31

NATURAL HISTORY

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Eighteenth-century natural history comprised a complex body of investigations that included local studies of botany and zoology, collection of natural artifacts, geographical and meteorological descriptions, geological study, landscape and gardening design, and other forms of inquiry conducted by an international group of practitioners.[1] Deriving inspiration from the researches and speculations of Aristotle, Dioscorides, Theophrastus, Pliny, and Vergil in Antiquity, natural historians of the period could also draw upon important Renaissance transformations of the field inspired by such naturalists and herbalists as Otto Brunfels (1488–1534), Conrad Gesner (1516–65), Guillaume Rondelet (1507–66), Andrea Cesalpino (1519–1603), and Ulysses Aldrovandi (1522–1605) who created the tradition of 'emblematic' natural history.[2] Institutionally, natural history developed in the seventeenth century in different forms of association with medical schools, in courts of the nobility, and in association with the new scientific academies inspired by the societies of London and Paris. Less elite forms of natural history were practiced by pharmacists, farmers, country clergy, and 'local' naturalists who created in the early modern period, particularly in the British Isles, the tradition of 'chorographic' natural history. This had originated in the works of William Lambarde and William Camden in the Elizabethan period and was developed by Gerard Boate and Joshua Childrey in the middle seventeenth century. It was exemplified for the early Enlightenment by Robert Plot's *The Natural History of Oxfordshire* of 1677 (Oxford).[3]

Each of these complex strands of development has a separable historical analysis and each feeds into the formation of eighteenth-century natural history. For the purposes of this chapter and this volume, the primary focus will be upon a select set of cognitive questions and will concentrate on an elite tradition of European naturalists, recognizing that a full understanding of the topic in this period requires analysis on several levels.[4]

I shall argue that it supplied for many natural philosophers an alternative form of scientific investigation to that represented by the physical and mathematical natural philosophy of the period. For a complete understanding of the sciences in the eighteenth century, the era must be seen as much as an 'age of Linnæus and Buffon' as an 'age of Newton'. During the course of the century, natural history developed its own institutional structures, novel epistemologies, and modes of inquiry. Evolutionism, historical geology, and the development of 'Humboldtian' sciences – quantitative meteorology, comparative ethnography, biogeography – in the nineteenth century manifested some of the consequences of these eighteenth-century developments. Romanticism and German *Naturphilosophie* also drew heavily upon these developments. This chapter seek to characterize this alternative natural philosophy.

The theoretical reflections that were to transform the original meaning and content of 'natural history' in the eighteenth century will be analysed by sub-periodisations. The first phase, running from approximately 1690 to the 1740s, represents the development of the great classification systems. The second period will be characterized in terms of the 'Buffonian' revolution of mid century. The third phase will deal with the 'vitalist' revolution of the late Enlightenment and its impact on the development of dynamic and constructive dimensions of natural history. The final section will deal with the extension of natural history into anthropology at the close of the century.

I. THE SEARCH FOR THE SYSTEM OF NATURE

1. *Institutionalising natural history*

A review of the *Eighteenth Century Short Title Catalogue* reveals some of the range and diversity of this domain. Of the numerous works published between 1701 and 1800 that have 'natural history', 'historia naturalis', 'histoire naturelle', 'Historie der Natur', or 'Naturgeschichte' in their titles, one finds treatises on the passions, religion, medicine, local geography, psychology, music, printing, exploratory voyages, arboriculture, natural theology, travel guides, and almanacs along with the anticipated descriptive treatises on animals, plants, geological phenomena, and minerals.[5] This displays the way in which 'natural history' characterized inquiries into a wide range of issues defined primarily by their distinction from mathematical physics, astronomy, and experimental science. A more positive definition requires attention to institutional developments and the nature of networks of interacting individuals whose work gave a more specific meaning to the subject.

In Francis Bacon's influential classification of the sciences in his *Parasceve ad historiam naturalem et experimentalum*, appended to the *Novum organon* of 1620, a classification drawn upon by d'Alembert and Diderot in the *Encyclopédie*, natural history was conceived as a 'preparatory' inquiry to natural philosophy:

It treats of the *liberty* of nature, or the *errors* of nature, or the *bonds* of nature; so that we may fairly distribute it into history of *Generations*, of *Pretergenerations*, and of *Arts*; which last I also call *Mechanical* or *Experimental* history.[6]

In the course of the century, however, natural history acquired the character of an autonomous scientific discipline. To understand this development requires initial attention to strategically located individuals occupying primary positions within eighteenth-century institutions pursuing specific aspects of a more broadly defined natural history. The teaching and research dimensions of these institutions made possible a considerable focus of inquiry and gave direction to speculative reflections that could be pursued by identifiable networks of inquirers. If these researches lacked the specificity and focus suggested by Thomas Kuhn's notion of paradigm-governed normal science, we can nonetheless speak of distinctive 'styles' of scientific inquiry, resulting in rival research programmes and competing groups of workers at these centres of inquiry.[7]

Natural history as a discipline was primarily practised within five main forms of institutional organization, all operative in the eighteenth century. Authors of major works were typically associated with at least one of these institutions, and each social body created networks of individuals. Many practitioners belonged to more than one of these institutional forms, but as a means of livelihood, typically only one of these constituted the primary means of support for a given individual.

