* (gelatin, jelly-like substance), or *Leim.* This *Gallert* was the substance initially present in the embryo before the *Bildungstreib* began to manifest itself.

The human embryo, whose general formation does not begin until the third week after conception, consists initially of a sticky gelatin [*leimichten Gallert*]. In the following weeks . . . it attains more solidity, so that in the first half of the second month of pregnancy . . . the more solid basis of the future bones, particularly the breastbone and spinal column is clearly discernible.[93]

At this stage, according to Blumenbach, the future skeleton consists primarily of cartilage. In fact, the growth and development of bones is always preceded by the amassing of cartilaginous substance. The "more solid" gelatinous substance that makes up the cartilage was what Blumenbach called *Knochensaft.*

Blumenbach was not the originator of this theory. It had its roots in the works of Albrecht von Haller. In his *Grundriss der Physiologie* Haller had described the embryo as a sticky substance [*Leim*], which acquired solidity through the additions of earthy materials.[94] Various kinds of fibrous tissues were formed by the addition of different earthy materials to this *Leim.*[95] One such set of fibers was solidified ultimately into bone:

It appears to belong to the order of nature that the fibrous tissues are all generated out of such a *Leim.* . . . . That even the bone tissues are generated from a solidified *Leim* is seen easily from illnesses in which the hardest bones are transformed again into cartilage, flesh and finally *Gallert.*[96]

Blumenbach took over these ideas from his great predecessor at Göttingen, but in linking them up with the theory of the *Bildungstrieb* he added a dimension relative to the questions of speciation and the construction of the natural system. For Blumenbach the *Knochensaft,* formed somehow in the arteries, had a determinate constitution corresponding to the class of the organism. The *Knochensaft* was composed of a base, which as we have seen was identical to the gelatinous substance found in the embryo. In addition it contained what Blumenbach called *Knochenerde,* a substance that differed in its constituents according to the class of organism. *Knochenerde* almost universally contained calcium phosphate [*phosphorsaure Kalkerde*] and carbonic acid [*Kohlensauer*]. But in addition to these standard components Blumenbach remarked that, in addition to these compounds the bones of animals from different classes, for example, horses, oxen, chickens and cartilaginous fishes, contain according to the analyses of Foucroy and Vauquelin a considerable portion of magnesium phosphate which is completely absent in human bones. On the other hand human bones contain urea [*Harne*] which is not found in the bones of these animals.[97]

While Blumenbach did not believe that bones or organized structures of any sort could be constructed artificially from a chemical synthesis of their material constituents, nevertheless those constituents were the basis for an emergent structuring force. The force differed in its structuring tendencies according to the materials in which it was rooted, but it was not identical with them. Each organism contained a hierarchy of such forces all directed by the *Bildungstrieb* specific to that class of organism. By grasping the material bases for these forces, the relationships of their constituents among one another at different levels of organization as well as their interdependencies with the external environment, the naturalist could grasp the inner motive forces giving rise to the system of nature. Just as the followers of Newton could claim to know *how* it was that the solar system came to be organized in terms of planets sweeping out equal areas in equal times in elliptical paths around the sun by providing a *Naturgeschichte des Himmels* without ever claiming to know the cause of the force that actually generated that system, so Blumenbach claimed to be able to grasp the historical genesis of the system of organic nature through the model of the *Bildungstrieb* without claiming to know the cause of that force.

Blumenbach's ideas on constructing a Newtonian dynamic theory of organic nature, which emerged as a synthesis of ideas drawn from numerous sources but fashioned along lines proposed by Buffon and Haller, were well in progress before he first read Kant. Nevertheless Blumenbach profited greatly from Kant's writings on biology, beginning with his discussion of the distinction between races and species in 1785 and his examination of the necessity for basing biological science on a teleological framework of explanation in 1788.[98] It is not surprising that Blumenbach found Kant's approach much in common with his own developing ideas on biology, for Kant's views were independently worked out through a careful consideration of exactly the same sources, particularly Haller and Buffon, that had influenced Blumenbach.[99] Kant's thought directly influenced the mature formulation of Blumenbach's theory of the *Bildungstrieb.* In the writings of the Königsberg philosopher he foresaw the most fruitful means of making explicit certain delicate distinctions crucial to his theory and expanding it into a general theory of organic nature.

Elsewhere I have attempted to document in detail the relationship between these two men and the extent to which Blumenbach incorporated Kant's work into the mature formulation of his ideas.[100] The importance of Kant's work did not consist in proposing hypotheses or a system of organic nature for which Blumenbach attempted to provide empirical support; neither can it be argued that Blumenbach fancied himself a follower of Kant. Rather the work of the two men was mutually supportive of the same program, the program that I have called the transcendental Naturphilosophie of the Göttingen School. Although not deficient in original ideas about how to improve biology, a point to which we will return, Kant's main contribution to Blumenbach's work was in making explicit the quite extraordinary assumptions behind the model of the *Bildungstrieb.* As we have seen in our discussion of Blumenbach's work, the theory of the *Bildungstrieb* tottered precariously on the brink of accepting an out-and-out vitalism on the one hand and a complete reductionism on the other. It was difficult to see how in Blumenbach's view the formative force could be completely rooted in the constitutive materials of the generative substance, to the extent that altering the organization of these constituents would result in the production of different organisms, and still somehow be incapable of reduction pure and simple via chemical and physical laws to the constitutive material itself–how it could be both dependent on and independent of the materials constitutive of the generative substance. Blumenbach always seemed to skirt this issue by invoking a parallel to Newton's refusal to entertain a mechanical explanation for gravity. Kant explained clearly and forcefully why this was not an ad hoc strategem–how biological explanations could be both teleological and mechanical without being occult. Kant's own reason for doing this was that he had encountered difficulties in attempting to extend to the organic realm the categorical framework of the *Kritik der reinen Vernunft,* which had seemed to work perfectly for the purposes of establishing the conceptual foundations of physics. Blumenbach's conception of the *Bildungstrieb* did not resolve that difficulty; but it did permit the construction of a theory that acknowledged the special character of organic phenomena while at the same time limiting explanations in biology to mechanical explanations. Thus in the accompanying letter with the copy of his *Kritik der Urteilskraft,* which Kant sent to Blumenbach in August 1790, he wrote: "Your works have taught me a great many things. Indeed your recent unification of the two principles, namely the physico-mechanical and the teleological, which everyone had otherwise thought to be incompatible, has a very close relation to the ideas that currently occupy me but which require just the sort of factual basis that you provide."[101]

The essential problem, which necessarily requires for its solution the assumption of the *Bildungstrieb* or its equivalent, according to Kant, is that mechanical modes of explanation are by themselves inadequate to deal with the organic realm. Although even in the inorganic realm there are reciprocal effects due to the dynamic interaction of matter which result in the deflection from a norm or ideal—as for instance the departure of one body from a smooth elliptical orbit around a second body by the introduction of a third—nevertheless such phenomena are capable of being analyzed in some way as a linear combination of causes and effects, A→B→C, etc. This is not the case in the organic realm, however. Here cause and effect are so mutually interdependent that it is impossible to think of one without the other, so that instead of a linear series it is much more appropriate to think of a sort of circular series, A→B→C→A. This is a teleological mode of explanation, for it involves the notion of a "final cause." In contrast to the mechanical mode where A can exist and have its effect independently of C, in the teleological mode A causes C but is not also capable itself of existing independently of C. A is both cause and effect of C. The final cause is, logically speaking, the first cause as Aristotle might have expressed it. Because of its similarity with human intentionality or purpose, Kant calls this form of causal explanation *Zweckmäßigkeit* and the objects that exhibit such patterns, namely organic bodies, he calls *Naturzwecke,* or natural purposes:

> The first principle required for the notion of an object conceived as a natural purpose is that the parts, with respect to both form and being, are only possible through their relationship to the whole [*das Ganze*] . . . . Secondly it is required that the parts bind themselves mutually into the unity of a whole in such a way that they are mutually cause and effect of one another.[102]

Now that such "natural purposes" exist is an objective fact of experience, according to Kant. Two sorts of evidence, both of which I have already discussed in connection with Blumenbach, confirm this. First, notes Kant, it is impossible, by such mechanical means as chemical combination, either empirically or theoretically to produce functional organisms.[103] Second, the evidence of generation, even in the case of misbirths, indicates that something analogous to "purpose" or final causation operates in the organic realm, for the goal of constructing a functional organism is always visible in the products of organic nature, including its unsuccessful attempts.

It might be objected that Kant (and Blumenbach) were overly hasty in asserting the impossibility of constructing organized bodies via mechanical means. In fact both Kant and Blumenbach were willing to admit this as a possibility. Kant was willing to admit—indeed he was strongly committed to the notion—that all natural products come about through natural-physical causation. Similarly, Blumenbach grounded the *Bildungstrieb* in the material constitution of the generative substance. But what Kant insisted upon is that even if nature somehow uses mechanical means in constituting organized bodies, and even if the process is capable of technical duplication, we are nevertheless incapable of understanding that constitutive act from a theoretical scientific point of view. The reason lies not in nature but in the limitations of human understanding. The problem is that human understanding is only capable of constructing scientific theories that employ the "linear" mode of causation discussed above. The types of objects that nature constructs in the organic realm, however, involve physical processes that require the teleological mode of causation. Since human reason is only capable of theoretically constructing (or reconstructing if one likes) objects that depend upon "linear" types of causal relation, the organic realm at its most fundamental constitutive level must therefore necessarily transcend the explanatory or theoretical constructive capacity of reason. Accordingly, the life sciences must rest upon a different set of assumptions, and a strategy different from that of the physical sciences must be worked out if biology is to enter upon the royal road of science.

To be sure, there is a certain analogy between the products of technology, according to Kant, and the products of nature. But there is an essential difference. Organisms can in a certain sense be viewed as similar to clockworks. Thus Kant was willing to argue that the functional organization of birds, for example–the air pockets in their bones, the shape and position of the wings and tail, etc.–can all be understood in terms of mechanical principles,[104] just as an a priori functional explanation of a clock can be given from the physical characteristics of its parts. But while in a clock each part is *arranged* with a view to its relationship to the whole, and thus satisfies the first condition to be fulfilled in a biological explanation as stated above, it is not the case–as it is in the organic realm–that each part is the *generative cause* of the other, as is required by the second condition to be fulfilled by a biological explanation according to Kant. The principles of mechanics are applicable to the analysis of functional relations, but the teleological explanations demanded by biology require an active, productive principle that transcends any form of causal (natural-physical) explanation available to human reason.

In order to understand the basis for Kant's position regarding biological explanations it is necessary to consider the argument set forth in the *Kritik der Urteilskraft.* This argument is extremely important for understanding the different biological traditions of the Romantic era, for transcendental Naturphilosophie can be considered as having accepted the position outlined by Kant, while the system of nature constructed by Romantic or metaphysical Naturphilosophie originated with the attempt to solve the problem concerning the theoretical construction of organized bodies that Kant had claimed must remain forever intractable. The special form of these Romantic theories, their employment of concepts such as polarity, unity, metamorphosis, and ideal types, as well as the structure of the system of nature constructed from them, were determined by their stand with respect to this Kantian problem and its resolution.

The task of the faculty of understanding, according to Kant, is judgment; that is it subsumes particulars given in sense experience under general concepts or rules. It can fulfill this task in two different ways: if the rule, law, or concept is already given a priori, then judgment is *determinate* [*bestimmende Urteilskraft*]; if the particulars only are given and a general rule is sought among them, then judgment is reflective [*reflectirende Urteilskraft*].[105] In the first case the understanding is constitutive when applied to nature, while in the latter it is merely regulative; that is, in the first case it is objective, and in the second it is subjective.

These distinctions are important to bear in mind. Both are necessary conditions of experience but in different senses. In the *Kritik der reinen Vernunft* and in the *Prolegomena* Kant showed that the reason why the deductions of Newtonian physics are a priori necessary, and hence can be characterized as science, is that they are expressions of and rest upon the categories of the understanding. They are necessary because they are expressions of the formal principles constitutive of objects of experience. This explains why in physics, on the basis of certain mathematical deductions, an experiment can be constructed in which an expectation established a priori can be verified. But there are other necessary conditions for experience that are not actually constitutive of objects. According to Kant, it is necessary, for example, that we seek unity in experience, that we seek to unite as many different experiences as possible under the fewest number of principles. This requirement is subjective and regulative. It concerns the rules that must be followed in the employment of reason and the understanding. They are subjective rules that are not constitutive of objects of experience. Thus, such maxims as "Nature makes no leaps," or "Nature always follows the shortest path" do not say anything about what actually happens; "that is according to which rule the powers of the understanding play their game [*ihr Spiel wirklich treiben*] and come to an actual determination, but rather how they *ought* to go about it."[106] Such principles then are merely subjective guidelines and the results of their application cannot be accorded objective reality.

This distinction having been made, the question is whether the concept of *Naturzweck* or natural purpose, which as we have seen is necessary for interpreting our experience of organized bodies, is a concept belonging to the *bestimmende* or to the *reflectierende Urteilskraft.* From the preceding discussion we see that the solution to this problem lies in determining whether the notion of *Naturzweck* is capable of generating a priori deductive statements constitutive of experience.

In order to prepare the ground for deciding this issue, Kant considers several examples. The laws whereby organic forms grow and develop, he notes, are completely different from the mechanical laws of the inorganic realm. The matter absorbed by the growing organism is transformed into basic organic matter by a process incapable of duplication by an artificial process not involving organic substances. This organic matter is then shaped into organs in such a way that each generated part is dependent on every other part for its continued preservation: The organism is both cause and effect of itself. "To be exact, therefore, organic matter is in no way analogous to any sort of causality that we know . . . and is therefore not capable of being explicated in terms analogous to any sort of physical capacities at our disposal. . . . The concept of an object which is itself a natural purpose is therefore not a concept of the determinate faculty of judgement; it can, however, be a regulative concept of the faculty of reflective judgement."[107]

The result of these considerations is that it is not possible to offer a deductive, a priori scientific treatment of organic forms. Biology cannot reduce life to physics or explain biological organization in terms of physical principles. Rather organization must be accepted as the primary given starting point of investigation within the organic realm. In order to conduct biological research it is necessary to assume the notion of *zweckmäßig* or purposive agents as a regulative concept. These are to be interpreted analogously to the notion of rational purpose in the construction of technical devices, but it is never admissable to attribute to this regulative principle an objective existence as though there were a physical agent selecting, arranging, and determining the outcome of organic processes. At the limits of mechanical explanation in biology we must assume the presence of other types of forces following types of laws different from those of physics. These forces can never be constructed a priori from other natural forces, but they can be the object of research. Within the organic realm the various empirical regularities associated with functional organisms can be investigated. Employing the principles of technology as a regulative guide, these regularities can be united after the analogy of artificial products. Restraint must always be exercised in attributing to nature powers that are the analogs of art, of seeing nature as a divine architect, of imposing a soul on matter. We cannot know that there are natural purposive agents; that would be to make constitutive use of a regulative principle. In order to satisfy all these requirements it is necessary, therefore, to unite the teleological and mechanical frameworks as Herr Hofrat Blumenbach had done by assuming a special force, the *Bildungstrieb,* as the basis for empirical scientific investigation of the organic realm.

In all physical explanations of organic formations Herr Hofrat Blumenbach starts from matter already organized. That crude matter should have originally formed itself according to mechanical laws, that life should have sprung from the nature of what is lifeless, that matter should have been able to dispose itself into the form of a self-maintaining purposiveness—this he rightly declares to be contradictory to reason. But at the same time he leaves to natural mechanism, under this to us indispensable principle of an original organization an undeterminable and yet unmistakable element, in reference to which the faculty of matter is an organized body called a *formative force* in contrast to and yet standing under the higher guidance and direction of that merely mechanical power universally resident in matter.[108]

According to the position developed by Kant in the *Kritik der Urteilskraft,* therefore, biology as a science must have a completely different character from physics. Biology must always be an empirical science. Its first principles must ultimately be found in experience. In contrast to physics it can never be an a priori science. It must assume that certain bodies are organized and the particular form of their organization must be taken as given in experience. The origin of these original forms themselves can never be the subject of a theoretical treatment. This contrasts sharply with physics. Whereas in physics, for example, it is possible, knowing the law of attraction between all particles of matter, to deduce the shape of the earth, it is not possible, knowing the elements of organic bodies and the laws of organic chemical combination, to deduce the form and organization of plants and animals actually existing.

We can also see from this discussion the point from which the biology of the Romantics would take its origin, for they sought to construct biology as an a priori science on a par with physics. This was the program of Goethe, Oken, Schelling, and Carus. To do this they had to deny the claim basic to Kant's philosophy of biology that the human faculty of understanding cannot be constitutive of organic forms: That is, they denied that human reason is incapable of making *determinate* teleological judgments. The ground for their assertion, paradoxically, is to be found in Kant's own position. For according to the view we have just explored what we take to be organic bodies are unities artificially constructed by the understanding in order to fulfill the subjective demand of reason for unity in the realm of experience. On this theory, therefore, it is difficult, indeed impossible, to distinguish between the unity of organization belonging to a pile of stones and that belonging to a living being. Moreover, it is questionable in Kant's view that organized bodies could ever in fact be an object of experience. If reason is not provided with some faculty of making constitutive teleological judgments, how is it possible for organic bodies to be given in experience in the first place? How do we recognize them as such? The Romantic Naturphilosophen sought to answer this question by constructing a new theory of mental activity. There is such a faculty of judgment, they argued; it is the same practical faculty that makes moral judgments.

From his analysis of the teleo-mechanical framework that must underpin the life sciences, Kant went on to draw several methodological consequences. A principal feature of Kant's conception of natural science is that a mechanical explanation is always to be pursued as far as possible. In the organic realm, however, purposive [*zweckmäßige*] organization has to be assumed as given. This primitive state of organization was then to serve as the starting point for constructing a mechanical explanation. Of methodological significance, therefore, was the question of exactly how in practice the mechanical framework was to be related to the teleological framework, and secondly, at what level of investigation a primitive state of organization no longer accessible to analysis by mechanical models had to be assumed. Kant set out to answer these questions in sections 80 and 81 of the *Kritik der Urteilskraft.* These sections contain some of his most significant reflections on biology, reflections that contain in embryo the biological theory of transcendental Naturphilosophie.