A traditional institutional home for natural history since the sixteenth century had been the medical faculties of major universities.[8] Beginning with the Italian universities, medical schools often included botanical gardens and, on occasion, substantial anatomical museums where fossils, comparative anatomical preparations, and specimens from wide ranges of animals and plants were displayed and studied by workers. Curators and demonstrators were required by these institutions to arrange collections and conduct teaching. Students were taught to recognize the medicinally important plants and might also study the comparative anatomy of animals at such locations. The botanical gardens in particular raised practical issues concerning the systems of classification by which such gardens were planted and by means of which the properties of plants could be remembered and taught. Important eighteenth-century natural historians associated with such medical teaching gardens and museums included Hermann Boerhaave (1668–1738) in Leiden, Carl von Linné (1707–78) in Uppsala, Albrecht von Haller (1708–77) and Johann Blumenbach (1752–1840) in Göttingen, and François Boissier de Sauvages (1706–67) and Antoine Gouan (1733–1821) in Montpellier. In this same tradition can be placed the Demonstrator of plants at the Physic Garden of the Society of Apothecaries in London.[9] In the American Colonies, the American natural historian Benjamin Smith Barton (1766–1815) was associated with the University of Pennsylvania.

The arts faculties of universities involved with teaching responsibilities in natural philosophy also provided a non-medical context for the prosecution of various aspects of natural history studies. Here can be mentioned Lazzaro Spallanzani (1729–99) at Pavia, Louis Bourguet (1678–1742) at Neûchatel, Nicolas-Joseph Jacquin (1727–1817) at Vienna, and Joseph Gottlieb Kölreuter (1733–1806) at Karlsruhe. In the British Isles, John Walker (1731–1803) became the first holder of the Chair of Natural History at the University of Edinburgh. Johann Jacob Dillenius (1684–1747) was named the first professor of botany at Oxford. Investigators in these positions were able to carry out inquiries into animal and plant physiology, chemistry, comparative anatomy, geology, and animal and plant geography.

Patronized academies, organized on the French or Italian models, formed a third means of support for many professional natural historians.[10] René Antoine Réaumur (1683–1757), Michel Adanson (1727–1806), and the Jussieu dynasty – Antoine (1686–1758), Bernard (1699–1777), Joseph (1704–79), and Antoine Laurent (1748–1836) – were all *pensionnaires* of the Paris Académie Royale des Sciences. Joseph Gärtner (1732–91), Jacob Theodor Klein (1685–1759), and Peter Simon Pallas (1741–1811) constituted an important group at the St. Petersburg Academy. Smaller academies supported important individuals such as John Turberville Needham (1713–81) at Brussels. Privately employed individuals associated with other important smaller academies included such workers as Jean Sénebier (1742–1809), Abraham Trembley (1710–84), and Charles Bonnet (1720–93), all active members of the Genevan academy of sciences. In the American Colonies William Bartram (1739–1823) was associated with the American Philosophical Society. The Edinburgh Philosophical Society had associated with it such individuals as James Hutton (1726–97), the early historian of the earth. However supported, these investigators were able to explore theoretical issues in considerable detail on a wide range of topics.

In contrast to the French model, the main British scientific association, the Royal Society of London, lacked pensioned positions. Much of the work in British natural history was carried out by members of metropolitan natural history societies that can be dated from the founding of the Temple House Botanic Club (1689). These reached their most illustrious expression in the founding of the Linnean Society of London in 1788, created to consolidate the many metropolitan and provincial inquiries into plants and animals.[11]

Separate from the academies, if often overlapping them in membership, were the private natural history museums, private collections, and *cabinets d'histoire naturelle* established in European contexts primarily by the nobility.[12] The foremost institution of this character was the Jardin du Roi in Paris, which by the late eighteenth century had acquired a remarkable physical facility and attained the considerable financial support of Europe's most powerful monarchy. Associated with this institution were Joseph Pitton de Tournefort (1656–1708), Sébastien Vaillant (1669–1722), Charles-François de Cisternay du Fay (1698–1739), Bernard de Jussieu, Georges Louis Le Clerc, comte de Buffon (1707–88), Louis Jean-Marie Daubenton (1716–1800), Michel Adanson (1727–1806), the Jussieu family, Jean Baptiste de Monet, Chevalier de Lamarck (1744–1829), and Bernard de Lacépède (1756–1825), to name only the most prominent members. Smaller cabinets and museums in Göttingen, Leiden, Zürich, and Bologna also employed important natural historians.

The British Museum, originating in 1753 from the enormous private collection of Sir Hans Sloane (1660–1753), provided support for a few individuals interested in natural history, most notably Joseph Banks (1743–1820), the naturalist who accompanied James Cook's first voyage, and also for Linnæus's disciple Daniel Solander (1736–82). But the looser forms of scientific organization in the British Isles also encouraged the development of natural history in the private medical and anatomical schools, widespread in London in the latter half of the century. Subscription courses in natural history and animal anatomy were commonly delivered at such private institutions. Representative of this tradition is the London surgeon John Hunter (1728–93), who delivered private natural history and comparative anatomy lectures at his sumptuous house in Leicester Square that included an anatomical museum of more than 13,000 preparations, forming by the 1790s one of the largest collections of fossils, animal specimens, skulls, and anatomical parts in the world. Hunter's collection was to form the basis for the great Hunterian Museum of comparative anatomy of the Royal College of Surgeons, established by Royal Charter in 1799 and officially opened in new quarters in 1813.