One strategy would be to assume that species are the most primitive natural groups united by a common generative capacity. Indeed Kant had early on announced that: "I deduce all organization from other organized beings through reproduction."[109] Using this definition of natural species Kant had gone on to provide a mechanical model in which races were distinguished as members of the same species but adapted to different environmental circumstances. The source of this adaptive capacity was presumed to lie in the original organization of the species, in a set of *Keime* and *Anlagen* present in the generative fluid. In certain environmental circumstances particular combinations of these structures and capacities would be developed while others would remain dormant. Prolonged exposure to the same climatic conditions over many generations would cause these suppressed capacities of the original form of organization to remain permanently dormant. In the case of races, the characters affected were external, such as the structure of the epidermis, hair, nails, etc., while internal organization and the capacity to interbreed and leave fertile offspring remained unaffected.[110]

In the *Kritik der Urteilskraft* Kant expanded upon this model. Perhaps it might be possible, he mused, to find other types of organic unities containing the generative source of several related species. Such an idea had no doubt crossed the mind of every perceptive naturalist, he observed in a footnote, but only to be rejected as a fantasy of reason, since it was no more acceptable to permit the generation of one species from another than it was to permit the generation of organized beings by mechanical means from inorganic matter. But the hypothesis he was proposing was not at all of this sort; for this was a *generatio univoca* in the most general sense, insofar as organized beings would still be assumed to produce other organisms of the same type, but specifically different in some respect.[111]

The path to these more fundamental organic unities lay in comparative anatomy and physiology:

> The agreement of so many species of animals in a particular common schema, which appears to be grounded not only in their skeletal structure but also in the organization of other parts, whereby a multiplicity of species may be

generated by an amazing simplicity of a fundamental plan, through the suppressed development of one part and the greater articulation of another, the lengthening of now this part accompanied by the shortening of another, gives at least a glimmer of hope that the principle of mechanism, without which no science of nature is possible, may be in a position to accomplish something here.[112]

The correctness of such hypothetical unities, Kant argued, would have to be established through careful archaeological investigation of the remains of previous revolutions. Beginning from the common forms that had been provided by comparative anatomy and physiology, the archaeologist must

in accordance with all the known or probable mechanisms available to him determine the generation of that large family of creatures (for they must be conceived as such [*i.e.*, as a family] if their presumed thoroughly interconnected interrelatedness is to have a material basis).[113]

Analogous to the reconstruction of the real unity at the basis of the phenomena of races of the same species, an entity he called the *Stammrasse,* Kant was now encouraging the construction of larger common groupings of species, which he called *Stammgattungen.* Just as a common set of structures and adaptive capacities [*Anlagen*] were thought to ground the purposive organization of the species, so a similar plan of organization and common set of organs would underpin the purposive organization of several species. When exposed to varying external circumstances, including climate and, as we shall see, other organisms, this original form of organization would be capable of manifesting itself in several different but closely related ways, each being a different species of the same natural family.

There are important differences between the model proposed for identifying races belonging to the same species and that for identifying species belonging to the same family. Members of the same species can be identified with certainty verified by experiment. Any two organisms capable of interbreeding and leaving fertile progeny belong to one and the same natural species, according to Kant. The reconstruction of natural families cannot proceed by direct experiment, however. Resting on evidence of comparative anatomy, physiology, and archaeology, it is much more hypothetical in character. We are introduced here directly to one of those regulative unities that must characterize biology as an empirical science. What is important, however, is that even here the approach is empirical and capable of (limited) test.

A question that must immediately occur, particularly to anyone familiar with the modern Darwinian theory of evolution, is whether Kant means to infer from his model that the form here being discussed as the generative source of different species is an actual historical, ancestral form. The answer is unequivocally no. Such an assumption can only be consistent with a completely mechanical and reductionistic theory of organic form in Kant's view. To understand what he means it is important to recall the model of the *Stammrasse* once again. While this *zweckmäßige* organization is the source of all members of the same species, it is not itself represented in an actual historical individual. Kant strenuously denied the thesis then common among contemporary naturalists, including Blumenbach, that the various races of man are modifications of an ancestral race, which most took to be the caucasian race.[114] What Kant had in mind is a distinction much closer to that between a genotype and its phenotypical representations.[115] For he describes the *Stammrasse* as a generative stock containing all its potential adaptive variations. This is important to bear in mind when considering the generalization of the model at the level of families. Were it the case that the *Stammgattung* has an actual representative, say in the fossil record, then in passing from this individual to others of the same family new and different characters would have to be *added* to the existing stock and this addition would have to occur by means of some mechanical agency. Such an account, in short, runs strongly counter to his teleological conception of biology. According to Kant it can never be argued that an organism *acquires* its ability to adapt to its changing environment. That adaptive capacity must already be present in the organism itself, in the original purposive organization that grounds it. How that purposive organization came originally to be constructed lies forever beyond the reach of scientific treatment. What the archaeologist must presume is that the same *Stammgattung,* which is in reality a complex interrelation of organic forces potentially capable of generating numerous adaptive responses to the environment, underlies a group of forms having both current and extinct representatives. The earlier representatives will, in Kant's view, necessarily be less complex. Once he understands this regulative unity in terms of comparative anatomy and physiology, it will appear to the archaeologist that these earlier representatives have pressed together into single organisms forms that have been broken up and distributed among many organisms in later periods. Due to the increasing demands of the environment, the potential originally present in the *Stammgattung* is "unpacked," appearing as differentiated into more complex representatives. The role of archaeology is to provide an empirical test and guideline for the correctness of the hypothetical or regulative unities constructed through comparative anatomy and physiology. In any given epoch the same forces reign, giving rise in the end to the manifold of nature. The task of biology is to uncover the laws in terms of which those forces in the organic realm operate.

Rather than seeing these organic unities reconstructed by comparative anatomy as potential historical ancestors, it is more appropriate to view them as *plans of organization,* as the particular ways in which the forces constituting the organic world can be assembled into functional organs and systems of organs capable of surviving. Under different circumstances these *zweckmäßige Ordnungen* are capable of various adaptive manifestations, that is, the forces that underlie these plans are capable of assuming various expressions in achieving their effect, which is the production of a functional organism. Only under the conditions of a dynamic interpretation of form can we understand how, in Kant's view, it is possible for the fossil record to reveal an ever-increasing complexity of forms having the same generative source, while at the same time assuming that this complexity is not the result of an addition of characters:

> [The archaeologist] can let the great womb of nature, which emerges from the original chaos as a great animal, give birth first to creatures of less purposive form, those in turn to others which are better adapted to their birthplace and to their inter-relations with one another; until this womb has petrified, fossilized and limited its progeny to determinate species incapable of further modification, and this manifold of forms remains just as it emerged at the end of the operation of that fruitful formative force. But in the end, he must attribute the imposition of the original purposive organization upon each of these creatures to the Mother herself.[116]

From this passage we see that the system of nature Kant envisions is a dynamic one that runs through a cycle of birth, a fruitful period of growth and the development of the potential organic forms stored in it originally, maturity, and finally ultimate decay. From the undifferentiated potential of the entire system, governed by certain organic laws of adaptive combination that are expressed in definite organizational plans, the first primitive organisms emerge. Each of these purposive organizations has associated with it a reserve of energy. Like Blumenbach's polyps, this *Bildungskraft* can be used up in regenerating duplicates of the same organisms, or it can be partitioned out so as to produce adaptive variations on the same theme. Originally these organisms are simple and, as Kielmeyer will demonstrate for us, the simplicity of structure is compensated by the enormous fecundity of the organisms themselves. These organisms are governed by a *zweckmäßig* generative force; hence, they are capable of adapting to their physical environment as well as to the relationships that emerge with other organisms, "but only by taking up into the generative substance those materials alone which are compatible with the original, undeveloped *Anlagen* of the system."[117] The result is the alteration of the formative force, and the alteration consists in a modification of complexity in structure. Each such divergence of the *Bildungstrieb* must be compensated in some fashion, as for instance in the loss of the ability to produce numerous offspring or in the ability to regenerate lost parts. There are limits on the extent to which these forces can vary and still maintain their functional integrity, however. When this occurs, the period of growth is over and all species then in existence continue unchanged into the future. A revolution of the globe, or perhaps even a gradual but continuous change, can lead to the destruction of this system and its replacement by an entirely new set of dynamically interrelated organisms.

Polyps, Paramecia, and the Integral of Life: The Transcendental Naturphilosophie of the Göttingen School

The work of Blumenbach in the late 1770s and early 1780s wove together a number of strands of thought that had been elements in discussions on the philosophy of nature, natural history, and physiology at Göttingen from the late 1750s. The central issues in these discussions focused on aspects of Buffon's *Histoire naturelle,* which was regarded as a speculative work but nonetheless rich in ideas for the future development of science. Especially important for developments at Göttingen was Haller's work in physiology, particularly his introduction of vital forces, which he conceived to operate analogously to the forces Newton had discovered for the inorganic realm. In a grand synthesis of Haller's theory of sensibility and irritability and his views on the formation of animal tissues, together with ideas developed by others at Göttingen concerning the role of ideal types and the *total habitus* in classification, Blumenbach succeeded in setting forth a program for the construction of the natural system. For the natural history of organized nature that program was analogous to the Newtonian program for constructing the natural history of the solar system; just as the exploration of the effects of universal gravitation gave rise to natural history of the heavens, so the exploration of the laws governing the activity of the *Bildungstrieb* and its effects would produce the natural system of organized bodies.

Kant had been led to his own similar ideas on the subject independently but nonetheless through careful analysis of the same tradition of Enlightenment thought on biology, which he saw as having achieved in the work of Blumenbach theoretical foundations for the elaboration of a systematic treatment of organic nature. In the sections dealing with teleological judgment in his *Kritik der Urteilskraft,* Kant had explicated the basic assumptions of this approach to biological phenomena, the necessity of pursuing mechanical explanations in biology under the guidance of a regulative teleological framework; and he had attempted to justify those assumptions by demonstrating their consistency with the conclusions of his own earlier *Kritik der reinen Vernunft.* The significance of this step should not at all be underestimated, for however modern science and its historians may regard the contribution of philosophy to science, the fact was that in 1790 not only was Kant himself certain, but everyone else in Germany concurred, that he had effected a Copernican revolution in philosophy, and that henceforth the philosophy of nature must be consistent with, if indeed it did not take its origins from, Kant's critique of scientific knowledge. Moreover, in the conclusion of the critique of teleological judgment Kant had explored the methodological consequences of these assumptions necessary for the life sciences. There he had sketched in outline a theory of natural history that rested on comparative anatomy, physiology, and archaeology, and that led to a dynamic system of nature, to the unfolding and development of genetically interconnected forms of life, a system closely resembling that broached by Blumenbach in his works from the late 1780s and early 1790s, particularly his *Beyträge zur Naturgeschichte.* Indeed, Kant's *Kritik der Urteilskraft* was strong endorsement for the research program of the Göttingen School.

There were a number of key ideas in Blumenbach's work that became central to the development of what I have characterized above as the Göttingen program for natural history in the work of his students as well as in the works of other scientists and philosophers. First it is important to note that while Blumenbach's theory of the *Bildungstrieb* certainly was a form of vitalism, it was a vitalism remarkably different from that of Stahl, Wolff, or even Leibniz. Blumenbach did not think that discussion of a soul in matter or of peculiar vital powers was scientifically relevant. This point of view he took over from Haller. On the other hand he did not think that organization could be explained in terms of a set of material constituents alone. He argued explicitly against both views. In their stead Blumenbach adopted what is best characterized as an emergent vitalism: that is to say, the vital force was not to be conceived as separate from matter, but matter was not the source of its existence; rather it was the *organization* of matter in certain ways that gave rise to the *Bildungstrieb.* Organization was taken here as the primary given: the presence of organization could not be further explained in terms of unorganized parts. The *manner* in which it operated, the mechanisms employed for achieving the ends of organization, could be explained in mechanical terms, however. This gave rise to one of the distinctive features of the work of Blumenbach's students and it was a characteristic of the works of others exploring the ramifications of the background of ideas from which his work emerged; namely that in the philosophy of organic nature, mechanism was to be regarded as subservient to the ends of organization.

In addition to these ideas of general theoretical interest in the work of Blumenbach and Kant there were also ideas of a more particular nature affecting the mechanism of the *Bildungstrieb* that were especially compatible with ideas emerging in other areas of scientific inquiry and accordingly made the "Newtonian" program outlined in Blumenbach's works much more capable of further development at the hands of students and followers. One such idea was the notion, derived in part from Haller's theory of tissue formation, that each new level of organic force was associated with a fluid and that this fluid was composed of a *basis* plus some combination of inorganic or organic compounds. The notion that metals were composed of a basis, phlogiston, and various concentrations of some metallic principle, such as mercury, had long been current in chemical literature. The work of Priestly and Cavendish on different types of gases also exploited such a conceptual framework. More important for later developments, however, was Lavoisier's description of elements as having a basis, light or caloric, as part of their make-up. A similar conceptual structure could be found in contemporary theories of the electric fluid, particularly those espoused by Lichtenberg and Gren. Thus Blumenbach's mechanism for the *Bildungstrieb* was compatible in many respects with the conceptual structures of other areas of inquiry to which persons attracted by his work would naturally turn for further development of the theory.

The "Göttingen program" for natural history contained two implicit lines of future inquiry. In order to construct the natural system it was necessary to classify organisms on the basis of multicharacteristics. Such a system would entail a determination of the laws governing the operation of the various components of the *total habitus* and their interrelations. This aspect of the research program gave rise to the attempt to provide what Kant and others such as Georg Forster called a complete *Naturbeschreibung.* It concerned the external relations between objects. As we have also seen, a principal feature of the historical development of the tradition at Göttingen, beginning with the discussion of issues surrounding Buffon's work, was the view that the construction of the natural system depended ultimately on grasping the "inner" organization of things. In Blumenbach's scheme the *Bildungstrieb* was that internal force giving rise to the external characteristics of the organism. Consequently a second line of inquiry concerned with discovering the laws governing the activity of the *Bildungstrieb* was an integral part of the research program. The first line of inquiry led to research in various aspects of natural history while the main thrust of the second was in the direction of physiology and comparative anatomy.

An impressive list could be assembled of colleagues and students who worked on aspects of this program over the next two decades. Among the most significant were two colleagues of Blumenbach from his student days, Johann Christian Reil (1759-1813) and Samuel Thomas Sömmering. Among some of the lesser-known names associated with this school is Blumenbach's student, Christoph Girtanner (1770-1800). Although his work had no major impact on his contemporaries, Girtanner's aim was to work out details of the Göttingen program. He had been a medical student at Göttingen from 1780-1783, having worked closely with Blumenbach during that period. After numerous travels, including a lengthy stay in Edinburgh and Paris, Girtanner returned to Göttingen in 1789 where he practiced medicine and wrote on matters concerning both science and the political events surrounding the

French Revolution. Although he was closely connected with scientific developments in Göttingen, Girtanner never held a university position. In 1796 he published a work entitled *Über das Kantische Prinzip für die Naturgeschichte,* which he dedicated to Blumenbach. The purpose of the work was to propose a means for advancing the study of natural history through a synthesis of views held by Kant and Blumenbach. In particular, he attempted to explain how one might go about empirically reconstructing the *Stammgattungen* central to the Göttingen program.[118]

Another lesser-known student of Blumenbach was Joachim Brandis (1762–1845), whose family was important in Hannoverian political circles. Brandis' brother, a champion of Kantian liberalism, was a professor of law at Göttingen. In 1795 Brandis published a work entitled *Versuche über die Lebenskraft.* This book was very similar in its problem orientation to a work published in the same year by another lesser known Blumenbach student, Christian Heinrich Pfaff. Pfaff was from an illustrious family of chemists and mathematicians. In his student days he had also studied under Kielmeyer, with whom he became close friends, and he was the roommate of Georges Cuvier when all three were together at the Hohen-Karlsschule in Stuttgart. Pfaff's treatise, *Über tierische Elektrizität und Reizbarkeit* (1795), was typical of works that attempted to develop the Göttingen program in physiology, and it merits our attention.

The question motivating Pfaff's treatise was whether all vital functions are modifications of a single *Grundkraft* or whether they are specific individual forces. Moreover he hoped to determine whether the vital forces were different in kind from mechanical forces. This question could be solved, he supposed, once the general form of the laws of organic force could be determined and the attempt had been made to reduce them to the general laws of physics.

In this treatise Pfaff focused his investigation on the vital forces of sensibility and irritability. Since the phenomena of animal electricity were manifestations of these two vital forces, a determination of the laws regulating galvanic phenomena would lead to a general force law for sensibility and irritability.

Since the phenomena of animal electricity are phenomena connected with the sensible and irritable parts; and since as phenomena connected with life, they presuppose vital forces as their first causes, we must direct our attention to these forces first before we seek the principle which sets them all in motion. The phenomena of animal electricity can be seen as signs or revelations of the relationships between certain external circumstances and those two forces. . . . [t]hus we must concern ourselves first only with the phenomena of sensibility and irritability, and in particular mainly with the forces upon which these depend, since the phenomena of animal electricity are merely manifestations of these forces. And we want especially to strive to express the interrelationship of these two forces which are so closely linked together.[119]

In pursuing these goals Pfaff conducted a great number of experiments establishing the conditions under which contractions could be excited in a prepared frog's leg by contact with metal conductors, and the relative strength of the contractions for various substances. From the generalizations derived from these experiments, he attempted to draw an analogy between these phenomena and the phenomena connected with electricity; his aim being to argue that the vital principle underlying sensibility and irritability was in fact the electric fluid, and that the forces of sensibility and irritability were "positive" and "negative" manifestations of this unitary *Grundkraft.*

Pfaff's work on animal electricity was extremely influential. The experiments and reflections recorded in the treatise served as the starting point for the researches of both Alexander von Humboldt and Johann Wilhelm Ritter. And in demonstrating that the phenomena connected with animal electricity were fundamentally chemical in nature, Ritter's work first established in a convincing way that the unity of organic and inorganic forms in nature postulated by Pfaff was not purely speculative.

For the later development of the Göttingen program and for German biology as a whole in the nineteenth century the most important figures were Heinrich Friedrich Link, Carl Friedrich Kielmeyer, Gottfried Reinhold Treviranus, and Alexander von Humboldt. Each of these men was a student of Blumenbach and they all maintained close contact with him over the years. It is in their work that we find the transcendental Naturphilosophie of the Göttingen School worked out in systematic detail.

Within this group the most impressive contributor by far to the Göttingen program—one whose contributions spanned detailed painstaking empirical research in organic chemistry, comparative anatomy, and physiology (particularly galvanic phenomena, plant and invertebrate physiology), as well as deep and powerful thoughts concerning the theory of the natural system—was Carl Friedrich Kielmeyer. Having studied previously at the Hohen-Karlsschule in Stuttgart, Kielmeyer moved on to Göttingen where he studied with Blumenbach, Gmelin, and Lichtenberg from 1786 to 1788. He returned to the Karlsschule from 1790 to 1793, during which time he lectured on comparative zoology as well as chemistry and natural history. He returned once again to Göttingen for several months during 1794. Kielmeyer was thus a participant in and, as we shall see, a lively contributor to the intense discussions on the construction of a theory of animal form going on in Blumenbach's circle during the late 1780s and early 1790s.