These institutions of natural history created major depositories of materials in Uppsala, London, Paris, Edinburgh, Philadelphia, and Leiden, where specimens obtained from exploratory expeditions to the interior of the Americas, Africa, and the South Pacific could be assembled and reviewed. Individuals in these cities were able to survey large collections of plants and animals from all over the world in a single location, and work in conjunction with cartographers and artists to analyse these in rational catalogues. By this process, the complexity of the geographical and biological space of the planet was reduced to the first bio-geographical maps and worldwide systematisations. The 'natural historian' in such contexts gained rational control of the world not only by personal visits to remote regions but also by systematisation and the mathematics of the cartographer.

Natural history cannot be considered a purely passive subject under this conception. The natural historian could intervene and manipulate the natural world, if not by experiment, at least by the systematising and revisions of classificatory systems in the great collections. The transportation to Europe of living exotic organisms for public display, or in the case of plants, as seeds and sprouts to be sown in hothouses, also allowed a wider public to participate in the encounter with the unusual dimensions of the natural world and made it possible for specialists to conduct experiments at centralized locations.[13] The emergence of the first national zoological garden with the founding in 1794 of the *Ménagerie* at the Paris Muséum national d'histoire naturelle, the Revolutionary successor to the Jardin du Roi, provided a model for public display that was followed in the nineteenth century by all major European nations. These displays also included the exhibition of man-like apes and aboriginal peoples, confronting a wider public with the complexities of defining human existence in European terms.[14]

2. *The ideal of the natural system*

Efforts to reduce the complexity of objects of the natural world to manageable tables, maps, classifications, and systems, initiated by Renaissance herbalists and encyclopedists, formed an important backdrop to the work of the eighteenth-century naturalists. The systematisation of organisms constituted a search for a truly 'natural' system of arrangement, one that reflected the objective structure of the world rather than human convenience or utility. How this was to be attained with any epistemic certainty was a more difficult problem.

An influential Renaissance solution to this question was offered by the Pisan professor of medicine and pharmacology, Andrea Cesalpino, who developed his conclusions on the framework of the Aristotelian theory of the soul in his *De plantis libri xvi* (Florence, 1583). Those parts associated with the primary vegetative functions of nutrition and reproduction, defined by Aristotle (*De Anima* Bk. ii, 414b 1–5) to be central to plant existence, were considered by Cesalpino to be the key to this natural system.[15] Although significant debates over Cesalpino's principle of the *fundamentum fructificationis* were to take place in the late seventeenth century, its axiomatic character was accepted by Joseph Pitton de Tournefort in his landmark *Elémens de botanique* of 1694, and subsequently by the Swedish physician and naturalist Carl von Linné (or Linnæus) (1707–78) in his fundamental works of the 1730s and 1740s as the rational basis of natural and artificial plant classification.

Less explicitly developed on Aristotelian theoretical foundations, but still in keeping with Aristotle's definition of the functions of 'animate' existence, a similar principle formed the basis of the important arrangement of the quadrupeds, birds, and fishes by the English divine and Fellow of the Royal Society, John Ray (1627–1705) in association with Francis Willughby (1635–72).[16] In these important works, the structures associated with circulation and locomotion furnished the primary grounds for classifying animals in a rational subordination of groups that presumably reflected their 'natural' relationships.

With the significant work of Tournefort, Ray, and especially Cesalpino as his principal sources, Linnæus opened up a new era in systematic natural history in a form that was to create much of the enthusiasm for the subject during the Enlightenment. Prior to his work – the point must be emphasized – there was no similar attempt to connect plants, animals, and minerals in a comprehensive system that openly claimed to be the key to the order of created nature. Furthermore, Linnaeus revolutionized anthropology by including human beings in his classification of the animals, including them with the apes and sloths.[17] Published at Leiden in 1735 in thirteen folio pages, the first edition of the *Systema naturae, sive, regna tria naturae systematice proposita per classes, ordines, genera, & species* organized the main genera of all three kingdoms into a system of subordinated Kingdoms, Orders, Classes, Genera, and Species. Although highly schematic in form, using brief characterizations by genera and essential differentiae, it suggested the kind of rational control possible over the objects of the natural world. Supplying a new nomenclature for the higher groups (Orders, Classes, Kingdoms) and taking in all natural forms in its purview, Linnæan natural history presented a bold, programmatic enterprise that was subsequently prosecuted by an expanding network of workers at numerous museums, academies, and cabinets.[18]

The importance of Linnæan science as an *alternative* eighteenth-century scientific programme to Cartesian-Newtonian natural philosophy has rarely been appreciated.[19] In terms of the familiar categories of eighteenth-century natural philosophy – experimental method, quantitative idealization, belief in an underlying mathematical structure of reality, primary-secondary qualities distinction, mechanistic and reductive explanations – Linnæan science presented almost a point by point contrast. Pervaded by a direct epistemological realism, in which the object of true science was 'to know things in themselves', Linnæan science was qualitative, non-experimental, and descriptive. It denied a radical subject-object dichotomy; it admitted no 'problem of knowledge' that troubled over epistemological scepticism and problems of sensation. It was theocentric, teleological, and more in touch with classical sources (Roman Stoicism, Scholastic logic) and Renaissance nature-philosophy than with the science of Descartes or

Newton. The natural world, as it was experienced by the interested layman in all its colours, shapes, even in its anthropomorphic analogies, took precedence over material and mathematical analysis. Represented not only in the familiar classificatory works and expositions of Linnæan systematics – *Systema naturae* (13 eds., 1735–1788); *Genera plantarum* (1737); *Species plantarum* (1753); *Fundamenta botanica* (1736); *Philosophia botanica* (1751) – but also in the important orations and dissertations carried out under Linnæus's direction during his forty-year tenure at the University of Uppsala,[20] Linnæan natural history formed a broad tradition of inquiry, pursued throughout much of the world by a cadre of devoted disciples and popularised in works by such influential authors as Jean-Jacques Rousseau.[21] In spite of these efforts, the larger Linnæan project of discovering and cataloguing the unique natural system of arrangement of plants remained an unachieved ideal for Linnæus, with his speculations left as fragments bequeathed to his disciples for completion.[22]

The original Linnæan systematisations – simply schematic tables in the first edition of the *Systema naturae* – formed a structure within which the explosive expansion of eighteenth-century knowledge of the natural world could be assimilated. With the invention of the accurate marine chronometer in the middle decades of the century, the persistent problem of longitudinal location had finally been solved.[23] Eighteenth-century naturalists were able to grasp for the first time an accurate view of the extent and contours of the world's surface. With this went the remarkable eighteenth-century encounters with exotic South-Sea islanders, romanticised in Louis Bougainville's circumglobal voyage (1766–69). Mapping of the west coast of the Americas was completed. The encounter with New Zealand and Australia, and James Cook's three famous voyages (1768–71; 1772–75; 1776–80), which included the European contact with the Hawaiian Islands, all contributed to the remarkable expansion of knowledge of new plants, animals, and human varieties in the century.[24] Expeditions to Siberia, the Bering Straits, and Kamchatka mapped the contours of the northern Pacific and brought back exotic creatures, including remains of frozen extinct mammoths, to European museums.

In some respects the data from these explorations presented a greater rational challenge to eighteenth-century European assumptions than the residual issues surrounding the Columbian encounters of the fifteenth and sixteenth centuries. The existence in the Americas of human beings and animal and plant life similar to European forms ceased to be the problem it had originally appeared, once the possibility of migrations across Siberia and North America became tenable solutions following the extended exploration of the upper Pacific rim by the 1760s. But the discovery of exotic human beings and novel organisms on remote islands of the Pacific, thousands of miles from the nearest land mass, presented new questions about origins that were not easily answered by nomadic migrations. The possibility of multiple and autonomous 'centres of creation', even implying different creations of human beings, seemed to many the only solution to these questions.[25]

Although Linnæus's best-known works were primarily descriptive, he had also turned his attention to problems of historical development and the distribution of organisms in his early oration of 1743, the *Oratio de telluris habitabilis incremento* (published 1744). In this he proposed an imaginative hypothesis of an original equatorial island in a primeval circumglobal ocean, on which an original pair of each primary species had been created. From this Edenic site, the plants and animals were able to spread as more land emerged, with species intermixing to form additional species. This historical thesis, reconciling natural and sacred history, suggested a means by which the problems of distribution might be explored by his successors in terms of migrations from primeval sources of origin.[26] It suggested one route by which historical questions might be combined with issues of systematisation.

Linnæus's theories had some remote similarities to hypotheses of species transformism suggested in such works as Benoît de Maillet's (1656–1738) *Telliamed* (1748), which had been circulated in manuscript since 1720. Nevertheless it would be incorrect to view Linnæus as putting forth 'evolutionary' views by such speculations. He never questioned the 'essentiality' of species, and his hybridization theory meant no more than a combining of these essential natures. Nor was he a strong advocate of the continuity of the *scala natura* or 'chain of beings', as developed by his contemporary Charles Bonnet.

II. THE BUFFONIAN REVOLUTION

Theoretical conflicts developed within natural history at mid century between Linnæus and his growing band of disciples and the French naturalist George Louis Le Clerc, comte de Buffon, the powerful *Intendant* of the King's garden and natural history collection in Paris after 1739. These conflicts display the tensions between two rival conceptions of the discipline that profoundly affected the aims and practices of the science. The dynamic interplay between these alternative research programmes forced naturalists to come to terms with the claims and consequences of both scientific styles. Neither programme could be pursued to the exclusion of the other. Their effective combination set the agenda for the disciplinary professionalisation of natural history in the nineteenth century.

In contrast to Linnæan natural history, the Buffonian tradition can be characterized as concerned with a causal, secular, and historical science of nature, a set of inquiries which by the end of the century was often designated as a 'history of nature' to distinguish it from natural history of the more traditional form. Aspects of this re-conceptualization represent a revival, after a significant historical hiatus, of the lines of speculation initiated by Réné Descartes in parts three and four of his *Principiæ philosophiæ* of 1644.