In his lectures at the Karlsschule Kielmeyer assembled into a grand and comprehensive program the various aspects of the approach to constructing a general theory of animal organization that I have sketched from the writings of Blumenbach and Kant. Although these lectures were never published, their contents were widely known, and copies of the lectures must have circulated. In a letter to Windischmann, Kielmeyer mentions that copies of these manuscripts were circulated. Cuvier's correspondence with Kielmeyer's student, Christian Heinrich Pfaff, demonstrate that while Cuvier did not receive copies of Kielmeyer's manuscripts he was following the development of Kielmeyer's thought in these lectures.[120] References to these lectures in the writings of Döllinger, von Baer and others leave little doubt that they must have been widely known.

In addition to stating the conditions for a materialistic interpretation of the teleological-mechanical conception of the phenomena of organization I have sketched from the works of Kant and Blumenbach, and stating the implications for generalizing the model for constructing a natural system, Kielmeyer's lectures made an essential contribution by describing a path for beginning to implement these ideas given the existing state of biological and chemical science. Two essential problems demanded solution. First, although ultimately the proposed scheme required that the basis of each type of organism lay in the system of organic chemical affinities embedded in the first instance in the generative substance, the analysis of organic materials had only just begun; and although the French chemists in particular had made some advances in this area, still no satisfactory application of chemical methods to the general theory of animal organization could be expected in the forseeable future. Kielmeyer, who made extensive and substantial contributions to the development of *Pflanzenchemie,* the beginnings of organic chemistry, was deeply sensitive to this problem.[121]

The second problem concerned the actual construction of the natural system viewed as a genealogical system based on the laws of generation and reproduction. As Blumenbach had noted, even though the natural system must be based on generation as a theoretical principle, the practical application of the breeding criterion is circumscribed within certain definite limits.[122] Although different races of the same species are theoretically capable of interbreeding, slight differences in periods of fecundity and differences in behavioral characteristics might set up natural barriers to interbreeding even among members of the same species.[123] Moreover, the breeding criterion was obviously useless for higher taxonomic levels. Blumenbach proposed as the solution to this problem the use of multiple characters in classifying organisms: based on comparative anatomical and physiological investigations animals were to be grouped together in accordance with their agreement in *total* number of characters. Kielmeyer built upon this idea.

In his lectures on comparative zoology Kielmeyer set forth a plan for constructing what he called the *Physik des Tierreichs.* Its design was to develop methods for revealing the laws of organic form through comparative anatomical studies of mammals, birds, amphibians, fish, insects, and worms. The program consisted of a multifaceted investigation of animal organization, first through a comparative study of the chemical basis or organization. This was to be followed by a comparative anatomy and physiology of basic organs as they exist fully developed and in the various periods of embryonic development. Here attention was devoted to three groups of organs. First those concerning the relation of the organism with its *external* environment; namely digestive organs, the lymphatic system, circulatory system, the brain and nervous system; also included in this group was a comparative study of sensory organs and the investigation of systems of motion; namely muscles, bones, and their "analogues" in various animal forms. The second group of organs for study were those concerned with the regulation of the *internal* functions. Here Kielmeyer included comparative studies of the kidneys and the various other "regulatory" glands of the animal economy. The third and final group of organs to be considered were those that served for the *communication* of the animal with other members of its species, namely organs of generation. Kielmeyer also included in this group the comparative anatomy and physiology of organs of speech, *Stimmorgane.*[124]

After establishing the "elements" of structure in the organic realm Kielmeyer's program proceeded to a general theory of the relations between them or to an *Allgemeine Physiologie der Tiere.* Here Kielmeyer advocated the use of developmental histories of the genesis of the germ and its material constituents, the subsequent development of the embryo, and finally the development of the mature organism and the changes it undergoes in relation to its environment. Since the principles regulating each type of organic form lay locked up in the *Keime* and *Anlagen* of its generative substance, comparative developmental histories would reveal interrelations between different organic systems; nature itself would provide, so to speak, its own experimental laboratory. By systematizing and unifying the patterns through which form is unfolded more general relations would emerge from which general laws could be constructed.

Thus far Kielmeyer had presented the methods for revealing the laws of the "deep structure," the internal forms of organization. In turning to an analysis of the external surface elements of form Kielmeyer attached special significance to behavioral studies as a means of understanding the principles of organization. He advocated the construction of a *Psychologie der Tiere.* Its object was to study a) the activities in terms of which animals seek out nourishment, a proper climate, and suitable habitat; b) activities through which they defend their position in the economy of nature against enemies.[125] Animal psychology was also to include the investigation of activities that promote the preservation of the species, among which he included mating behavior and the rearing of offspring.[126]

Like Blumenbach and Reil, Kielmeyer believed that a systematic study of the variation to which animal forms are subject and the patterns of these anomalies would provide positive insight into the principles of organization. Consequently, he advocated the construction of a *vergleichende Pathologie der Tiere* as a third methodological tool to be employed in the new science of zoology. Here "permanent, inborn as well as accidental variations of species would be investigated; and chiefly under two classes of variation, 1) malformations, monstrous births, bastards; variations with respect to geographical location and other (similar) circumstances; inheritable degenerations and permanent, inborn variations induced by climatic and geographic variation; universality of variation; b) variations in capabilities of the organs and their stimulation; temperament, both individual natural temperament and characteristic idiosyncracies."[127]

Kielmeyer summarized the various aspects of his *Physik des Tierreichs* and the order of their application as follows:

a) The number of organs in the machine of the animal kingdom or the number of animal forms generally and the laws according to which these are divided into different groups. Causes, consequences, or purposes [*Zwecke*].

b) The relative position of the organs in the machine of the animal kingdom, or the division of the animal kingdom into groups upon the earth (geography) according to different characters. Laws of the differences according to different groups. Causes and effects.

c) The interrelated formation of organs in the animal kingdom. Gradation of animals and affinities in their formation generally as well as according to groups. Laws, causes, and effects of this gradation.

In the next category Kielmeyer introduced an area of study which he had not previously mentioned in the outline of his lectures, namely paleontological research:

d) Changes the animal kingdom and its groups have suffered on the earth. *The developmental history of the animal kingdom* in relation to the epochs of the earth and those probable for our solar system. Symbolized by the parabola.

e) Changes the animal kingdom and its groups undergo repeatedly [throughout all epochs]. The life of the machine of the animal kingdom or its *physiology*. Symbolized by the circle.[128]

In a concluding section of this manuscript, which Kielmeyer crossed out, the *Physik des Tierreichs* was characterized generally as a kind of Laplacian dynamics of animal organization according to which the series of animals and the elements of their organization were to be viewed as a series of attempts by nature to break up the integral of life into a series of partial fractions.

From this plan of a general science of animal form sketched in his lectures we see that Kielmeyer, in addition to uniting the various elements characteristic of the approach of Blumenbach and the Göttingen School, had begun to introduce a completely new dimension to the discussion, namely the use of the embryological criterion for detecting affinities between animal forms. To be sure this was to some extent implicit in the earlier notion of a generative stock shared by different groups of organisms and the related interest in inheritable degenerations and malformations, but the idea of utilizing embryogenesis as a means for investigating the unity of the generative stock was Kielmeyer's most significant contribution.

Kielmeyer expanded upon his notion of the biogenetic law in a treatise, which like almost all of Kielmeyer's work was never published. It was written in 1793-1794 and entitled "Ideen zu einer allgemeinen Geschichte und Theorie der Entwickelungserscheinungen der Organizationen." Several aspects of Kielmeyer's conception of the relationship between phylogeny and ontogeny presented in this manuscript provide an important context for later developments in Germany.

Kielmeyer begins by pointing to a fundamental difference between the results to be expected from teratology and embryology. Malformations appear to be dependent on external circumstances, such as environment, and while they are probably rooted in the matter of the germ, they are departures from the rule and are not repeated similarly in all individuals. Embryological development, however, always reveals a patterned series of successive changes that is the same for each individual of the same species and patterned differently for different species.[129] These patterns of embryogenesis are, therefore, more dependent on an internal directive force: they tell us more about the internal organizing principles of animals, which as we have seen depend not so essentially on the chemical conditions of life as much more on the *order* and arrangement of those conditions. For Kielmeyer the beauty of focusing on embryological patterns was that "they demonstrate the path and contents of the system of animal organization as a whole without requiring the assumption of a special directive force existing outside of the individual organism, through which the life and economy of organic nature is maintained."[130] That is, recourse need not be taken to a *Weltseele,* to any supra-material organizing force. Furthermore, although in his view embryological investigation is the most useful means for constructing a general theory of animal organization, it can also aid in the construction of natural classification, which most "descriptive" biologists regard as the highest aim of their science

insofar as the relationships between the different forces and different forms of manifestation of the same force in different organisms is exactly that which determines the essence of the differences and relationships between species. With the determination of these forces, therefore, and the laws they obey, the path toward constructing the natural system would be given at the same time.[131]

In a letter to Windischmann of 1804, Kielmeyer explained the reasoning behind his postulation of an interdependence of the results of embryological and paleontological research in his earlier lectures at the Karlsschule.

The idea of a close relationship between the developmental history of the earth and the series of organized bodies, in which each can be used interchangeably to illuminate the other, appears to me to be worthy of praise. The reason is this: Because I consider the force by means of which the *series* of organized forms has been brought forth on the earth to be in its essence and the laws of its manisfestation *identical* with the force by means of which the series of developmental stages in each *individual* are produced, which are *similar* to those in the series of organized bodies. . . . These forms, however, demonstrate a certain regular graduation in structure as well as similarity to the stages of individual development; therefore it can be concluded that the developmental history of the earth and that of the series of organized bodies *are related to one another exactly* and therefore their histories must be bound together.[132]

Kielmeyer went on to add an extremely important qualification to this thesis. He wanted to emphasize that in his view this "series" of forms must not be conceived as *continuous*. There are gaps in the developmental series that can never be filled, not simply because of defects in the fossil record, but because there are different types of organization.[133] Like Blumenbach, Kielmeyer denied the existence of a chain of beings.[134]

Nevertheless, while Kielmeyer denied the existence of a continuous developmental series, he did argue for the transformation of species and the interconnection of forms within the intervals punctuated by the gaps in the developmental series.

Many species have apparently emerged from other species, just as now the butterfly emerges from the caterpillar. . . . *They were originally developmental states and only later achieved the rank of independent species;* they are transformed developmental stages. Others on the other hand are original children of the earth. Perhaps, however, all of these primitive ancestors have died out.[135]

He went on to note that, like Lamarck—and though he is not cited in this context, Blumenbach—he believed that the production of these genetically related but distinct forms "was due to an altered direction of the formative force introduced by changes in the earth."[136] But this alternation of the *Bildungstrieb* did not proceed continuously. In Kielmeyer's view the "paths through which the different series of organisms has been brought forth have been very different in different periods of the history of the earth."[137] Thus, not only were the genetic relations between groups of organisms to be viewed as circumscribed within definite limits due to the internal organization of different types, but the manner in which these fundamental organizational plans were worked out in different periods and the (limited) developmental series of organisms descendent from them were dependent upon and circumscribed by the external conditions prevailing within a given geological age.[138]

We might summarize the general theory of natural history emerging from Kielmeyer's works as follows. There are definite epochs of nature, during which a different flora and fauna, specific to that epoch, flourish. Within each of these epochs the same laws regulating animal organization prevail, just as the same laws continue to regulate inorganic phenomena. Each epoch contains a system of interrelated organisms based on a small number of ground plans. Within each epoch gradual transitions occur within the forces of both the inorganic and organic realm. As gradual shifts in environmental circumstances occur within an epoch the *Bildungstrieb* of the primitive forms are modified, giving rise to divergent phylogenetic lines of organisms within the same type. Although the forms of the next epoch are based on the same principal plans there is no continuation of the previous forms. A change in one element of the system entails a modification in all the others, for each individual form is related to the whole of organized nature. Each epoch, therefore, is its own complete, closed system; and it is not possible to trace a single phylogenetic line, even within the same ground plan, from the most recent epoch.

The quintessence of the position developed in his unpublished lecture notes was distilled elegantly by Kielmeyer in his famous lecture delivered at the Karlsschule on February 11, 1793, entitled, "Über die Verhältniße der organischen Kräfte untereinander in der Reihe der verschiedenen Organizationen: Die Gesetze und Folgen dieser Verhältniße." This paper, approximately forty pages in length, is one of the milestones of the Romantic era; anyone wishing to understand the biology of this period would do well to examine it carefully.

The lecture begins by discussing the general methodological framework that must be assumed if success is to be achieved in constructing the system of nature. The framework is that set forth by Kant in the *Kritik der Urteilskraft:* the constitutive causes of organic nature cannot be grasped. Nature must be treated as if it employed a technique analogous to purposive action, one that relates means to ends in teleological fashion. The definition of an organized body, following Kant, is one in which all its parts are reciprocally cause and effect of one another.[139] In a literary vein, but one reflecting Kant's powerful imagery of the great womb of nature as well as indicating that the most fundamental secrets of nature can at best be reflected in a story conscious of its analogy to purposive human activity, Kielmeyer himself speaks forth as *die*

Natur. To underscore the necessity but at the same time the futility of ever penetrating the secrets of organization through teleological judgments, Nature is asked what her intentions were in constructing this multiplicity of forms. Her answer is: "I had no intentions, even though the intermingling of cause and effect appears analogous to the connections your reason makes between means and ends; but you will find it easier to understand these matters if you assume such a linkage of cause and effect as though it were in reality one of means to ends."[140]

Lyonet and Bonnet had estimated at least seven million different organic forms on the surface of the earth. Each of these is represented by at least 10,000 different individuals. Each individual in turn is constructed from as many as 1,000 to 10,000 organs. In order to make a system out of this fullness of life, according to Kielmeyer, it is necessary to understand the forces that are united in and generative of these individuals. Next it is important to understand the relationship of these forces with respect to one another in different species of animals and the laws according to which this relationship changes in the series of organic forms. "Finally the task is to understand how both the continuity and change in species are grounded in the causes and effects of these forces."[141]

In answer to the first question–what are the forces united in individuals?–Kielmeyer identifies five forces: sensibility, irritability, reproductive power, power of secretion, and power of propulsion. In order to measure these forces and compare them to one another, he proposes that the strength of vital force be conceived as a compound function of a) the frequency of its effect, b) the diversity of this effect (i.e., the number of diverse forms in which it is manifested), and c) the magnitude of the opposition it encounters from other forces. In the absence of an exact measure and until one satisfying the demands of this function can be constructed, Kielmeyer notes that in essence a vital force is one that demonstrates "permanence of effects under otherwise constant conditions,"[142] a definition that seeks to identify vital force as the source of regulative maintenance of the organized body. The similarity in formulation to Newton's principle of inertia–the force of inactivity as it was then understood–is strong.

Kielmeyer's plan in the work was to look at each of the five vital forces considered singly, and then compare each of their strengths within different species of animals. Beginning his examination with sensibility, Kielmeyer notes that the capacity for retaining a diversity of types of sensations specifically different from one another falls off in a graduated series beginning with man. In the mammals, birds, snakes, and fish all the same sense organs as in man are present, but the degree of complexity of these organs differs for the different classes and even within the same class. In the insects the organ for hearing is absent, while the sensitivity to odors is much enhanced; and even if the eye appears multiplied a thousandfold in these animals, it is for the most part immobile and only capable of admitting light in a few species. In the worms, finally, all the diverse organs of the other species are replaced by a single sensibility to touch and light. It must not be overlooked, Kielmeyer tells us, that when in the series of organic forms one sense organ is lost, hence diminishing the diversity of the effect of the force of sensibility—component b) of the function above—greater opportunity for the development of one of the other senses is afforded; and when one sense is less developed, another will be more sensitive, its organ more delicately structured.

From these observations we derive the following law: The diversity of possible sensations falls off in the series of organic forms in proportion to the increase in the fineness and discrimination of the remaining senses within a limited domain.[143]

A little reflection revealed that this law is not exactly correct, that even within the same class of animals the reduction in capacity of one of the senses is not always compensated by an increase in another. The ground for departure from this first law Kielmeyer sought to find in the law governing the effects of the second force named above, namely irritability. In contrast to sensibility, irritability manifests variations not only in the diversity of its effect [component a) in the definition of vital force], but also in the frequency of its manifestation in a given time and in the length of its manifestation under similar circumstances [i.e., components b) and c) from the definition].

In the mammals and in the birds, if the trunk is severed from the head, and individual members from the trunk, all traces of irritability vanish within a short time. Cold-blooded animals exhibit quite a contrary set of phenomena. Frogs can hop around with their heads removed, and decapitated turtles can move around with their hearts removed for several days.[144] Kielmeyer noted similar observations for spiders and fish.

The phenomena lead to the conclusion that irritability *increases* its strength and independence from the rest of the organic system in the series of organisms beginning with man. Looking toward other characteristics associated with this phenomenon, Kielmeyer notes that most of the animals that tenaciously preserve this power of irritability are animals in which either very few irritable organs are present or ones in which the muscles are separated from one another. Mussels, for instance, which exhibit a high degree of irritability, have at most two or three distinct muscles.[145] Fish, while possessing numerous muscles, have only a small number of different types of muscles, in contrast with man, where there are relatively few muscles but a great variety of muscle-types and complexity. Moreover, those animals capable of preserving irritability in the highest degree are also those that move the slowest. From all of these observations Kielmeyer derives the following law:

Irritability increases in the permanence of its manifestation in the same proportion as the speed, frequency, or diversity of its effect and as the multiplicity of different types of sensation decreases.[146]

The second law, therefore, provides the needed corrective factor to the first law, for we see that in the series of different organic forms deficiency in sensibility is compensated by an increase in irritability. But it provides only part of the needed correction, Kielmeyer tells us. The force of irritability cannot be preserved as long in mussels, or even in plants, as it can in amphibians. Another force must be sought that affects irritability, accounting for its departure from the norm in certain forms.

Kielmeyer finds the needed modification in the force of reproduction. As a first approximation to the law of the reproductive force, he notes that the mammals normally produce one to fifteen offspring, while birds produce many more than fifteen, and some species of amphibians produce at least one hundred thousand. Examining these phenomena more closely, Kielmeyer observes that the animals that bring forth the fewest offspring in each class are those having the largest bodies. Thus rats give birth to from ten to fifteen offspring at once, while whales produce only one calf. Furthermore, it appears that the less prolific animals are also those having more complex structure and the ones whose offspring require the most time to come to term. "Thus it takes nature two years to make an elephant, while only a few weeks suffice for constructing a rat."[147] These observations result in the following law for the reproductive force:

The more the reproductive force is expressed in the number of new individuals, the smaller are the bodies of these new individuals, the less complex are they, the smaller is the period required for their production, and the shorter is the active period of this force itself.[148]

As in his discussion of the previous laws, Kielmeyer went on to point out several exceptions to this one. The exceptions in this case, however, were only apparent. Thus, while some insects are less prolific than certain fish, it is exactly these insects that exhibit the greatest number of metamorphoses or possess the capacity for regeneration in the greatest degree. Similarly the least prolific amphibians, namely the lizards and snakes, are also the ones capable of achieving the largest body size. Also, according to Kielmeyer, the least prolific mammals and birds are exactly the ones that exhibit the greatest degree of difference in their sexual organs; species of insects and worms exhibiting unlimited growth and high capacity for regenerating damaged parts are also the ones in which sexual differentiation is either absent or in which both sexes are very similar. Kielmeyer was, however, willing to acknowledge certain exceptions to the operation of the law of the reproductive force, but he thought they could be clarified by determining the influence of the external medium in which the animal lives and also the effect of temperature on the reproductive force.[149] These considerations led finally to a reformulation of the law of the reproductive force:

The more so we find all the different modes of reproductive force united in a single organism, the sooner do we find sensibility excluded, and the sooner also does even irritability disappear.[150]

Having made a comparative study of the three most important forces in his original list, Kielmeyer turned to a consideration of their relations with respect to one another. The system implied by his preceding analysis is obviously a dynamic one. Taken together his three laws imply that in the series of organic forms, sensibility is gradually superceded by the reproductive force. Irritability too is finally superceded by the reproductive force, the increase in one of these forces being compensated by a decrease in one of the others. These are the *internal* forces giving rise to animal form and function, and while they do not operate independently of external forces such as the medium, temperature, etc., they are the only sources of animal structure. These forces alone, the same forces operating in every individual, give rise to the entire structure of the organic realm. This point, as we have seen, was essential to the Göttingen program, and it was especially emphasized by Kant: a purposive unity of forces must give rise to the organic realm. The same forces must operate at all levels of differentiation bringing forth families, species, races, varieties, and ultimately individuals. The individual carries in it the organic forces that differentiate it as a member of each of these higher collective unities. This differentiation cannot at all come about as a result of accidental external modification of inorganic nature. Rather the conditions for bringing forth specifically different types of organisms must always lie in those organisms themselves, in the purposive interrelation of the organic forces productive of organic bodies. External factors provide the conditions for expressing now one permissable expression of these forces and then another, but the true source of this manifold diversity lies in the internal forces of organization.

Fundamental to Kielmeyer's conception, therefore, a point he emphasized at the beginning of his lecture, is that the same set of forces united in every individual, though expressed in different degrees, are also the forces that give rise to the entire system of organic nature. This led to the major claim of the paper, and to Kielmeyer's greatest contribution to the Göttingen program; namely that the order in the appearance of these forces in the generation of an individual is the same as the order of appearance of these forces in the system of nature. Ontogeny recapitulates phylogeny:

The simplicity of these laws becomes evident, when one considers that the laws according to which the organic forces are distributed among the different forms of life are exactly the same laws according to which these forces are distributed amongst individuals of the same species and even within the same individuals in different developmental stages: even men and birds are plant-like in their earliest stages of development; the reproductive force is highly excited in them during this period; at a later period the irritable element emerges in the moist substance in which they live—according to experiments which I have made on chickens, geese, and ducks, even the heart is possessed of almost indestructable irritability during this period—and only later does one sense organ after another emerge appearing almost exactly in the order of their appearance from the lowest to the highest in the series of organized beings, and what previously was irritability develops in the end into the power of understanding, or at least into its immediate material organ.[151]

This principle—that the distribution of forces in the series of organized beings is the same as the division between different developmental states of the same individual—offers a means for constructing the system of nature. According to it the lowest classes are the ones in which the reproductive force is most pronounced. These we might call *Reproductivtieren.* Being characterized by a prolific reproductive and regenerative capacity, this class will contain among all other classes the greatest number of species. Included in this class will be the worms and insects. Similarly there will be *Irritabilitätstieren* and *Sensibilitätstieren,* these classes corresponding to the invertebrates, amphibians, mammals, and birds. Within these various classes of animals the same pattern will be repeated; animals possessing the greatest reproductive power will stand first (or lowest) and so forth.

An important aspect of Kielmeyer's theory is that in neither the lecture on the series of organic forces nor in any of his other lecture materials did he ever assert that the series of beings is linear, so that the ontogeny of man recapitulates the phylogeny of the entire animal kingdom. Although he never explicitly developed the system in detail, the evidence of his writings seems to suggest that he regarded each class of animal as having various interconnected sets of organs as the material expression of the system of forces grounding them. In the *Sensibilitätstiere,* for example, the sense organs were the predominant organizing principle of the class, although it is clear that being the highest class, all the organs of the other classes must also be available to them. These animals would then specialize in the development of one or more of the sense organs. There could be varying degrees of development of each of these organs. Due to the dynamic interrelation of all the organic forces, the particular preponderance of one (or more) sense organs would entail a corresponding functional arrangement as compensation among the other organs. The system resulting from this scheme would not be linear but rather radial in structure. At the core of the stem for each group must be imagined not an actual animal, but the specific purposive combination of organic forces (the five named above) containing *in potentia* all the organs and combinations of organs that will be developed by the different species of the group. Different species will correspond to the developmental grades of this primary functional unity. The series of forms developed will not be such that each developmental grade of a particular organ or closely related system of organs follows upon one another in a tight temporal series. Much more consonant with Kielmeyer's view that all animal forms limit one another is the notion that several different species of the same family develop simultaneously, each one representing a developmental grade specialized on a different organ system. Viewed in this manner, Kielmeyer's system is quite compatible with that sketched by Kant in the *Kritik der Urteilskraft,* but in it one can see rudimentary traces of ideas that would be developed more clearly and systematically later on by Karl Ernst von Baer.

At the end of his lecture of 1793 Kielmeyer entertained the idea that all of the organic forces he had discussed were in fact different manifestations of a single unitary force, a *Grundkraft.* Perhaps, he said, the entire machine of nature derives its motion from a single force originally awakened into action by light.[152] This was an idea similar to that proposed earlier by his teacher Georg Christoph Lichtenberg in a short paper written in 1778, entitled, "Über eine neue Methode, die Natur und die Bewegung der elektrischen Materie zu erforschen." But it was also an idea that would have a strong resonance in the mind of the young Schelling, who in nearby Tübingen was dreaming of the *Weltseele.*

Although Kielmeyer's lectures attempted to set forth a systematic theoretical account of the program designed to explore the physics of organization, he did not publish the results of any empirical research that actually implemented the program. There were others, however, who shared Kielmeyer's views, but who did attempt to realize the aims of the program through extensive empirical research. One such individual was Alexander von Humboldt.

Not only are all the theoretical and metaphysical components of what I have been describing as a Newtonian research program persistent themes in Humboldt's writings, but of all those who worked in this tradition Humboldt came closest to realizing its goals. The traces of Blumenbach's formative influence on Humboldt's research plans are evident in his first publication, *Aphorismi ex doctrina physiologiae chemicae plantarum* (1793). The physiological investigations that Humboldt set forth in his treatise were intended to reveal the laws governing the activity of the *Bildungstrieb.* The definition of vital force in terms of which the investigation proceeded bore unmistakable marks of Blumenbach's influence.

I call *Lebenskraft* that internal force which dissolves the bonds of chemical affinity and hinders the free interaction of the elements in the body. Thus there is no more certain sign of death than the decomposition through which the elements [*Urstoffe*] re-establish their previous rights and order themselves according to the laws of chemical affinity.[153]

Like Blumenbach, he pointed out that any theory of organic form required some special vital organizing principle. There was sound empirical evidence for assuming the existence of such an organizing force: Humboldt pointed out that of the thirty-seven known elements, only eighteen were to be found in organic bodies. More important, however, was the fact that these elements were found in combinations that human art was incapable of reproducing.[154] It appeared therefore that some vital principle was capable of overcoming the forces of chemical affinity and combining elements into specific organic forms.

Although Humboldt's principal objective in this treatise was to draw together the results of his chemical researches on plant physiology, indirect evidence in the work indicates that he envisioned the research as contributing to the construction of the natural system. The treatise, which appeared originally in Latin, was translated into German in 1794 at the bidding of Johann Hedwig, to whom Humboldt had dedicated the work. Hedwig had also worked on plant physiology. In the foreword composed by the German translator, we find an interesting linkage between Humboldt's physiological researches and the goal of constructing the natural system.

Although Linnaeus was in actuality more than a mere systematist, . . . his work has had a disadvantageous effect on the development of natural history [*Naturgeschichte*], in that for more than half a century, natural history has been investigated only with respect to problems of classification.

As a result the careful description of nature [*die Naturbeschreibung*] has been neglected and accordingly numerous aspects remain without application, which would otherwise open the prospect for connections between the various branches of science.[155]

Since Humboldt was consulted on the translation of his work from the Latin it is likely that the ideas expressed in the foreword reflected his own view of its importance. Independently of that point, however, it is clear that Hedwig, Christian Friedrich Ludwig, and Gotthelf Fisher, who collaborated on putting out the German edition, saw the work as providing the kind of research necessary for advancing the study of natural history. By investigating the effects of various gases, and the effects of light, electricity, and magnetism on plant physiology, Humboldt was providing a data base from which descriptive regularities regarding forms and functions of plant life could be derived. Through this effort a deeper insight into the *total habitus* of plant life would be obtained from which a natural classification would ultimately emerge.

Humboldt's commitment to the Newtonian research program extended into areas other than physiology. He was also concerned directly with problems of classification. This particular interest is evident in the early work, but it is most conspicuous in treatises composed after his expedition to South America. The *Ideen zu einer Physiognomik der Gewächse* in particular bears evidence of the concern for constructing an ideal typology characteristic of the tradition at Göttingen that we have been exploring. Humboldt writes in the *Ideen,* for example:

In spite of a certain freedom in the abnormal development of individual parts, the deepest [*urtiefste*] force of organization binds all animal and vegetable forms to fixed, eternally recurring types.[156]

Through comparative studies in the botanical gardens of Europe as well as through observations made during his expeditions, Humboldt had come to the conclusion that all genera and species of plants could be reduced to a small number of ideal types.

If one comprehends in a single glance the different phanerogamous varieties of plants which are already housed in herbaria and whose number is currently estimated to be more than 80,000, one recognizes in this amazing number certain primary forms to which most of the others can be reduced. . . . Sixteen such plant forms determine primarily the physiognomy of nature.[157]

Like Blumenbach, Humboldt regarded these ideal types as internal forces giving rise to the basic structure of organisms. It was his aim to find the laws in terms of which external factors diverted the activity of these internal forces, giving rise to the various classes of organized beings found in nature.

In the enormous cats of Africa and America, in the tiger, lion and jaguar, the form of one of our smallest domestic animals is repeated in a larger measure. If we penetrate the inner crust of the earth . . . we find a distribution of forms which not only no longer agrees with those of the present climatic zones: they also reveal colossal forms which hardly differ at all from those presently existing [except in size alone]. If the temperature of the earth has undergone considerable, perhaps periodically recurrent changes, if the relationships between sea and land, or even if the height of the atmosphere and its pressure has not always been constant; then the physiognomy of nature, the size and structure of organization itself, must have already been subjected to numerous changes.[158]

Just as in the works of Kielmeyer, one sees in Humboldt's writings the intention of constructing a dynamics of organic form. What he attempted was to construct mathematical regularities relating change in form with change in temperature, geographical distribution, and geological change.

Humboldt considered this work as partially accomplishing some of these ambitious ends, particularly in regard to the variables affecting plant distribution. He proposed a statistical method for studying plant distribution, a method that agreed with that proposed by Alfonse Candolle and Robert Brown, although he claimed to have hit upon the idea independently.[159] What he did was to find for any given zone, such as that between the fifty-fifth and sixtieth north parallels, the ratio between the number of natural families and the total number of phanerogamous species.[160] An alternative approach consisted in simply comparing the ratios of the absolute number of varieties of species belonging to each natural family in a given zone; but for the purpose of drawing general laws, Humboldt preferred the method of forming ratios with respect to the total number of phanerogamous species.

Humboldt's method for constructing the system of nature had two distinct quantitative components. On the one hand it involved the construction of an ideal typology based on comparative anatomical studies. Independent of that, however, was the statistical study of the distribution of plant forms and the numerical relations between genera and species in different geographical and thermal zones. Humboldt contrasted these two methods of investigation and the questions to which they gave rise in the following terms:

> The quantitative relationships of plant forms and the laws that are observed in their geographical distribution can be considered from two distinct aspects. If one considers the arrangement of plant forms according to natural families independently of their geographical distribution, one asks: what are the fundamental forms, the types of organization, that lie at the basis of the formation of the classes? What is the relationship between the monocotyledons and the dicotolydens? These are all questions of general phytology, the science which investigates the organization of plant life and the relationships between organisms presently existing.
>
> On the other hand, if one considers the classes of plants which have been united in terms of similarities in structure not according to the abstract method but rather in accordance with their distribution over the earth, a different set of questions emerges. One investigates then, what plant families are more dominant in the torrid zone than toward the polar circle. . . . Do the forms which cease to dominate in moving from the equator toward the poles follow the same law of decline as the pattern of dominance in the ascent of equatorial mountains?[161]

As we have seen, both of these methods, both the use of an ideal typology and the determination of the laws governing the *habitus,* were integral parts of the Göttingen program for natural history. Although Humboldt added new elements to Blumenbach's original formulation of the program, particularly in his use of statistical methods for studying plant distribution, these were not fundamental modifications of the research program as envisioned by Blumenbach and reflected in the works of Kielmeyer. There can be no doubt that Humboldt was deeply influenced by Candolle, LaPlace, Werner, Forster, and others, but what they provided were insights into means for bringing about a realization of the Newtonian research program for natural history that he had encountered as a student in Göttingen. This point emerges most clearly perhaps in the following passages from Humboldt's last and greatest work, *Kosmos,* in which he discussed the necessity of unifying the two methods mentioned above:

The systematically ordered register of all organic forms, which used to be designated splendidly by the term "natural system," offers an amazing linkage of form (structure) in accordance with internal principles. . . . not a linkage according to spatial grouping, viz. according to geographic zones, altitude, influences of temperature, etc., which affect the entire surface of the planet. But the highest goal of the physical observation of the earth [*physische Erdbetrachtung*] is . . . to grasp unity in multiplicity, to undertake research into the inner connection of terrestrial phenomena. Where particulars are mentioned [in this science] it is only in order to bring the laws of organic arrangement into agreement with the laws regulating geographical distribution. . . . The natural series of plant and animal structure is thus something given, as taken over from descriptive botany and zoology. The task of physical geography is to trace how quite different sorts of forms, although apparently dispersed randomly over the surface of the earth, stand nonetheless in a secret genetic relationship to one another [*in geheimnissvoller genetischer Beziehung zu einander stehen*].[162]

The science Humboldt sought to establish and which he called *physicalische Weltbeschreibung* was, like Kielmeyer's comparative "world" zoology, a dynamics of organized nature; it was a causal account of the interconnection between the structures in "static" taxonomic systems:

In grasping nature, Being is not to be distinguished absolutely from Becoming. . . . In this sense *Naturgeschichte* and *Naturbeschreibung* are not to be treated separately. The geologist cannot grasp the present without the past. Both interpenetrate and coalesce into one another . . . just as in the field of languages, the entire past process of language formation is reflected in the present. In the material world, however, this reflection [of the past] is even more apparent. . . . *Its form is its history.*[163]

In reflecting on the implications of this dynamic approach to organic form, Humboldt was led to the same conclusion, explicitly stated in the works of both Blumenbach and Kielmeyer: to wit, that the imbalances in the forces of nature have led to the destruction of whole groups of organisms and their replacement by others,[164] and that simple forms of the *Urwelt* have been divided up, "dissected" as it were, and spread out through time by the forces of the *Nachwelt.*[165]

In a footnote to his *Rede* of 1793 Kielmeyer mentioned that he was at work on a general theory of the organic realm in which the dynamic system he had outlined would be worked out in all its empirical details. The work never appeared. Had it been completed it would have undoubtedly borne strong resemblance to the six-volume work published by Gottfried Reinhold Treviranus entitled *Biologie: Oder Philosophie der lebenden Natur* (Göttingen, 1802-1822). This work was the crowning achievement of the transcendental Naturphilosophie developed by the Göttingen School. Gathering together the best empirical research of the day, Treviranus attempted to set forth the natural system in bold panorama. The structure of that system, the assumptions upon which it rested and the general view of the organic realm it espoused differed in almost no detail from that set forth by Kielmeyer in his magnificent lectures on the "Physik des Tierreichs."

The stated object of Treviranus' *Biologie* was to construct the natural system: to determine the conditions and laws under which the different forms and phenomena of life exist and their causes. The science that treats these matters was henceforth to be called "biology, or the theory of life."[166]

In order to set out upon the construction of this new science Treviranus argued that agreement must first be reached on a definition of life. Life must, according to him, be viewed as a structured *internal* activity giving rise to form, growth, and motion. While the source of this activity is an internal cause, it expresses itself only in relation to external phenomena; and accordingly every motion that it brings forth is necessarily a mechanical one.[167] The question arose, then: how is this activity to be distinguished from mere external, mechanical motion? After rejecting several proposals, among them those of Stahl and Alexander von Humboldt, which he regarded as too vitalistic, he settled upon a definition of life as consisting in the capacity to produce a continuity and an apparent necessary interconnection among phenomena while reacting to accidental influences originating in the external world, a definition close in content to that proposed by Kielmeyer in his *Rede.*

Treviranus grounded this concept of life in Kant's theory of matter. All matter must be thought of as the result of a momentary equilibrium among opposing forces. Kant had argued in his *Metaphysische Anfangsgründe der Naturlehre* that at the basis of the concept of matter must be thought the unity of an attractive and repulsive force. This approach made all matter self-limiting, the source of its structural boundaries being generated from within. Treviranus made an important modification of this Kantian theory, which had significant consequences for his understanding of the generation of organic form. He argued, by contrast with Kant, that a single type of *Grundkraft,* namely repulsive force, is sufficient. If one assumed a manifold of such independent centers of activity, the result would be the mutual self-limitation of these forces, the momentary equilibration of which could account for the same material phenomena Kant had sought to explain with two forces. Treviranus attributed this improvement in the Kantian theory to

Schelling, but Schelling was wrong, he argued, in postulating a single hyperphysical *Grundkraft* as the unity of these opposing forces: "Force" is that which stands at the limit of our capacity to inquire further into the appearances of material nature. Furthermore, "force" must be thought as something finite, according to both Kant and Treviranus. It is not possible to think of a force without also conceiving another force opposed to it. Therefore, while two opposing forces may indeed be united, it could not be a third, unopposed force that unites them. This third thing must, therefore, lie beyond the limits of a possible physical account. Schelling's *Weltseele* was, therefore, a metaphysical hypothesis having no place in natural science.[168]

These reflections on the construction of matter led Treviranus to two important conclusions. First that no change in the world is possible without disrupting the equilibrium of forces in some small neighborhood. With every expansion of one force must follow the contraction of another and vice versa; every chemical change must produce a mechanical change; similarly, mechanical rearrangements must lead to changes in all other forces such as electricity, magnetism, and light.[169] Every material system must, therefore, pass through an infinite series of changes, without ever returning exactly to the same point from which it started:

> The series of changes through which every material system passes must be so constructed that after several revolutions it returns nearly to a point where it had been previously without, however, ever returning to it exactly. Each material system is best represented therefore in the form of a spiral.[170]

We see here the theoretical foundations being laid for establishing a claim to be made later on that certain material systems, namely major groups of animals, including species, have been transformed into other genetically related forms as a result of continuously changing conditions in the external world. Also implicit in this position was the notion that since the system of material conditions never returns exactly to the same point, it is impossible to reconstruct through experiment the conditions that obtained when the present forms of life were being generated.