Descartes had developed the implications of his theory of matter as *res extensa* by sketching out the first modern hypothetical account of the formation of the solar system and the earth by the simple transference of an initial quantity of motion to an extended plenum by God acting by means of the Cartesian rules of contact action and the three Cartesian laws of nature. In this system, the earth was formed by the consolidation and cooling of a star. By a drying and fissuring of the crust, the surface was broken and by violent processes, the 'mountains, plains, oceans' were created through natural causes.[27] This quasi-historical account – formally non-literal because it is presented as a counterfactual hypothesis[28] – supplied an influential model for subsequent speculations on 'theories of the earth'. Revised in the late seventeenth century by the Danish natural philosopher Niels Stensen (Steno) (1638–86), and given its most influential expression by the English divine Thomas Burnet (1635?–1715) in his *Sacred Theory of the Earth* (*Telluris theoria sacras*, 1681), Cartesian genetic history of the earth was transformed into literal history by its reconciliation with traditional Mosaic cosmology.[29]

Natural philosophers of the eighteenth century confronted a significant problem with reference to these issues in the wake of Newton's revolution. A few disciples of Newton – most notably William Whiston (1667–1752) – continued Burnet's efforts to reconcile a history of the earth with Mosaic genesis, employing Newtonian, rather than Cartesian, mechanics.[30] Newton, however, explicitly rejected these efforts in his published works. Emphasizing the mathematical analysis of the motions of bodies according to the established synchronously acting laws of nature, which he distinguished from speculations about the first origins of this world order, Newton's planetary system was functionally non-historical, if not strictly eternalist.[31] His disciple John Keill (1671–1721) directly attacked the hypothetical character of Descartes's and Burnet's 'world building' in both its Newtonian and Cartesian variants in his *An Examination of Dr. Burnet's Theory of the Earth, Together with Some Remarks on Mr. Whiston's New Theory of the Earth* (Oxford, 1698), suggesting that rejection of such speculation was an important means of distinguishing Cartesian and Newtonian natural philosophies. Although some notable efforts to continue a tradition of speculation about the 'theory of the earth' as it was commonly termed in the early eighteenth century can be cited,[32] the paucity of literature dealing with these questions in the early decades of the century suggests that these Newtonian criticisms formed an important block to the development of historical cosmology and geology until the middle decades of the century.[33]

In this context Buffon played a primary, if not exclusive, role in the eighteenth-century revival of historical cosmology and theories of the world, subsuming this under a broadened and altered conception of natural history that eventually resulted in a synthesis of cosmological, geological, historical, and biological questions.

Buffon's emergence as the foremost architect of this new 'natural history' in several respects resulted from an unusual intellectual biography. Important dimensions of his intellectual formation connect him with the standard picture of a Newton-Locke-empiricist tradition in eighteenth-century thought. Nonetheless, this chapter takes the position that Buffon's thought also departed in important ways from this philosophical axis, and it is in this divergence that his novelty is to be understood.[34] His reformulation of the character and directions of natural history involved on the one hand an important revival of Aristotelianism, and on the other the construction of a complex synthesis of Cartesian and Leibnizian natural philosophies that Newton's hegemony had served to check. It also involved his formulation of a novel epistemology for natural history that departed from the assumptions of mathematical physics.

First admitted to the prestigious Académie royale des sciences in 1734 for his work in probability theory, Buffon's interest in the life sciences was evidently sparked by his first published work, a translation, with his own introduction, of Stephen Hales's Newton-inspired *Vegetable Staticks and Analysis of the Air* (1727), an important work dealing both with the physiology of plants and with the chemical analysis of gases.[35] In the same year that Linnæus had publicly entered the field of botany with the *Systema naturæ*, Buffon had established his early reputation in the Académie as an advocate of Newtonian experimental methods applied to the organic realm. The diametric opposition of methodologies and conceptions of scientific inquiry that were to divide Buffon and Linnæus only deepened from this date.

In 1739 Buffon was named the successor to Charles-François de Cisternay du Fay as *Intendant* of the Jardin du Roi in Paris, both a botanical garden and the repository for the extensive zoological, anthropological, and geological specimens gathered by French investigators from at home and in the colonies. Through his administrative skills and political finesse, over the next forty-nine years he was able to transform the Jardin into the century's foremost research institution in natural history, with workers dedicated to botany, various branches of zoology, animal and human anatomy, mineralogy, chemistry, and bio-geographical studies.

The development of Buffon's thought between 1739 and 1749, the date of publication of the first three volumes of his *Histoire naturelle générale et particulière, avec la description du cabinet du Roy* (HN), remains one of the main interpretive issues in Buffon scholarship.[36] Spanning this period, his published works include an important translation of and introduction to Newton's work on the calculus (1740),[37] and a series of articles in the *Mémoires de l'Académie royale des sciences* dealing with such subjects as the strength of wood, the construction of large-scale burning-mirrors, a series of exchanges with Alexis-Claude Clairaut (1713–65) on the interpretation of Newton's inverse-square law of universal gravitation, and a paper dealing with the claimed microscopic discovery of spermatic bodies in female mammals.[38] Little in this immediately suggests strong interests in the traditional domain of natural history as it was understood in this period. Taking shape in the background, however, was an ambitious project that was only to emerge to public view in 1749.

Buffon's unusual career qualified him to engage several of the fundamental questions of Enlightenment philosophy at issue in the 1730s and 1740s as he prepared for his entry into natural history. His early writings display his awareness of the debates on the foundations of Newtonianism initiated by the Leibniz-Clarke dispute (1717). Contacts with Genevan mathematicians and natural philosophers acquainted him with the efforts of members of the Genevan Academy to reconcile aspects of Cartesian, Newtonian, and Leibnizian natural philosophies.[39] His early concern with probability mathematics engaged him with the combination of epistemological and mathematical questions that lay at the foundations of this mathematics of certitude.[40] Able to read English writers at an early age, Buffon was conversant with British natural philosophy and with British philosophical works, including those of Locke and Berkeley. He displays familiarity with the debates on the relation of mind, world, and sensation brought into focus by authors such as Etienne Bonnot de Mably de Condillac (1715–80). On the other hand, his direct study of the biological writings of Aristotle and of biological thinkers influenced by Aristotelian theories of the organism, such as William Harvey (1578–1657), also contributed significantly to his thinking.[41] All these factors play a role in the formation of Buffon's novel 'relational' epistemology, developed at greatest length in the 'De la manière d'étudier et de traiter l'histoire naturelle', which prefaced the first volume of the *Histoire naturelle* (1749), and also in the long 'Discours sur la nature des animaux' opening volume four (1753).[42]

Buffon's contact with the Leibniz-Wolff philosophy, diffused in French circles in the 1730s and 1740s, has significance for his revolution on three fronts.[43] First, the Leibnizian philosophy offered a fundamental systematic critique of the Newtonian conceptions of absolute time and space, offering in their place an immanent conception of time and space that intimately connected the existence of time with the material succession of the empirical world. Second, Leibnizianism grounded a substantive conception of 'nature' that conceived it as an autonomous, teleological system developing in relation to the unfolding of immanent time and space. Finally, it provided a philosophical foundation for re-establishing a genetic theory of the earth in a form that seemed to escape the Newtonian critique of 'world-building'. These will be elaborated briefly.

1. *Time in nature*

The complexities of the Leibnizian philosophy of time and space were rendered more systematic, concrete, and empirically applicable for a Francophone audience in the 1740s by their reformulations in the writings of the Halle professor of philosophy Christian Wolff (1679–1754). These restatements allowed the highly metaphysical discussions of Leibniz himself, only incompletely accessible during most of the century, to be given popular expositions that could also be applied to specific issues in the sciences. The concept of time is one primary example of how these views were assimilated by French enthusiasts for the Leibnizian philosophy.

Isaac Newton's definitions of absolute time and space, most clearly stated in the scholium to Definition Eight of the *Principia mathematica*, defined 'true mathematical' time and space as absolutes standing independent of any empirical instantiation or measurement of these quantities. Furthermore, these two absolute infinities, identified in the 'General Scholium' to the second edition of the *Principia* (1713) with attributes of God, were conceptually unconnected with the history or origin of the material world order. Time and space are dimensionalities within which world or cosmic history transpires. But in Newton's philosophy of nature no intimate connection exists between the absolute infinity of time, for example, and the history of the cosmic system or the world. Consequently, Newton conceived the age of the universe in terms reasonably consistent with accepted biblical chronologies. The planetary system is a nearly steady-state system, created within relatively recent time, undergoing a slow historical decay of motion.

In his critique of the foundations of Newtonian natural philosophy in the series of letter exchanges with Newton's proxy Samuel Clarke, published jointly in French and English in 1717, Leibniz had challenged this Newtonian independence of time and space along with several other components of the Newtonian system. In its place he offered a purely relational definition of time and space in which neither entity was considered conceivable apart from the relations of substances.[44]

Christian Wolff's refashioning of Leibniz's fragmentary and complex ideas into a systematic textbook tradition was particularly important in making these notions applicable in scientifically practical ways. Expounding these views in systematic Latin treatises, which were made available to a Francophone readership in the early 1740s in popular expositions,[45] Wolff reshaped Leibnizianism into a concrete philosophy, pruned of the more abstruse metaphysical dimensions of Leibniz's monad theory. Even before these French expositions of the Wolffian interpretation of Leibniz were available, Buffon's circle of associates was made aware of the importance and novelty of the Leibnizian-Wolffian philosophy through the substantial contacts that had developed between French intellectuals, most notably Buffon's friend Pierre de Maupertuis (1698–1759), and the Berlin Academy of Sciences. Also important was the anonymously published exposition of Wolffian principles, the *Institutions de physique* (Paris, 1740; 2nd ed. 1742) by Gabrielle-Émilie le Tonnelier de Breteuil, marquise du Châtelet (1709–49). This work attempted to synthesize Newtonian mechanics with Leibniz-Wolffian metaphysics. Buffon is known to have read this work late in 1740.[46] Prefaced by a long introductory exposition of the essentials of Wolff's philosophy as it had been taught to her personally by Wolff's disciple Samuel Koenig (1712–57),[47] du Châtelet defended Leibnizian relational interpretations of time and space against the Newtonian absolutes that she, along with Wolff, considered mere abstractions. Time, she writes,

> is therefore in reality nothing else than the order of successive beings [*Etres*]; and one forms the idea of it only in so far as one considers it as the order of their succession. Thus there is no time without true beings successively arranged in a continuous series, and there is time as soon as such beings exist.[48]

In these terms, temporality and historicity are intrinsically imbedded in the structure of existent things. Furthermore, this development of temporality is concretely realised by the unfolding of a succession of entities in a connected series. Very similar notions were subsequently to reappear as an important feature of Buffon's biological and geological reflections.