The second result of Treviranus' reflections on the construction of matter concerned the conception of organized matter directly. Since all the manifestations of the *Grundkräfte* were tightly interconnected, each was simultaneously cause and effect of the other, means and at the same time end. Nature, including inorganic nature, had, therefore, to be viewed as a single, unlimited organism.[171] The only difference between the inorganic and the organic realms was in the degree to which this mutual interdependence of cause and effect is evident. In the organic realm, moreover, the number, order, and interconnection of forces is much more finely tuned. Inorganic matter, according to Treviranus, is characterized by *actions*, and these can be exercised in relative independence of one another. The life of organized bodies on the other hand is determined by functions, i.e., closely interconnected actions such that each is at the same time cause and effect of the other. Because of this functional interdependence of forces in the organic realm, organic bodies are much less adaptable to changed conditions; the equilibrium of forces is much more easily disturbed. There are accordingly certain definite boundaries set by the functional interdependence of these forces beyond which it is impossible to go without destroying the life of the organism.[172] Moreover, in keeping with the force model set forth in the beginning, Treviranus assumed that, as functional unities of forces, every organism must be opposed by other limiting forms of life:[173]

> These forms are not otherwise intelligible than under the assumption that the different classes and orders of organized beings differ not only in degree, but also in their mode of receptivity for external influences and are capable of opposing these external influences with reactions of their own. This difference in receptivity and this reactive capacity, however, can only have its ground in a difference in form of organization. Accordingly, there are as many different types of organization as there are different forms of life. And to every form of life there must correspond a particular type of organization.[174]

Treviranus went on to argue that within the same type of organization the same principle must apply. There must be a mutual limitation of forms leading to a differentiation and gradation of different modes of the fundamental organizational unity of the class. In discussing Kant and Kielmeyer I have argued that a central notion of the Göttingen program was that all the different groups of related organisms in the natural system had to be conceived as related through the development of the adaptive potential of an original purposively organized ground plan. In these opening arguments of his *Biologie* Treviranus was seeking to provide a theoretical grounding for this model in his teleological reconstruction of matter.

Treviranus' conception of the *Lebenskraft* and the *Bildungstrieb* also places him in the direct line of ancestors of the Göttingen School. There are three ways of conceiving organic forces, he argued. According to the first system the vital force is a direct product of inorganic materials. This view was rejected, for it implied the possibility of an artificial production of organic substances, which Treviranus regarded as impossible. Furthermore, it seemed to him that for many inorganic elements, such as carbon and calcium, nature is dependent ultimately on organic bodies.

The second system held that the vital force is simply superimposed on inorganic materials, directing them into a purposive organization. This position was likewise swiftly rejected. If one assumed it, commitment was necessarily made to the view that organisms can under no circumstances bring forth forms different from themselves. According to this view, every organic form must only reproduce its own kind. Such a view could not explain, therefore, the source of interconnection among large families of existing forms, nor could it explain the apparent interconnection of forms throughout the history of the earth.

Since all matter must be conceived as organized in different degrees, according to Treviranus, it followed that there must be a sort of ground state of organization, a *vita minima,* from which all other higher forms of organic matter emerge.[175] Like Haller and Blumenbach, he assumed the existence of a basic organic *Grundstoff.* Treviranus himself related this notion directly to the work of Needham and Buffon, a point to which we will return later.

> Organic matter must in itself be formless but capable of receiving every form of life. By combining with inorganic materials it takes on a special form and structure. Moreover, this form of organization must be different according to the difference in these inorganic materials.[176]

Once again Treviranus was laying foundations in terms of which he could deal with the phenomena deemed central to the theory of organic nature by the Göttingen School. On the one hand organic materials could be dissolved into the materials of the inorganic realm, and physiological processes could be understood in terms of chemical and physical mechanisms. On the other hand, it was not possible through chemical and mechanical means to produce organic material artificially; some organic substance must always be present to act as a catalyst. In one fell swoop Treviranus proposed a materialistic model in which the teleological and mechanical frameworks were neatly linked. This accomplished, he attempted next to ground this conception of organic matter in empirical data and to extend it to the construction of the natural system.

In constructing the natural system two principles must be followed, according to Treviranus. From the preceding discussion we have seen that each type of organization in the organic realm demands its own particular *Mischung* or specific set of chemical constituents, which it joins to the *Grundstoff* of the organic realm; its own *Textur,* which Treviranus took to be the forms in which these chemical elements are united into organs; and *Struktur,* the overall anatomical arrangement of the organic parts and the specific external identifying characteristics. These latter two categories depended ultimately on the first, according to Treviranus, and hence the ultimate goal in biology was to press on in understanding the operations of organic chemistry well enough to be able to generate the structure and texture of organic bodies completely from their material constituents alone.[177] Such a science of biology would never be attainable by human reason, however. It would be an objective and constitutive science, which, as we have seen from our analysis of the Kantian foundations of the Göttingen program, was deemed unobtainable for us.[178] The science of biology must remain for us a teleological discipline: "In the classification of living organisms the rule must be followed: wherever the chemical mixtures are well known, to deduce the chief characteristics from these; but where these are not sufficiently well known, to take recourse first to the texture and only as a last resort to structure as a means of understanding the dependent characteristics."[179] This implied that it is not the general shape of the animal and the most striking structural resemblances that must be taken as the focal point of classification, but rather it is the *organs*, the internal elements of structure that must be taken as primary. This followed from the dynamic theory we have seen outlined both by Kielmeyer and by Treviranus in the opening sections of the *Biologie*. According to this theory, material systems were distinguished in degrees of complication by the number of points of contact they have with the external world (i.e. their sense organs and nervous system), by their ability to react to the impressions they receive (i.e. the organs of motion and respiration), and by their generative capacity (i.e. reproductive organs and digestive system). Related organisms specialize in differentiating in one or more directions these related systems of forces. Hence focusing on overall shape and similarity of structure rather than upon gradations in the relationship of these forms can result in the oversight of extremely important connections in the natural system.

Recognition of the teleological character of biology implied another extremely important principle. Unlike physics, it was impossible for the biologist to start with simple elements and their laws of interaction and deduce from these laws the shape and texture of nature. Not only because of the complex nature of organic beings, but also due to the different mode of causation employed in the organic world and the specific structure of human understanding, which is not suited to deal directly with that sort of causation, biological organization must be assumed as *given*. In our case, this turns out not to be a hindrance for constructing the natural system. We are capable of grasping the natural system because *we are living, organized beings*. This point cannot be discussed fully here, but it is so singularly important to the entire biology of the Romantic era that it should be noted with some care.[180] Since we are forced by the limited nature of our understanding to interpret nature by constructing a framework analogous to the sort of causation employed in human practical, technical decisions, it is necessary that the biological given we take as the model for the framework be *man himself*. In moments of scientific frivolity, Treviranus tells us, we might pretend that biology is a science that starts from the *Ursuppe* and builds organized bodies from the least to the most complex without reference to man; but in point of fact, for all the reasons we have discussed above in reference to Kant, this is simply impossible.[181] Man is and must remain for biology the model on which the natural system is to be built. As it turns out this is not a source for regret and condolence, because man belongs to the class of organisms, namely the vertebrates, that contains the most complicated organisms in the system of nature, and within that class man is the most complex organism. This is not a subjective judgment, it is an objective fact confirmed every day by experience. Man is the highest, most complex, and fully developed organism in nature. That might change, and indeed Kielmeyer, Treviranus, and the entire Göttingen School thought it would—that a revolution of the globe might bring forth a new set of organized beings. But the necessity of falling back on man as the model for the present system suffices. According to Treviranus, however, this could not be the case if man occupied a different position in the system. How do we know that the present system will not bring forth more complex animals? Kielmeyer provided the grounds for an answer. The productive period of our epoch is over; new species are no longer being generated. Man is currently in possession of the fullness of his being, capable of developing all his capacities. It is the Age of Enlightenment, the age when men are capable for the first time of acting in terms of ethical judgments that are the practical fulfillment of the principles of reason.

Having set forth the principles for constructing the system of nature within the teleological framework, Treviranus set to work on organizing the animal kingdom. Following Cuvier,[182] he divided the animal kingdom in two classes: red-blooded animals with an internal articulated skeleton, and white-blooded animals with either no skeleton, an articulated internal skeleton, or an external skeleton. It is instructive of the approach to biology being developed here to follow the construction of the first class, the red-blooded animals, within which Treviranus included the mammals, birds, amphibians, and fish.

Treviranus began by naming the organs all the animals in this class have in common. In addition to the characters already named, they all have a brain protected by an enclosed skull. "The brain is always divided in two halves; they all have a double optic lobe; a cerebellum; four ventricles, including a double frontal ventricle and two unpaired ventricles. . . . one almost always finds at least three types of sense organs, sight, hearing, and smell."[183] After inventorying the parts of the vertebrate brain, Treviranus went on to list the parts of the eyes and ears that all these animals have in common.

> The ears [for example] always have three semicircular bony or cartilaginous canals which likewise contain the same number of membraneous semicircular canals. These swell at the places where the acoustic nerves enter forming a sac-shaped hollow, which is always surrounded by and filled with labyrinth fluid. . . . The muscles in these animals are united by cellular tissue; the heart always lies beneath the brain and above the digestive and generative organs between the respiratory organs. The heart can have one or two chambers. . . .

The maxillary bone of these animals always lies horizontal, and always opens downward, by which motion a tongue is revealed. . . . The digestive tract always stretches from the mouth. All have a peritoneum which encloses the digestive organs and all have a liver. . . . most also have a spleen and a pancreas. . . . All have two kidneys, distinct sexes with two gonads in the male sex.[184]

These organs and the general plan of their organization formed the core of the vertebrate class. It is important to emphasize that for Treviranus, as for the others in the Göttingen School, this group of organs, partially listed above, was not a mere descriptive catalogue. As we have seen from the dynamic system discussed by Kielmeyer, these organs and their interrelations were thought to be the material expression of a group of closely interdependent vital forces. The purposive or *zweckmäßig* character of these forces led them to be expressed as organs and organ systems. These were the *zweckmäßig Keime* and *Analagen* [seeds=organs=Textur, and organ systems] upon which Kant had argued the dynamic theory of the natural system must rest. Accordingly, each of the different orders of the vertebrate class was envisioned as a functional differentiation of this fundamental unity. The different species of each family of animals was viewed as a different grade of this functional type, and so forth. In order to reconstruct the path of this process of differentiation and thereby the order of families, genera, and species within each group, it was imperative that the most fully developed, structurally complex species be taken as the model for the whole family: Thus for the mammals, man was the prototype:

We can regard man as the prototype in regard to the formation of the mammals. . . . It can be assumed that the shape of the human body can be transformed into that of the other mammals through the lengthening or shortening of the different parts. Thus the difference between the human skull and that of the other mammals consists only in that the latter are more oblate, and that the line drawn from the base of the nose to the foremost incisors (or the area where these teeth are located in man) is almost perpendicular to the plane in which the lower end of the teeth of the upper maxillary are found, while in the other mammals it makes a larger or smaller angle with this plane. Thus the angle is greatest in the elephants and the apes, least in the deer, dolphin and the anteaters, where it lies almost in the plane itself.[185]

Treviranus went on to note that, excluding the cervical ligament and tail, man has all the anatomical components of the other mammals, but each different group has developed some of these characters to a higher degree of specialization. The human brain, on the other hand, has many special characteristics lacking in the other animals of this class.

After completing a comparison among the various mammalian organ systems, Treviranus proceeded to determine the order among the various families of mammals according to their degree of divergence from man.[186] As a focal point indicative of other connected divergencies among organ systems; Treviranus chose the hand as the key to his ordering of the mammals. Thus the apes stood next to man as a separate family, then came animals with claws, namely the canines, the bats, which were the connecting link to the next family, the rodents, and finally the sloths. Each of these classes was also characterized by divergence from or complete lack of some characteristics found in man. Thus, in consideration of their pinnate members, the whales came next, their teeth and multiple stomachs placing them close to the sloths and rodents.

The hoofed animals followed. There were three different orders in this subclass: *Porci,* or *Schweine; Pecora* or *Rinde;* and *Equi,* or *Pferde,* these divisions being made according to the number of toes or clefts on the hoof. First in this class were the *Schweine,* or pigs, among which Treviranus included the rhinocerous, tapirs, elephants, hippopotomae, and the hogs. This was an extremely difficult class to organize, according to Treviranus. It has numerous anomolous genera closely linked neither to other genera within the order nor to genera of other orders. Such anomalies led Treviranus to remark that these forms almost appear as if they could be the remains [*Überbleibsel*] of forms that flourished in an earlier age of the earth and that were destroyed by a revolution of the globe.[187]

This was a significant observation, for it underscored a major difference between the biology of the Göttingen School and the evolutionary theory later to be developed by Darwin. The system envisioned here was conceived to be a causal theory of the natural system; and because it investigated the laws productive of animal form as the condition for establishing the natural system, it was regarded by its proponents as a *generative* theory. Now it was assumed that at the basis of each class lies a group of organs and particular modes for arranging them according to the same plan. The order in which these forms appear in the fossil record, however, need not reflect the natural order among individual species, but only of major functional groupings. It is extremely important to bear in mind that, for this theory, species were not the natural units upon which nature works. Species characters were the most external adaptive modification of the vital internal functional unity of forces lying at the basis of a major group. Species were part of the fine tuning that this functional unity made in adapting to external conditions. The purposive organization at the basis of any class of animals was assumed to provide the condition for its adaptation to a range of habitats, but the Göttingen biologists did not regard the prior existence of any one of those specific adaptive responses to be a necessary precondition for the development of another. This would have resulted in the total dependence of form upon the environment, a position they persistently denied. If the natural sequence of potential developmental grades of a stem were completely determined by the sequence of environments, and not by a set of organic laws providing the internal source of form and function, then there would be no need to assume a purposive organization in the first place, and certainly no need to ground classification on the laws of biological organization. It is not surprising, therefore, that Treviranus did not identify the *Porci* [*Schweine*] as the species *from which* the other higher mammals evolved, even though they together with the horses and oxen occupy the lowest developmental rank among the mammals in his scheme. For he did not argue that these species, which may indeed be the remnants of forms from a previous period of the earth, are in fact the physical ancestors of these higher forms.

A similar approach was followed by Treviranus in ordering the birds. He selected the ostrich as the archetype of this class. The reason for this choice, was that the ostrich is the closest link between the birds and the mammals, being most nearly connected, according to him, to the camel:

> It has more hair than feathers over most of its body; the long neck bends in the same manner as that of the camel; its thighs are thick and not muscular; its sinewy feet have only two toes, just like the camel; its wings are more like arms; its upper eyelids are mobile just as in the mammals, and it is provided with lashes, just as in man and the elephants. . . . the male has a penis which is much longer than that of the other birds and which is very similar to that of the mammals, and the female has a kind of clitoris. The ostrich forms the transition therefore, between the last two families of the mammals and the birds.[188]

When turning to the amphibians, however, Treviranus employed a different approach. In this class he did not select a single archetypical form to serve as the model for the rest of the class. Nor did he select the feet and toes as a clue to other relations. Instead he pointed to gradations in the complication of three different but ultimately closely interdependent organ systems: the heart and respiratory system, the acoustic organs, and the reproductive organs. The acoustic apparatus proceeds in a seriated gradation, he observed, from the turtles, where it possesses nearly the same degree of complexity as it has in the birds, to the frogs, where it is similar in structure and complication to the corresponding organ in the fish. A similar series is revealed with respect to the structure of the heart. This series, according to Treviranus, is the most significant with respect to the overall organization of the class, for "the differences in the structure of the acoustic organs and the reproductive organs as well as all the other organs and the reproductive system are parallel to the differences in the structure of the heart."[189] These considerations led him to two different orders of amphibians; namely those with either a double atrium and three ventricles or those with only a single atrium and ventricle.

Differences in several other characters led Treviranus to divide the first order once again into three classes, so that taken together the amphibians contained four orders; the turtles, lizards, snakes, and frogs.

After rounding out his ordering of the vertebrates with the classification of the fish, Treviranus went on to apply the principles of his new science of biology to arranging the invertebrates and plants. At the conclusion of these efforts, he re-emphasized the main points of his approach in addressing the question of whether there is a chain of beings from man to the infusorians and mosses. The answer, he said, is both yes and no. If single organs of a single organ system are considered in isolation, then nature offers the appearance of a single continuous chain; but there are many organs and hence "a thousand and even many thousands of chains which are woven together with infinite artistry into the tightest knots to constitute the whole of nature."[190] These "knots" are functional unities constituting a *zweckmäßige Grundform* at the basis of each class:

> In every family, in every genus, even in every species of living being nature develops some organ or system of organs principally, while she leaves some of the others unchanged and still others more simplified; and this articulation as well as the related simplification are normally the repetition of the same plan. [*Grundform*].[191]

Central to this whole conception of biology is the dynamic postulate stated by Kant and Blumenbach and developed by Kielmeyer: nature never increases the complication of any organ or organ system without diminishing in compensatory fashion the complexity of some other related organs. The source of dynamic and purposively organized forces lies within the organism itself. In order to understand the manner in which these internal principles of organization are expressed fully, however, it is necessary to consider their connection to the opposing forces of the external world in response to which they are capable of generating adaptive modifications. Treviranus turned to this theme in the second volume of the *Biologie.*

In discussing the relationship of organization to the external world, Treviranus began from a postulate which he went on to ground with a mountain of evidence, namely that the characteristics of classes, families, genera, and even species stand inseparably connected to the organization of the environment in which they live.[192] "A preference for this or that element is often the only factor wherein many families, genera, and species are distinguished."[193] Moreover, it is extremely important to note that the characteristics Treviranus had in mind were not simply morphological characters. He also regarded behavior and temperament as characteristics bearing upon the place of an animal in the economy of nature.[194]

The first half of his treatment consisted in a factual overview of what was known about the geographical distribution of plants, zoophytes, and animals. Several generalizations emerge repeatedly from his data. First he was struck by the dynamic interdependence of climate, habitat, and the forms of life that occupy them as well as the interdependence of these forms upon one another. Recorded history provided much evidence indicating that the local economy of nature has been changed by man. Through the cutting of forests, damming of streams and rivers, draining of bottom lands, etc, many animals had been displaced, some becoming nearly extinct and being replaced by others over the same geographical range. Man himself had, he noted, directly altered many animals through domestication. But man was not alone in possessing this power. What he has accomplished mirrors what nature herself has done through natural and gradual physical causation. Changes in climate, geological forces, and the relation of animals to one another result in parallel phenomena. But one rule that seemed to prevail among all these variations was that whenever the same external conditions are present, the same types and gradation of animals appear. Whether in the Alps or the Andes, wherever we find the same temperature, soil constitution, and general atmospheric conditions, the same kinds of animals are present. Whatever slight variations found in otherwise similar conditions were due ultimately to physical conditions, which could never be duplicated exactly.[195]

In discussing the internal organization of plants and animals above, we have seen that central to Treviranus' conception was the notion that the overall system of forms in each major group can be treated as a radial system branching out from a central stem to several knots, which form the center for a bundle of rays, which in turn branch out in all directions. Treviranus saw the relationship of organisms to their external environment as reflected in the distribution of forms as exactly parallel to this internal structure. The plant kingdom, for instance, "can be compared to a tree whose trunk is in the polar regions and whose branches are extended southwards over the earth, in that as they approach the limits of the southern temperate zones, they multiply and separate ever more from one another. In their first emergence many of these branches form smaller side-branches through which anastomoses are formed once again with the trunk."[196] The same proposition held for the animal kingdom: "It can be maintained with certainty that all these animals form a tree, just as in the plant kingdom, in which the multiplicity of genuses and species increases in a seriated fashion [*Stufenfolge*], which is only interrupted by local circumstances from the polar circles to the equator."[197] These two trees of plants and animals were not independent of one another, however; they stood related in a most wondrous harmony: "All land mammals, all birds and most of the amphibians, fish and insects are linked in their distribution almost completely to the distribution of the plants."[198]

A final important proposition related to Treviranus' use of the tree metaphor and its connection to the physical distribution of plants and animals was his conclusion that there are certain geographical centers for each genus, in the neighborhood of which the greatest number of species of that genus are to be found. Thus for the dicotyledons, there were eight such geographical centers.[199]

For the science of biology, as Treviranus defined it, it was not sufficient that a set of empirical generalizations be drawn from the data of natural history. Natural history must not only have its Kepler, it must also have its Newton. Biology was not *Naturbeschreibung;* its aim was to seek explanations, or following the usage most consistent with Kant's teleology, its aim was to provide *Erörterungen.* Ultimately it must seek to trace the grounds for these empirical generalizations back to the postulates of the dynamic theory of matter under the guidance of the principle of teleology. In the third section of his treatment of the distribution of plants and animals, therefore, Treviranus turned to the construction of a theoretical model for explaining these phenomena.

The principal thesis of Treviranus' work was that all living organisms are the product of physical forces, that the same forces that have produced different forms of life in different epochs are identical with those still in operation, and that the effect of these forces differs only in degree or direction as a result of external conditions.[200] This being the case it was required to seek some set of phenomena among the present activity of these forces which could provide a clue to understanding the gradation of forms and their interrelation. Fortunately, the solution lay immediately at hand. It was provided by the experiments on vegetable matter and infusorians of Priestly, Needham, Buffon, Wrisberg, Müller, Ingenhouss, and (in spite of himself) Spallanzani.

The details of the controversies surrounding Needham's infusorians are well enough known not to require discussion here.[201] Some of the highlights that found such strong resonance within the Göttingen School and in the work of Treviranus in particular are worthy of attention, however. The discussion of Needham's experiments always occupied a central position in Blumenbach's works, particularly in his work *Über den Bildungstrieb.* It is probably not insignificant that Kielmeyer was promoted to his position at the University of Tübingen with a treatise entitled "Observationes quaedam ad investigandum ortum animalculorum infusionum."

Needham's conviction that spontaneous generation could not be effected from an artificial synthesis of inorganic materials in the absence of organic matter or an organizing principle, such as heat or light, was well suited to Treviranus' purposes.[202] This principle was further confirmed by experiments done by Wrisberg. In Priestly's vegetable substance, the *grüne Materie,* Treviranus saw that formless organic matter capable of generating all forms in connection with the external influence of the environment that was so central to his whole conception of organic nature.

Almost paradigmatic for his explanation of the relation between form and environment were Needham's infusions with wheat kernels. The kernels gradually degraded into a kind of gelatin [*Gallert*] with numerous fibres. After a while these began to move, transforming into veritable plant-like zoophytes. In the next stage small movable particles of a different shape were seen to emerge from this first generation. These latter ceased to move after a few days. They then united into a large mass from which new spherical shaped zoophytes emerged.[203] Herein Treviranus saw a beautiful confirmation of his definition of life as a phenomenon expressed by the mutual interaction of vital and physical forces; for only from this definition, he had argued, could it be possible to understand how one species of animal can give rise not only to members of its own kind, but transform into other different forms when altered conditions no longer favor its preservation.

Wrisberg's observations gave even more exciting evidence of such transformations. In his "Observationes de animalculis infusioriis satura" Wrisberg had observed that vegetable or animal infusions containing neither acids nor anything that would hinder fermentation would, shortly after the first appearance of air-bubbles, contain a multitude of tiny circular objects that would after a while become enclosed by a thin membrane. These tiny molecules were the building blocks of all plants and animals. They differed in no major appearance from the smallest infusorians, except in their inability to move, and the lowest grade of infusorians emerge directly from them. In infusions where these molecules did not develop, infusorians did not emerge either. Once one of these tiny molecules had become mobile, it united with others to form a larger animal. These in turn united to form larger infusorians. Often a small section would separate from one of these and move off independently. Wrisberg observed that the presence of these larger organisms always followed upon the presence of the smaller, less complex ones. Equally important from Treviranus' perspective, Wrisberg had noted that his populations of infusorians limited one another and replaced one another in cyclical fashion. In an infusion of fly larvae he observed first the molecules, then formations of small animals of very simple structure; then came some with a fish-like appearance, others oval in shape, and still others he identified as polyps. The fish-shaped infusoria and polyps underwent a period of decline that was directly associated with a decline in the population of the smallest infusoria. After these latter had all but disappeared, the whole process started up again, first with an increase in the smallest infusoria, followed by the fish-shaped ones, and finally by the polyps.[204]

The importance of these observations for the foundation of his theory led Treviranus to set up experiments of his own with infusoria, which he reported at great length. He found the observations of Needham and Wrisberg fully confirmed by his own. He too saw a successive series of ever more complex infusoria being constructed out of an original set of spherical molecules. In one experiment he saw a single large spherical-shaped infusorian divide in two, both parts of which continued to move independently. Likewise he saw the interdependence of forms and alternate contraction and expansion of populations of paramecia, rotifers, and vorticells. In one experiment the "epoch of the paramecia lasted only about ten days."[205]

All of these considerations on infusorians emboldened Treviranus to make a major conceptual leap. The major thesis of his earlier investigation of the internal principles of organization had been that each new division of animals consists in an addition in the kinds of organs constituting the animal accompanied by a corresponding increase in potential complexity and in the number of contacts with the external world.[206] As we have just seen, Treviranus thought this same pattern could be seen being repeated directly on a small scale in the experiments with infusoria. The tiny molecules were the first "organs"; combinations of these led to a differentiation in kind and complexity in a succession of organisms:

> Supported by the analogy with the zoophytes, plants and lower classes of animals, therefore, we may assume that the *Urformen* of the mammals and birds were once generated in that same manner in which now only the zoophytes are still formed.[207]

The justification for making this analogical leap of faith rested on the assumption of the continuity in the operation of natural forces. In countering the objection that nothing directly comparable to the construction of such complex forms as birds and mammals is observable in the present operation of these forces, Treviranus called upon the dynamic theory of the epochs of the earth developed by Kielmeyer:

> It cannot be objected that a similar generation of higher classes ought to be observable if this theory were true. For what occurred in that period when the system of nature was coming into being can never happen again once it has already achieved its organization.[208]

In concluding this discussion Treviranus drew attention to the fact that the theory of organic nature he had developed in the second volume was not original with him. It was really the theory first proposed by Buffon and Needham, but which they were unable to develop consistently. Like his own theory, theirs rested upon two postulates: first, that a single organic substance is the material basis of the entire organic realm, and that this matter is capable of receiving any form; second, that nature has certain formal principles, *innerliche Formen* or *moules intérieurs* by means of which this organic matter is structured from within. But each of these forms could only retain its particular structure so long as external influences remained constant.

Through continuous action of gradually and only slightly modified circumstances, these organisms could take on a new form. This new form was, so to speak, the result of the new equilibrium established between the internal system of forces constituting the animal and those forces in the external environment.[209]

In the last few pages of the second volume, Treviranus provided an overview of the essential external influences that affect the form and distribution of plants and animals. The empirical evidence for these factors was explored in great detail in the third volume of the *Biologie.* They were the same factors to which Blumenbach had first called attention in his small treatise on the *Bildungstreib* and in his book, *Beyträge zur Naturgeschichte:* slight changes in the chemical constitution of the soil, air, water, etc., can ultimately effect changes in the sources of nutrition and eventually in the constitution of the generative fluids; when sufficient numbers of individuals are thus affected over long periods of time, a modification of form can result. The reason for these changes was that inorganic matter could enter into chemical combination with the basic *Urstoff* of organic matter, generating thereby the material potential for structurally more complex forms of organization. The specific manner in which these forms were organized depended upon a) the internal organization of the organic (vital) forces already present in the organism, the internal forces that account for generation, growth, and nutrition, and b) the forces of the external environment that either permit these internal forces free reign to develop in a particular direction or throw up some hindrance to such a development. The model for this theory, we have seen, was provided by Blumenbach's *Knochenlehre* and by Haller's work on tissue formation. Finally, among the material external factors of change mentioned above, Treviranus placed great emphasis on another that both Kielmeyer and Humboldt thought to be extremely important: temperature. An empirical generalization he drew from his investigations on this subject was that "the multiplicity of types, number and the size of organic beings stands in direct proportion to the gradation of temperature."[210]

From all of these postulates and the empirical data he had assembled to support them, Treviranus drew two conclusions that express in capsule form the philosophy of nature of the Göttingen School:

From these postulates the original products of organic nature can be explained. With the emergence of these first products, however, new forces were awakened which influenced the formation of the following generations. Foremost among these [forces], however, is to be included the dynamic effect which every organism has on the rest of nature.[211]

We believe that encrinites, pentacrinites and zoophytes of the prehistoric world are the original forms from which all the organisms of the higher classes have come into being through gradual evolution [*Entwicklung*]. . . . And it appears to us to follow that, contrary to what is commonly said, the animals of the prehistoric world were not destroyed by great catastrophes; rather many of these forms have survived, but they have disappeared from nature because the species to which they belong have been transformed into other species [*in andere Gattungen übergegangen sind*].[212]

Conclusion

With the *Biologie* of Treviranus the transcendental biology of the Göttingen School had concluded its formative period. In that work he had succeeded in pulling together all the various aspects of the program that had been under intense discussion since 1790, the individual elements of which can be traced back to discussions beginning in 1750 with the translation of Buffon's *Histoire naturelle.* Treviranus synthesized these conceptual elements into what he described as the dynamic theory of organic nature, which he attempted to ground in an incredible encyclopedic overview of biological research since the mid-eighteenth century. In this study I have attempted to reassemble those various elements by following their genesis and ultimate integration in the work of Treviranus and his efforts to found a new science, which he called "Biology."

The Göttingen program was merely coming into being during the period discussed here, however. It continued to be developed after Treviranus' epoch-making work, and indeed it was the principal framework of biological research in Germany well into the nineteenth century. A thorough understanding of the Göttingen program provides a background against which we can interpret some key conceptual elements of early nineteenth-century biology and in terms of which some of the major threads of empirical research in German biology become consistently interrelated. In concluding this study I would like to call attention to some directions in which the program was developed after 1803, the date of publication of the second volume of Treviranus' *Biologie.* Three areas of research stand out as having an especially significant role for carrying through to completion the program we have seen outlined here: sensory physiology, embryology, and the construction of general laws for the geographical distribution of forms.

Central to the theory of organization developed in the Göttingen program, especially the formulation given to it by Kielmeyer, was an understanding of the laws governing the "number of contacts" an organism has with its environment. For this problem research in sensory physiology became absolutely essential. Certainly the general emphasis on subjective experience during the Romantic era helped to make this research more fashionable, even providing princes, universities, and governments with motivation for funding it;

but research in this domain was clearly envisioned as essential to understanding the organization of nature as a whole. This point was made clear by Rudolphi in 1810.[213]

In a paper delivered before the Berlin Academy, Rudolphi claimed that while the external forms of organisms are modeled in large part in accordance with the external conditions of their environment, so that "species, genera, families, and perhaps even orders can be identified by external characters, classes can only be identified by internal principles of organization."[214] Rudolphi insisted that a system based on the internal principles of the entire organization of the animal ought to be the goal of physiology, but one system in particular serves as a key to that organizational plan: the nervous system. In a very important discussion of this problem, which has been overlooked by most historians, he came to the conclusion that there are four basic plans of neural organization in the animal kingdom and that while generative series can be constructed within each of these classes, there is no possibility of transforming one plan into another.[215]

It is within the framework of the Göttingen program that much of Johannes Müller's research in sensory physiology is to be understood, although he was certainly also deeply influenced by Goethe. Müller's theory of specific sense energies, however, has direct roots in Kielmeyer's dynamic theory of vital forces and especially in the conception of an "organ" so central to Kielmeyer's *Rede.* An "organ" for Kielmeyer was the material expression of a dynamic interaction of a purposively organized set of forces. The material constitution of an organ permitted it to have a graded variety of specific adaptive responses to external stimuli. Moreover an organ possessed its own internal activity. Its functional operation was not just a passive response to external stimuli but rather an active engagement with the external world occasioned by external impulses. In accordance with this view, the "appearances" generated in this interaction were completely conditioned by the internal structure and functional character of the organ itself. This very idea was explored in the context of sensory physiology in 1795 by Sömmering in a treatise called *Über das Organ der Seele,* a book, incidentally, that was dedicated to Kant and which Kant acknowledged as in fundamental agreement with his own views.[216] But this conception is also in fundamental agreement in almost every particular with the theory later developed by Müller on the specific sense energies.

A second area of research clearly indicated as central to the concerns of the Göttingen program is embryology. That embryology might offer a key to understanding the laws of purposive organization in nature was central to Blumenbach's thought. We have seen in the work of Kielmeyer an explicit statement of the importance of embryology in this regard and an intimation of the view that ontogeny recapitulates phylogeny. This idea was taken up and explored directly by another Blumenbach student, Johann Friedrich Meckel.[217] Von Baer's embryological work can also be seen in the framework of the Göttingen program. Several aspects of his work bear the marks of the system we have treated here. Foremost among these is the emphasis he placed on developmental plans of internal organization grounded in a *zweckmäßig* set of interconnected forces. His notion of different grades of expression of these structural forces and his related idea of a radial scheme of classification as corresponding to the natural system bears very strong resemblance to ideas we have seen treated by Kielmeyer and Treviranus.

Another area of research the Göttingen School perceived as central to its aims was the external laws governing the distribution of animal and plant forms. We have seen this as a principal theme in the work of Kielmeyer, Treviranus, and Humboldt. It was also regarded by Rudolphi to be an absolutely critical problem demanding research.[218] Contributions toward this aspect of the theory were made by this first generation of practioners of the Göttingen program, but the success of the Göttingen School in attacking this problem was best exemplified by the work of the Göttingen physiologist Carl Bergmann in his formulation of the rule relating size, distribution, and temperature.[219]

Our understanding of the biological theories of the Romantic period will not be complete until we come to grips ultimately with the traditions of speculative and metaphysical *Naturphilosophie.* It is my thesis that before this—in many ways much more difficult—task can be attempted it is first necessary to understand the biological tradition of transcendental *Naturphilosophie.* I am convinced that a careful reading of Schelling, Hegel, and even Ritter, Oken, and Carus will reveal that for almost the entirety of the empirical research upon which they based their approach to nature, these men were dependent upon research emanating from Göttingen. These other biological traditions attempted to go beyond the program of the Göttingen biologists to treat problems that were inaccessable with the approach of transcendental *Naturphilosophie,* particularly in the realm of social life.

Goethe's connections to Göttingen biologists, and to Blumenbach and Humboldt in particular, have been well established.[220] Through careful reading of Schelling's early works on *Naturphilosophie* in conjunction with the critical edition of his correspondence provided in the excellent edition of Horst Fuhrmanns, it is possible to show that while in Leipzig, in the period during which he devoted himself almost exclusively to acquiring background in natural science, Schelling concentrated on the works of the Göttingen School, particularly Lichtenberg, Blumenbach, and Kielmeyer. Through direct personal contact with C. H. Pfaff and Eschenmaier, Schelling gained an in depth knowledge of Kielmeyer's "Physik des Tierreichs."[221] Hegel's *Naturphilosophie* is equally indebted to the Göttingen School. Having, after 1806, rejected Schelling's increasingly speculative approach to nature as "the night in which all cows are black," he turned principally to Treviranus' *Biologie* for the biological sections of his own *Naturphilosophie.*

In addition to these personal ties and indebtedness to the Göttingen School for much scientific material, there were other intellectual ties between transcendental *Naturphilosophie* and speculative theories of nature. The concepts of *Einheit, Stufenfolge, Polarität, Metamorphose, Urtyp,* and *Analogie* have been described as distinguishing characteristic elements of this approach to nature.[222] We can see strong family resemblances to some of these ideas in the work of the Göttingen School. The notion of ideal types, for instance, was central to Göttingen thought on comparative anatomy. Similarly, in the work of Kielmeyer the dynamic interaction of vital forces, the expansion of one and the corresponding contraction of others, bears strong similarity to Schelling's notion of polarity, as well as the use made of that notion in the work of Nees von Essenbeck and Oken. The concept of metamorphosis central to speculative thought is closely parallel to the modification of an original ground plan that we have seen developed in the work of the Göttingen biologists. Finally, we have seen in Treviranus' discussion of the analogy between the infusoria and the phenomena connected with the emergence of all forms of life an example of the use of the concept of *Analogie* not at all unlike that found in the speculative tradition.