2. *The idea of nature*

A second important component of the Leibniz-Wolff philosophy that seems formative for Buffon's views is the dynamic and substantive conception of nature found within this tradition. For the primary seventeenth-century natural philosophers enamoured with mechanical philosophy, nature functioned primarily as a passive, inert, created order of things.[49] This passive, nominalist conception of nature of seventeenth-century mechanism was to undergo important transformations in the eighteenth century under the complex impact of the natural philosophies of Newton, Leibniz, Spinoza, and the Cambridge Platonists.[50] Re-established was the concept of nature as a substantive, causal agency, either as an intermediary between God and matter, as advocated by the Cambridge Platonists, or as the inherent principle of action underlying the dynamic force (*vis*) of matter, the view of Leibniz.[51] Restated by du Châtelet in her *Institutions*, this Leibnizian-Wolffian conception of 'nature' was defined as

> an internal principle of changes that occur in the world; thus, it is not a little God distinct from the world, who has governance over this machine. It is only the motive force joined to the other properties [of matter] which together with it compose the essence of bodies.[52]

Nature in this sense provided a metaphysical object for a science concerned generally with the inner system of forces and dynamic actions and relations immanent in matter itself. Again, it is in terms closely similar to these Leibniz-Wolff formulations that the concept of nature will be encountered in Buffon's writings.

3. Reviving the theory of the earth

The immanent nature of time in the Leibniz-Wolff philosophy suggests at least one important reason that it is within the writings of those in close contact with the Leibnizian tradition in the eighteenth century that we perceive a willingness to revive the historical cosmology and theory of the earth which had seemingly been discredited by the epistemic strictures of Newtonian science. Historicity is a necessary, and not simply a contingent and accidental, dimension of Leibnizian natural philosophy. Nature is a dynamic, unfolding system, manifested through the inner powers of matter in which time itself cannot be separated from this successional unfolding of phenomena. The principle of sufficient reason renders the order of this unfolding reality a unique system with an inherent rationality, autonomous and without need of miraculous interventions. Leibniz's own effort at developing a genetic history of the world, the *Protogaea*, available only as a short prospectus until 1749 but circulated in manuscript before then, opened with the claim that 'if one wishes to return to the most remote origin of our land, one must say something about the first configuration of the earth [*terrarum*], the nature of the soil and that which it contains'.[53] Although Leibniz himself does not attempt an epistemological justification of the knowledge claims involved in such discussions of origins – the point at issue with the Newtonians – once again Wolff was to supply this in a form readily accessible to a wide audience. Defining 'Cosmology' as a science that applied the principles of his comprehensive metaphysical system to empirical nature, Wolff related the issue of the origin of beings and the origin of the universe to the succession of time. The empirical reality of the world is to be understood as a chain of connections in a causal relationship, either contemporaneously in space, or diachronically in time.[54] The earth, for example, is related causally to the sun, and changes in one are related to changes in the other.[55]

Although Wolff did not himself enter into specific discussion of various theories of the formation of the world, it is particularly through the writings of individuals in some contact with this Leibnizian-Wolffian tradition that one encounters a revival of the defunct theory of the earth.[56] One example is the Swiss polymath Louis Bourguet (1678–1742), who proposed the outlines of a 'théorie de la terre' in a treatise of 1729 that was to influence Buffon's views.[57] These three contributions of Leibniz-Wolff philosophy outlined above form important components of Buffon's new conception of natural history.

4. *Buffonian history of nature*

The publication in 1749 by the Imprimerie royale of the first three volumes of Buffon's *Histoire naturelle* presented the eighteenth century with its principal alternative to the Linnæan conception of natural history. Voluminous in form, elegantly written, and discursive rather than analytical and classificatory in style, it presented a marked contrast to Linnæan natural history in its immediate presentation. Opening with a lengthy 'discourse on method' reminiscent of Descartes's famous treatise, Buffon set out a programmatic agenda for his new approach to natural history.

Opposition to Linnæan natural history forms a central focus of his opening discourse. Linnæus's Latin style, his crabbed classificatory presentations, and his system-building mentality were in marked contrast to Buffon's approach. Buffon's discourse also advocated the restoration of metaphysics to science, and as part of this he sought to provide natural history with epistemic foundations that could overcome sceptical critiques of historical knowledge. In the discussion of truth closing the discourse, the impact of the Leibniz-Wolff notion of physical truth was prominent.[58] Buffon made the attainment of the truth in the physical world a consequence of understanding natural objects and phenomena in terms of relations of connected and temporal succession.[59] On these grounds, he surprisingly denied a central claim of seventeenth-century natural philosophy – namely that abstract mathematical idealisation provided the privileged means to acquire this physical truth. On the contrary, mathematics yielded only abstract truth, grounded on the relations of ideas rather than on the successional relations of real things. For this reason it was inferior to the natural knowledge founded on the observation of a succession of events:

> There are several kinds of truths, and customarily placed in the first order are mathematical truths, which are, however, only truths of definition. . . . Physical truths, to the

contrary, are in no way arbitrary, and do not depend on us. Instead of being founded on suppositions that we have made, they are only grounded upon facts. A series of similar facts or, if you prefer, a frequent repetition and uninterrupted succession of the same events constitutes the essence of physical truth. What is called physical truth is thus only a probability, but a probability so great that it is equivalent to certitude. . . . One goes [*va*] from definition to definition in the abstract sciences, but one proceeds [*marche*] from observation to observation in the sciences of the real. In the first case one arrives at evidence, in the latter at certainty.[60]