It would be a mistake to regard these approaches to nature as one and the same, however. There are indeed strong similarities in key concepts of these approaches, but there are major differences in both the interpretation and significance of these concepts within the transcendental and speculative schools. It is most important to realize that the transcendental approach worked hard at remaining consistent with Kant's philosophy of organic nature. The starting point for Schelling, Hegel, and Goethe, on the other hand, was made precisely in the conscious attempt to transcend the viewpoint of practical philosophy (i.e., moral and political philosophy) implied by Kant's critique of teleological judgment. The philosophical solution they worked out led them to construct a theory of nature that was much closer in the spirit of its conceptual foundations to the aesthetic conception of Buffon, namely, the approach the Göttingen School sought to avoid through strict adherence to empirical methodological canons. This preference for the aesthetic solution to the problems of the philosophy of biology can be seen reflected in the different notion of the *Urtyp* in the works of Oken, Goethe, and Carus. They seek to transform a particular shape or structure into a related set of forms. The Göttingen School, by contrast, emphasized the notion of a plan of functional organization. Their type, which they designated by the term *Grundform,* might be more appropriately labeled a "physiological type." Furthermore, it is important to note that Oken and Carus, for example, sought to construct a purely *deductive* and constitutive theory of organic nature, a theory that they grounded on a single unified force in nature. As we have seen in our discussion of both Kant and Treviranus, both of these aspects were considered by the Göttingen School to be a hyperphysical and illegitimate use of the principle of teleology. Schelling, too, emphasized the need for deducing all of nature from a single unity. Only in this way could the problem of distinguishing a collection of stones from a genuinely organized body encountered in Kant's theory of teleology be overcome. An organized body had to be constructed by differentiation of a single unity. The parts of this whole would not then be a collection of atomic organs held together somehow by the opposing force of an external nature; rather each part would only exist and have its life in the whole. In order to bring about the structural differentiation of nature Schelling argued that an original tension must exist in an originally homogeneous infinite material substrate, and that this tension must manifest itself as polarity, thereby providing the internal source for a structurally differentiated unity. Consonant with this view many speculative biologists, such as Oken, Goldfuß, and Carus, for example, made a direct analogy between nature as a whole and the mammalian ovum. This was not fashionable among Göttingen biologists, however, even though they too were committed strongly to an epigenetic theory of development. Thus Treviranus emphasized that the original organic matter was broken up into small organic spherelets, and that these became the building blocks for larger and more complex animals. He expressly denied that the unity of forces in nature could ever be grounded in a single unifying active principle. His definition of life always assumed the awakening of internal potential for reaction by means of an external nature.

In order to understand the philosophical issues behind the speculative tradition of biology more fully a trail will have to be blazed through some difficult passages in Schelling's early works, through Fichte's *Wissenschaftslehre* and through Hegel's *Logik*. We have seen that according to Kant the special nature of causal relations in the organic realm and the discursive nature of human understanding require that biology rest on regulative teleological principles. If one were to deny that thesis, however, as Hegel and Schelling did, and assert that the principle of teleological judgment can be *constitutive*, then in order to carry through the program of biological science consistent with this assumption, a new logic would have to be constructed, one in which constitutive determinate judgments can be rendered of objects that are both causes and effects of themselves. It was need of such a form of logic that could handle the special issues of organic casuality that led Schelling to attribute such a significance to polarity within his theory of organic nature, and it was this problem equally that led Hegel to formulate his own dialectical form of logic. Focusing on the special requirements of the theory of causality in biology will reveal the reason for the significance of other concepts in Romantic *Naturphilosophie,* such as *Urtyp, Stufenfolge,* etc., and it will reveal the structural interrelation of these concepts in a system of nature.[223]

In my view, however, it will be necessary ultimately to look beyond the substantive issues of these philosophical disputes to understand more fully the motivations of natural philosophers for preferring one over the other of these related approaches to biology in the Romantic era. In closing I will suggest one avenue for understanding this problem within a broader cultural perspective.

A thesis that has been widely accepted among German political historians is that the major political movements of the nineteenth century trace their source to a common fund of ideas in late Enlightenment thought. An exactly parallel phenomenon is evident in German biology. The main tenets of German liberal-conservatism, the view of society and the structure of the state to which they led, are reflected in and strongly supported by the view of nature developed by the Kantian school of biologists at Göttingen. The fact that the Göttingen legal faculty was a major center of liberal conservatism, particularly modeled after the English, may be indicative of the mutual support these two lines of thought were capable of lending one another; they were different aspects of the same world view. Similarly the biological theories of the metaphysical *Naturphilosophen* provided ample support for the conservative political ideology of the German Idealists and Romantics. In fact we can see from the first program statement of German idealism formulated by Schelling, Hegel, and Hölderlin, as well as from Hegel's early treatise on natural law that the originators of the speculative/metaphysical approach fashioned their view of organic nature much more consciously than did the Göttingen biologists in terms of a definite picture of certain social and political ends that they hoped to realize. The principle elements of the Volkish Ideology, which underpinned conservative culture throughout the nineteenth century,[224] are present in the biological theories of the Idealists; and the fact that Hegel was one of the major theoreticians of both conservative political theory and the Romantic-Idealist conception of nature cannot fail to alert us to the mutual affinity of these two aspects of German intellectual culture in the early nineteenth century.

Preference for one of these styles of *Naturphilosophie* rather than another, which differed more in terms of organizational emphases than in terms of empirical content, may reflect the response of German intellectuals to the main events affecting German society and culture at the turn of the century. Germany during the 1790s was entering a period of deep social and cultural crisis. The bonds of the feudal world were undergoing rapid dissolution, but within this general ferment, the outlines of the new world were not yet clearly visible. What was clear was that a return to the old world was impossible;

the effects in Germany of the French Revolution, the Napoleonic occupation, and the collapse of the Holy Roman Empire had permanently shut that door. While shouldering the burden of being thrust into the future, albeit in most cases with some reluctance, German intellectuals asked themselves whether it was necessary to sever completely the concrete ties to the past and rush forward headlong without any apparent direction, as the French had seemed to do, or whether it might be possible to preserve elements of the past, weaving them rationally into the fabric of a new state that might more appropriately realize the cultural aims of genuine freedom, morality, and the recognition of human dignity, which had been aborted in the misguided results of the Revolution.

These were the primary problems confronting German intellectuals in their daily lives; it simply was not possible to escape considering them. Various visions of how best to solve them and the practical implications for implementation of these solutions through political, social, economic, and educational reform provided the overarching framework of discourse, the set of socio-cultural givens within which other concerns took their meaning and orientation. Foremost among these was natural science, and the nascent life sciences in particular, for they purported to provide insight into man's place in nature and his ability to know and shape it. As heirs of the Enlightenment these men could not avoid the issue of whether nature was constituted in a manner consistent with the realization of human freedom and what the laws of nature, particularly the laws of organic nature, had to say about the organization of the state structured toward that end. It is not surprising, therefore, that the different styles of natural philosophy during the period 1790–1830, the differing views of nature and the organic realm, reflect in large measure the different political orientations of the period, for the sciences provided part of the rationale for constructing a particular vision of the future.

NOTES

1. C. C. Gillispie, *The Edge of Objectivity* (Princeton: Princeton University Press, 1960), p. 197.

2. Discoveries potentially attributable to the influence of Naturphilosophie have been electrochemistry (Ritter), electromagnetism (Oersted, Faraday), and the conservation of energy (Mayer, Helmholtz). On these problems see the following: Friedrich Klemm and Armin Hermann, eds., *Briefe eines romantischen Physikers* (Munich, 1966), p. 9, n. 2; Armin Hermann, "Das wissenschaftliche Weltbild Lichtenbergs," in *Aufklärung über Lichtenberg*, ed. Wolfgang Promies (Göttingen: Vandenhoeck and Ruprecht, 1974), p. 55; Walter D. Wetzels, *Johann Wilhelm Ritter: Physik im Wirkungsfeld der Deutschen Romantik* (Berlin-New York: De Gruyter, 1973), p. 25; R. C. Stauffer, "Speculation and Experiment in the Background of Oersted's Discovery of Electromagnetism," *Isis* 48 (1957): 33–50; L. Pearce Williams, *Michael Faraday* (New York: Basic Books, 1966), pp. 138 ff; T. S. Kuhn, "Energy Conservation as an Example of Simultaneous Discovery," in *Critical Problems in the History of Science*, ed. M. Clagett (Madison: University

of Wisconsin Press, 1955), pp. 321–56; Yehuda Elkana, *The Discovery of the Conservation of Energy* (Cambridge: Cambridge University Press, 1974), pp. 171–72, n. 31; Everett Mendelsohn, "Revolution and Reduction: The Sociology and Methodological and Philosophical Concerns in Nineteenth-Century Biology," in *The Interaction between Science and Philosophy*, ed. Yehuda Elkana (Atlantic Highlands, N.J.: Humanities Press, 1974), p. 419; Reinhard Löw, "The Progress of Organic Chemistry during the Period of German Romantic Naturphilosophie (1795–1825)," *Ambix* 27 (1980): 1–10. Löw has established the importance of Naturphilosophie for the development of structural chemistry; W. Riese, "The Impact of Romanticism on Experimental Method," *Studies in Romanticism* 2 (1962): 11–22.

3. Shmuel Sambursky, "Hegel's Philosophy of Nature," in Elkana, ed., *Interaction between Science and Philosophy*, p. 153.

4. For Novalis see Martin Dyck, *Novalis and Mathematics* (Chapel Hill: University of North Carolina Press, 1960); Kate Hamburger, "Novalis und die Mathematik; eine Studie zur Erkenntnistheorie der Romantik," *Romantik-Forschungen* (Hall, 1929), vol. 16; John Neubauer, *Bifocal Vision* (Chapel Hill: University of North Carolina Press, 1971).

On Goethe see H. Bräuning-Oktavio, "Vom Zwischenkieferknochen zur Idee des Typus. Goethe als Naturforscher in den Jahren 1780–1786," *Nova Acta Leopoldina*, N.F. Nr. 126, vol. 18; Andreas Wachsmuth, *Geeinte Zwienatur* (Berlin, Weimar, 1966); H. B. Nisbet, *Goethe and the Scientific Tradition* (London, 1972).

On Oken and Carus see Rudolph Zaunick, "Oken, Carus, Goethe. Zur Geschichte des Gedankens der Wirbelmetamorphose," *Historische Studien und Skizzen zu Natur und Heilwissenschaft* (Berlin, 1930).

5. See especially Dietrich von Engelhart, *Hegel und die Chemie* (Wiesbaden: Guido Pressler, 1976). Also relevant is D. M. Knight, "The Physical Sciences and the Romantic Movement," *History of Science* 9 (1970): 54–75.

6. See Dietrich von Engelhart, "Naturphilosophie im Urteil der 'Heidelberger Jahrbücher der Literatur': 1808–1832," *Heidelberger Jahrbücher* 19 (1975): 35–82. For an interesting negative critique of Schelling Naturphilosophie see Kielmeyer's (anonymous) review in the *Tübinger Anzeigen* (Spring 1798). Other interesting critical reviews appeared in the *Allgemeine Literatur Zeitung* 4 (1799).

7. Thus Schelling could (mistakenly) argue that the approach to biology outlined by Kielmeyer in his famous lecture, "Über die Verhältnisse der organischen Krafte untereinander in der Reihe der verschiedenen Organisationen," (1793), was completely compatible with the system discussed in his own work, *Von der Weltseele*. See Schelling *Werke*, vol. 2 (1857), p. 565.

8. Kant, "Prolegomena zu einer jeden künftigen Metaphysik die als Wissenschaft wird auftretten können (1783)," *Werke*, vol. 4 (Berlin, 1903), p. 297.

9. Hegel, *Philosophy of Nature* (Oxford: Clarendon Press, 1970), tr. A. V. Miller, p. 37, section 246.

10. Reinhard Löw, *Die Planzenchemie zwischen Lavoisier und Liebig* (Munich: Donau Verlag, 1977); Reinhard Löw, *Die Philosophie des Lebendigen: Der Begriff des Organischen bei Kant, sein Grund und seine Aktualität* (Munich: Suhrkamp, 1980); see Dietrich von Engelhardt, *Hegel und die Chemie* (Wiesbaden: Guido Pressler Verlag, 1976). Also of interest is Peter Kaptza, *Die frühromantische Theorie der Mischung: Über den Zusammenhang von romantischer Dichtungstheorie und Zeitgenossischer Chemie* (Munich: Max Hueber Verlag, 1968). Kapitza makes the point that Romanticism not only affected the way the Naturphilosophen viewed chemistry but conversely that chemical theories of affinity also had a formative influence on the content of Romanticism itself. This is a marvelous study, which has received far too little attention in the literature; H.A.M. Snelders, "Romanticism and Naturphilosophie and the Inorganic Natural Sci-

ences 1797–1840: An Introductory Survey," *Studies in Romanticism* 9 (1970): 193–215; H.A.M. Snelders, "De outvangst van Kant bij enige Nederlandse Natuurwetenschaps beoefenaars omstreeks 1800," *Scientiarum Historia* 12 (1970): 22–38.

11. See Nelly Tsouyopoulos, "Die neue Auffassung der klinischen Medizin als Wissenschaft unter dem Einfluss der Philosophie im frühen 19. Jahrhundert," *Berichte zur Wissenschaftsgeschichte* 1 (1978): 87–100.

12. Georg Gruber, *Naturwissenschaftliche und medizinische Einrichtungen der jungen Georg-August-Universität zu Göttingen* (Berlin, 1955), p. 7.

13. Quoted from Johannes Joachim, Die Anfänge der Königlichen Societät der Wissenschaften zu Göttingen," *Abhandlungen der Gesellschaft der Wissenschaften zu Göttingen,* Philosophisch-Historische Classe, Dritte Folge, Nr. 19 (1936), 4.

The view being defended here that at Göttingen an interest in pure science was developing during the late eighteenth century differs sharply from the interpretation offered by R. Steven Turner, who places the development somewhat later. See R. Steven Turner, "The Growth of Professorial Research in Prussia, 1818 to 1848–Causes and Context," *Historical Studies in the Physical Sciences* (Baltimore: The Johns Hopkins University Press, 1972), 3, especially pp. 146–47 for Göttingen.

14. On this point see the excellent discussion in Roger Hahn, *The Anatomy of a Scientific Institution: The Paris Academy of Sciences 1666–1803* (Berkeley: University of California Press, 1971).

15. Extensive documentation for this point is provided in Johannes Joachim, loc. cit., fn. 1 above.

16. See Johan Stephan Pütter, *Versuch einer gelehrten akademischen Geschichte der Georg-August-Universität zu Göttingen,* I (Göttingen, 1765). A similar interest in theoretical matters was evident in many of the prize questions for the medical faculty as well. Thus the Preisfrage for 1766 ran: "Cum quasdam plantarum varietates credant botanici a diversorum generum commixtione (ut animalia hybrida) nasci: illam questionem experimentis, non conjecturis decidere; et si confirmetur veritas suspicionis huius, ad leges simul, quas sequunter istae varietates attendere." As we shall see this interest in finding the laws of variation among species became a central research problem for students in Göttingen in the late 1780s.

17. Gruber, loc. cit., p. 7.

18. On this point see the course descriptions included in Pütter, *Geschichte.*

19. On this point see Pütter, but also Christian Gottlob Heyne, *Akademische Vorlesungen über die Archäologie der Kunst des Altertums* (Braunschweig, 1822).

20. W. Brednow, *Jena und Göttingen* (Jena, 1949), p. 2.

21. Albrecht von Haller, "Vom Nutzen der Hypothesen" *Sammlung kleiner Hallerischer Schriften* (Bern, 1772), Teil I, p. 55.

22. Ibid., p. 55.

23. Ibid., p. 58.

24. Ibid., p. 59.

25. Ibid., p. 60.

26. Ibid., p. 67.

27. Buffon, *Allgemeine Historie der Natur* (Leipzig, 1750), tr. Abraham Gotthelf Kaestner, Bd. I., Teil I, p. 4. A similar statement is found in Bd. II, Teil I, p. 4. Because the notes to the German edition of Buffon's work prepared by Kaestner are useful in gaining an insight into the research plans of Göttingen naturalists during the 1760s and 1770s, I will cite the German text.

28. Ibid., p. 8.

29. Ibid., pp. 14–15.

30. Ibid., p. 26. I have translated "Arten" here by "genera," because Buffon clearly did believe in the physical reality of species. They were identified infallibly by the ability to produce fertile offspring.

31. Philip R. Sloan, "Buffon, German Biology and the Historical Interpretation of Biological Species," *British Journal for the History of Science* 12 (1979): 109–53.

32. Buffon, loc. cit., p. 8.

33. Ibid., p. 17.

34. Professor Sloan argues (loc. cit., fn. 31 above) that a tension existed between two approaches to natural history in late eighteenth-century German biological thought. There were those who defended a phenomenalistic approach, claiming that natural history could never be more than a description (*Naturbeschreibung*) of the phenomena. Opposed to this approach were those who claimed that a natural history could be constructed that got at the true interrelations among organisms. The proponents of this view argued that the historical succession of individuals would provide a system of nature. Thus they claimed that a genuine *Naturgeschichte* could be given. In Sloan's view, the defenders of this method were the true inheritors of Buffon's ideas. It seems to me that at Göttingen both of these approaches were pursued simultaneously, and both were seen to have been linked together as mutually supportive in Buffon's work. There may indeed have been a tension between the two methods, but it was one that Göttingen scientifists attempted to resolve.

35. This point will be made explicit below.

36. Buffon, loc. cit., Bd. II, Teil I, p. 16.

37. Ibid., p. 22. For a further discussion of this problem, see the excellent treatment by Paul Farber, "Buffon and the Concept of Species," *Journal of the History of Biology* 5 (1972): 259–84.

38. Cf. ibid., Bd. I. Teil I, pp. 12–13.

39. Ibid., Bd. II, Teil I, pp. 4–5.

40. See the summaries of Euler's correspondence concerning Büttner in *Euler Opera Omnia,* Series IV, Teil A, Bd. I. Register band, ed. A. P. Juschkewitsch (Basel, 1975).

41. Georg Ernst Stahl, Theorie der Heilkunde (Berlin, 1831). Translation of the *Theoria medica vera,* p. 5.

42. Ibid., p. 4.

43. Ibid., pp. 14–15.

44. Ibid., p. 12.

45. Johann Friedrich Blumenbach, *Beyträge zur Naturgeschichte* (Göttingen, 1805), p. 42.

46. Pütter, loc. cit., Teil I, pp. 290–91.

47. In his dissertation, *De generis humani varietate nativa* (Göttingen, 1775).

48. Pütter, loc. cit., p. 291.

49. Cf. Christian Wilhelm Bütter, *Vergleichungstafeln der Schriftarten verschiedener Völker in der vergangenen und gegenwärtigen Zeiten* (Göttingen, 1771–81), 2 vols.

50. Thus Buffon writes, loc. cit., Bd. IV, p. 102: "For every species in nature there exists a general type [*Urbild*] after which each individual is formed. The first animal, the first horse, is the external and internal model for all horses that have been and ever will be born. . . . But even though millions of individuals exist, not one of them has identical characteristics either to another individual or to the model." An obvious correlation existed in Buffon's theory between the *moule interieur* and the ideal type, underscoring once more the importance of generation for natural history. One crucial difference should be emphasized between Buffon's theory and that of the German naturalists, however. As the above passage indicates, the *Urbild* for Buffon was an in-

vidual horse or animal with an actual historical existence. All members of the same species were descendants of this original (pair) through the process of reproduction. For the German naturalists, however, the *Urbild* never had a concrete existence. Always subject to the effects of the environment, the *Urbild* itself never appeared in nature, rather only its phenomenal manifestations. On this point see the discussion on Girtanner and Blumenbach below as well as my paper, "Generational Factors in the Origin of romantische Naturphilosophie," *Journal of the History of Biology* 2 (1978): 57-100.

51. The connection between Heyne's views and those of Diderot was noted by Blumenbach in his *Knochenlehre* (2. Auflage, Göttingen, 1807), pp. 84-86.

52. Heyne, *Akademische Vorlesungen über Archaeologie* (Braunschweig, 1882), p. 13.

53. See Denis Diderot, "Essais sur la peinture," in *Oeuvres esthetiques* (Paris: Clasiques Garnier, 1959), p. 666. Compare with this Buffon, loc. cit., Bd. II, pp. 22-24. Kaestner points out in his note to this passage that the manner in which reason affects this penetration to the "unsichtbar innerliche Form" is not at all clear.

54. Götz von Selle, *Die Matrikel der Georg-Augustus Universität zu Göttingen* (Hildesheim, Leipzig, 1937), Bd. 1, p. 198.

55. Blumenbach, *Treatise on Man,* pp. 97-99. All selections from the *De generis varietate humani nativa* quoted in this paper have been taken from *The Anthropological Treatises of Johann Friedrich Blumenbach* (London, 1865) tr. Thomas Bendyshe.

56. Ibid., p. 188.

57. Ibid., pp. 188-89.

58. Ibid., p. 190.

59. Ibid., pp. 190-91.

60. Ibid., pp. 74-76.

61. Ibid., p. 71.

62. Blumenbach, *Handbuch der Naturgeschichte* (Göttingen, 1802, sixth ed.), p. 8.

63. Blumenbach, *Handbuch der vergleichenden Anatomie* (Göttingen, 1805), pp. v-vi.

64. Caspar Friedrich Wolff, "De inconstantia fabrica corporus humani," *Acta Petropolitianae* (1778), p. 218.

65. Ibid., p. 226.

66. Diderot, "Essais sur la peinture," in *Oeuvres esthetique* (Paris: Classiques Garnier, 1959), pp. 665-66.

67. Blumenbach, *Handbuch der vergleichenden Anatomie,* pp. 84-86.

68. This is catalogued in the Blumenbach Nachlass at Göttingen as Cod. Ms. Blumenbach XXIX, über *Monstra.*

69. Cod. Ms. Blumenbach XI, in the unnumbered handwritten introductory material to the *Handbuch der vergleichenden Anatomie* used by Blumenbach for his lectures.

70. Buffon, *Allgemeine Historie der Natur,* Bd. II, pp. 23-24.

71. That Haller and Blumenbach corresponded on this problem was acknowledged explicitly by Blumenbach in his treatise, *Über den Bildungstrieb* (Göttingen, 1781), p. 6.

72. Haller, "De partibus corporus humani sensibilibus et irritabilibus," *Commentarii Societatis Regiae Scientarum Göttingensis,* Tom II (1753), pp. 114-58. See as well Haller's statement of his problem in his extremely popular *Grundriss der Physiologie* (Berlin, 1788), Meckel, Wrisberg and Sömmering (eds.), pp. 69-70 and p. 311.

73. Blumenbach, *Handbuch der Naturgeschichte,* p. 19.

74. Ibid., p. 19.

75. Blumenbach, *Über den Bildungstrieb,* p. 6.

76. Ibid., p. 10.

77. Ibid., pp. 12-13.

78. Ibid., p. 19.
79. Ibid., p. 14.
80. Ibid., pp. 55–56.
81. Cod. Ms. Blumenbach XII, *Handbuch der Naturgeschichte* (1799), pp. 615–16.
82. Blumenbach, *Beyträge zur Naturgeschichte*, pp. 6–8.
83. Ibid., p. 19.
84. Ibid., p. 20.
85. Ibid., pp. 19–20. On p. 25 Blumenbach asserts: "And just as nothing prevents a species from being destroyed, so on the other hand a new one can be created [*nacherschaffen*] from time to time."
86. Ibid., p. 23.
87. Blumenbach, *Über den Bildungstrieb*, p. 43.
88. Ibid., p. 42.
89. Ibid., p. 62.
90. Ibid., p. 61.
91. Blumenbach, *Beschreibung und Geschichte der Knochen des Menschlichen Korpers* (Göttingen, 1807, second ed.), p. 41.
92. Ibid., p. 41.
93. Ibid., p. 6.
94. Haller, *Grundriss der Physiologie*, p. 4.
95. Ibid., p. 4.
96. Ibid., pp. 8–9.
97. Blumenbach, *Beschreibung und Geschichte der Knochen des Menschlichen Korpers*, p. 10.
98. Kant, "Die Bestimmung des Begriffs einer Menschenrasse," *Berlinischer Monatschrift* (1785), in *Kant's Gesammelte Schriften*, vol. VII. Kant, "Über den Gebrauch teleologischer Prinzipien in der Philosophie," Teutscher Merkur (1788), in *Kant's Gesammelte Schriften*, vol. VIII.
99. See Phillip R. Sloan, "Buffon, German Biology, and the Historical Interpretation of Biological Species," *British Journal for the History of Science* 12 (1979): 109–53.
100. Timothy Lenoir, "Kant, Blumenbach, and Vital Materialism in German Biology," *Isis* 71 (1980): 77–108.
101. Kant, *Gesammelte Schriften*, vol. XI, p. 176.
102. Kant, *Kritik der Urteilschraft* in *Kant's Gesammelte Schriften*, ed., Königlichen Preussischen Akademie der Wissenschaften (Georg Reimer: Berlin, 1902–23), vol. V (1908), p. 373.
103. Ibid., p. 371.
104. Ibid., p. 360.
105. Ibid., p. 179.
106. Ibid., p. 182.
107. Ibid., p. 375.
108. Ibid., p. 424.
109. Kant, "Über den Gebrauch teleologischer Prinzipien in der Philosophie," *Gesammelte Schriften*, vol. 8, p. 179.
110. For a fuller discussion of this point see my article, "Kant, Blumenbach and Vital Materialism."
111. Kant, *Kritik der Urteilskraft*, in *Gesammelte Schriften*, Vol. 5, p. 419.
112. Ibid., p. 418. The approach advocated by Kant, Blumenbach, and, as we shall see, Kielmeyer has many points of close similarity to ideas being developed contemporaneously by Cuvier. He too advocated a teleological approach based on plans of organiza-

tion to the fundamental unit. There were significant differences, however. Cuvier denied the environmental elements of the approach being developed by the Göttingen School. His theory was rabidly ahistorical and anti-developmental as evidenced by his rejection of Lamarck's ideas and his neglect of embryology, which came to be a central feature of the later work of the Göttingen traditions. On this issue see William Coleman, *George Cuvier, Zoologist: A Study of the History of Evolution Theory* (Cambridge: Harvard University Press, 1964), especially Chapters 2 and 3 and p. 157 ff. This problem is treated in detail in my forthcoming book, *Vital Materialism in Nineteenth Century German Biology.*

113. Ibid., p. 419.

114. For Blumenbach's path to a reconciliation of his views with this aspect of Kant's position, see my article in *Isis,* loc. cit.

115. Shirley Roe, "Rationalism and Embryology: Caspar Friedrich Wolff's Theory of Epigenesis," *Journal of the History of Biology* 12 (1979): 1-43.

116. Kant, *Kritik der Urteilskraft,* p. 419. On the difference between the functional theory proposed by Kant and the Göttingen school and the descent theory of Darwin, see the important paper by William Coleman, "Morphology between Type Concept and Descent Theory," *Journal of the History of Medicine* 31 (1976): 149-75. My own views on this problem are deeply indebted to Professor Coleman's work.

117. Ibid., p. 420.

118. For a discussion of the relationship between Kant, Girtanner and Blumenbach, see Phillip R. Sloan, loc. cit. in note 31 above, pp. 137-38.

119. Christian Heinrich Pfaff, *Über tierische Elektrizität und Reizbarkeit* (Leipzig, 1795), pp. 2-3, 234-36.

120. Christian Heinrich Pfaff, *George Cuviers Briefe an C. H. Pfaff aus den Jahren 1788-1792. Nebst eine biographischen Notiz von Pfaff* (Kiel, 1845). See especially February 1790, p. 141, February 19, 1791, p. 213, and August 1792, pp. 283-84.

121. Cf. Reinhard Löw, *Die Pflanzenchemie zwischen Lavoisier und Liebig* (Straubing and Munich, 1977), particularly Chapter 3.

122. Blumenbach, *Handbuch der Naturgeschichte* (1797), p. 24n.

123. Ibid., p. 24.

124. Kielmeyer, "Entwurf zu einer vergleichenden Zoologie," in *Gesammelte Schriften,* ed. F. H. Holler (Berlin, 1938), pp. 17-19. The importance of this organ for the classification of animals was emphasized by Blumenbach as well as later by Meckel, Agassiz, and Johannes Müller.

125. Ibid., pp. 25-26.

126. Ibid., p. 26.

127. Ibid., p. 27.

128. Ibid., pp. 28-29.

129. Kielmeyer, "Ideen zu einer allgemeineren Geschichte und Theorie der Entwicklungserscheinungen der Organizationen," in *Schriften,* p. 107. In a Kantian vein he goes on to indicate the importance of temporal relations for indicating lawlike patterns of phenomena as our only possible sign of the organization of things in themselves.

130. Ibid., pp. 122-23.

131. Ibid., p. 123.

132. Kielmeyer, "Ideen zu einer Entwickelungsgeschichte der Erde und ihrer Organizationen" in loc. cit., pp. 205-6.

133. Ibid., pp. 207-8.

134. Cf. Blumenbach, *Handbuch der Naturgeschichte* (1802), pp. 8-9.

135. Kielmeyer, loc. cit., note 129 above, p. 209.

136. Ibid., p. 210.

137. Ibid., p. 209.
138. For further discussion of this point Cf. William Coleman, "Limits of the Recapitulation Theory: Carl Friedrich Kielmeyer's Critique of the Presumed Parallelism of Earth History, Ontogeny and the Present Order of Organisms," *Isis* 64 (1973): 341–50.
139. Carl Friedrich Kielmeyer, "Über die Verhältniße der organischen Kräfte untereinander in der Reihe der verschiedenen Organization: Die Gesetze und Folgen dieser Verhältniße," in *Gesammelte Schriften,* p. 63.
140. Ibid., pp. 66-67.
141. Ibid., p. 67.
142. Ibid., p. 71.
143. Ibid., p. 75.
144. Ibid., p. 77.
145. Ibid., p. 78.
146. Ibid., p. 80.
147. Ibid., p. 85.
148. Ibid., p. 86.
149. Ibid., p. 89.
150. Ibid., p. 89.
151. Ibid., pp. 91-92.
152. Ibid., p. 98.
153. Alexander von Humboldt, *Aphorismen aus der chemischen Physiologie der Pflanzen* (Leipzig, 1794), p. 9. This was a German translation of Humboldt's Latin text by Gotthelf Fischer.
154. Ibid., p. 5.
155. Ibid., pp. v–vi.
156. Humboldt, *Ideen zu einer Physiognomik der Gewächse* (Stuttgart, 1871, 3rd ed.), Bd. 2, p. 16.
157. Ibid., pp. 21-22.
158. Ibid., pp. 24-25.
159. Cf. ibid., p. 121 ff.
160. Ibid., pp. 124-25. See also Alexander von Humboldt, *De distributione geographica plantarum secundum coeli temperiem et altitudinem montium* (1817), pp. 24–44.
161. Ibid., pp. 122-24.
162. Kosmos Humboldt, *Entwurf einer physischen Weltbeschreibung* (Stuttgart, 1845), Bd. I, pp. 55-56.
163. Ibid., pp. 63-64.
164. Ibid., p. 63.
165. Humboldt, *Ideen zu einer Physiognomik der Gewächse,* p. 15. In discussing this point Humboldt cites Heinrich Friedrich Link, with whom he had also studied at Göttingen. The passage quoted from Link is as follows: "In the *Urwelt* we find the most distant structures pressed together in the most amazing forms, pointing at the same time to great development and division [*Entwicklung und Gliederung*] in the *Nachwelt.*" Quoted from *Abhandlungen der Akademie der Wissenschaften zu Berlin,* Jahrgang 1846, p. 322. Link expressed similar views in other works as well. Cf. his *Natur und Philosophie* (Rostock und Leipzig, 1811), pp. 336–41. An almost identical set of views is set forth by G. R. Treviranus in his *Biologie.*
166. Gottfried Reinhold Treviranus, *Biologie: Oder Philosophie der lebenden Natur* (Göttingen, 1802-22), 1: 4.
167. Ibid., p. 17.

168. Ibid., pp. 32–34.
169. Ibid., pp. 35 and 55–56.
170. Ibid., p. 50.
171. Ibid., p. 34.
172. Ibid., p. 65.
173. Ibid., p. 69.
174. Ibid., pp. 69–70.
175. Ibid., pp. 98–99.
176. Ibid., p. 98.
177. Ibid., pp. 160–61.
178. Ibid., pp. 162–63.
179. Ibid., pp. 165–66.
180. This problem is examined by Reinhold Löw, *Philosophie des Lebendigen. Der Begriff des Organischen bei Kant, sein Grund und seine Aktualität* (Munich: Suhrkamp Verlag, 1980), pp. 227–29, pp, 284–308. Löw's work not only provides the key to understanding the philosophical foundations of the life sciences in the Romantic era, it is also extremely relevant to problems in contemporary biology and organic chemistry.
181. Treviranus, loc. cit., pp. 175–76.
182. The principal works cited by Treviranus in this section of his *Biologie* are Blumenbach, *Naturgeschichte,* Linnaeus, Georg Forster, Haller, Buffon, and Cuvier, *Vorlesungen über die vergleichenden Anatomie* (1801).
183. Ibid., pp. 179–80.
184. Ibid., pp. 180–81.
185. Ibid., p. 185.
186. Ibid., p. 192.
187. Ibid., p. 198.
188. Ibid., p. 235.
189. Ibid., p. 258.
190. Ibid., p. 475.
191. Ibid., p. 470.
192. Treviranus, *Biologie,* vol. 2, p. 157.
193. Ibid., p. 157.
194. Ibid., pp. 171–72, and p. 191.
195. Ibid., p. 135; see also vol. 3, p. 8 ff.
196. Ibid., p. 126.
197. Ibid., p. 173.
198. Ibid., p. 205.
199. Ibid., p. 85.
200. Ibid., p. 264.
201. See Elizabeth Gasking, *Investigations into Generation: 1651–1828* (London: Hutchinson, 1967) and Jacques Roger, *Les sciences de la vie dans la pensée français du xviii^e siècle* (Paris: Armand Colin, 1963).
202. Ibid., p. 297.
203. Ibid., p. 269.
204. Ibid., pp. 271–77.
205. Ibid., p. 325.
206. Cf. vol. 1, p. 458.
207. Ibid., p. 377.
208. Ibid., p. 378.
209. Ibid., pp. 400–403.

210. Ibid., p. 407.

211. Ibid., p. 453.

212. Vol. 3, pp. 225–26.

213. Rudolphi was closely connected to Göttingen, having worked with Link on a project in 1805 that won the prize of the Göttingen Societät der Wissenschaften. These two were later colleagues at the University of Berlin. Moreover, Rudolphi expressly states his full agreement with Treviranus' approach in the *Biologie*; cf. Rudolphi, *Beiträge zur Anthropologie und allegemeine Naturgeschichte* (Berlin, 1812), p. 131.

214. Rudolphi, "Über eine neue Einteilung der Tiere," in *Beyträge*, p. 83.

215. See especially pp. 95–106.

216. See Kant's letter to Sömmering, *Kant's Gesammelte Schriften*, vol. 12, pp. 30–35.

217. See Stephen Gould, *Ontogeny and Phylogeny* (Cambridge: Harvard University Press, 1977), pp. 46–47. Meckel's work is treated in some detail in my *Vital Materialism in Nineteenth Century Biology* (forthcoming).

218. Rudolphi, loc. cit., pp. 109–72 in his lecture entitled "Über die Verbreitung der organischen Körper."

219. See William Coleman, "Bergmann's Rule: Animal Heat as a Biological Phenomenon," *Studies in the History of Biology* (Baltimore: The Johns Hopkins University Press, 1979), 3: 67–88.

220. See H. Bräuning-Oktavio, "Vom Zwischenkieferknochen zur Idee des Typus: Goethe als Naturforscher in den Jahren 1780–86," *Nova Acta Leopoldina*, N. F., Nr. 126, vol. 18; F. T. Bratranek, *Goethes Briefwechsel mit den Gebrüdern von Humboldt: 1795–1832* (Leipzig, 1876); W. Brednow, *Jena und Göttingen: Medizinische Beziehungen im 18. und 19. Jahrhundert* (Jena, 1949); Georg Uschmann, *Der morphologische Vervollkommungsbegriff bei Goethe und seine problemeschichtliche Zusammenhänge* (Jena, 1939).

221. See Horst Fuhrmanns, ed., *Schelling Briefe* (Bonn: H. Bouvier, 1973).

222. See Reinhard Löw, *Die Pflanzenchemie zwischen Lavoisier und Liebig* (Munich: Donau Verlag, 1977); Brigitte Hoppe, "Polarität, Stufung und Metamorphose in der spekulative Biologie der Romantik," *Naturwissenschaftliche Rundschau* 20 (1967): 380–83.

223. This problem is treated in the forthcoming book by Reinhard Löw, *Das teleologische Denken.*

224. See, for example, Fritz Ringer, *The German Mandarins* (Cambridge: Harvard University Press, 1968); George Mosse, *The Crisis of German Ideology* (New York: Grosset and Dunlap, 1964).