In this discussion, Buffon effectively reversed the conclusions of his contemporary David Hume (1711–76) on the relationship of analytic and synthetic truths. Only a year previously, Hume had made this distinction in his *Enquiry Concerning Human Understanding*, and from this had drawn sceptical conclusions about the certitude of empirical knowledge.[61] To the contrary, for Buffon this distinction of analytic and synthetic truths implied that the latter, if understood in terms of a physical succession of phenomena, offered a greater epistemic certitude than that available through the mere abstract relations of ideas. This unusual epistemology – a 'realism' seen by the late Professor Jacques Roger as Buffon's most revolutionary concept – forms the unifying theme of his new conception of natural history.[62] It implied that the knowledge to be gained through natural history was superior to the abstractions of mathematical physics. This premise also supplied the grounds for his attack on Linnæan systematics set forth in the 'First Discourse.'

The new directions implied by these principles are immediately evident in the plan and content of the *Histoire naturelle*. Claiming that Linnæan classification is a mere abstract arrangement of forms without connection to their true physical relations, Buffon returned to Aristotle's suggestion in the *Historia animalium* (491a 20) that organisms were to be classified in terms of their relation to human beings. This implied for Buffon the novel conclusion that the forms closest to human beings were the domestic animals rather than the apes and monkeys, rejecting the Linnaean classification of humans in the *Systema*. The expository arrangement of the *Histoire naturelle* was to pursue this novel anthropocentric system as its basic plan of organization through the initial series of the work, the *Histoire naturelle des quadrupèdes* (1753–67).

The rest of the three original volumes of the *Histoire naturelle* display further dimensions of Buffon's concern with temporal succession and material relation. In the first of the two long discourses that complete the first volume, he offered a secular account of the slow, causal agencies – in this case the action of water – that have given shape to the earth and formed the mountains, sea basins, and continents. Technically rejecting the earlier speculations of Thomas Burnet, John Woodward, and William Whiston because they required catastrophic causes outside ordinary purview, Buffon's initial account was not intended as a theory of first origins, but as a secular explanation of the immediate formative causes of the world as it currently exists. To this degree he apparently accepted Newtonian epistemic restrictions on world building.[63]

In a second discourse, however, Buffon did consider the issue of first origins. In the long article 'Proofs of the theory of the earth', which forms the conclusion of the first volume, he returned to the question of the origins of the solar system itself, offering a secular account that postulated the collision of a passing comet with the sun. This is assumed to have resulted in the ejection into space of masses of molten material that have consolidated into the planets as they cooled. Proof of this theory is offered in the form of mathematical calculations based on the orbital velocity of the planets. However, Buffon makes no effort to unite this catastrophic theory of planetary origin with the history of the earth. Only later would this integration take place.

The themes of the second and third volumes of the *Histoire naturelle* display again the character of Buffon's divergence from the reigning Linnæan programme. His treatment of organic beings adopts a functional, rather than a classificatory approach, opening with a long discussion of the process of generation. In this discourse he offers an explanation of embryological formation and the maintenance of form through sexual reproduction, offering an ambitious theory of organic molecules organized by immanent force-fields, the 'internal moulds'. The developmental history of man forms the topic of the latter part of the second volume, and the third volume deals with the natural history of the human species, accompanied by the detailed anatomical descriptions by his collaborator Louis Daubenton, offering the eighteenth century the longest treatise hitherto on this subject. In these discussions of the human species Buffon characterized the various stages of human life, the function of the senses, and then summarized the physical differences, habits, and geographical distributions of the main varieties of the human species.

In contrast to Linnæus's creationist, classificatory natural history, Buffon's science makes no effort to synthesise his natural history accounts with biblical history. Nature is related to a divine order only in the establishment of the laws of motion and the creation of the first internal moulds of each species. But in company with the Leibnizian tradition, Buffon's nature is neither a separate demiurge nor merely a mechanical order of things. As he was later to define the concept of nature in an influential discourse, it is 'an immense, living force, which embraces all things, which animates all, and which subordinated to that [power] of the first Being, commenced its action only by his order, and acts still only by his concourse or consent'.[64]

5. *Degenerating species*

In his analysis of the quadruped animals commencing with the fourth volume of the *Histoire naturelle* (1753), Buffon's emphasis was geographical, ecological, and relational rather than classificatory. This emphasis is displayed strikingly in his re-definition of organic species, most explicitly presented in the article on the Ass (1753). Arguing that the traditional notion of a species as a logical class of similar individuals did not meet the criterion of a properly physical definition, Buffon introduced into the literature a revolutionary conception of organic species defining it as a 'constant succession and uninterrupted renewal of the individuals constituting it'.[65] Such species were to be recognized empirically by reproductive compatibility rather than by morphological characteristics. This novel definition, given wider circulation by Diderot's *Encyclopédie*,[66] supplied a substantive ontology for the concept of biological species that deeply affected the subsequent history of the life sciences. This novel redefinition of 'species' as a successional lineage of organisms, rather than as a universal of logic, opened up a discourse about species in which naturalists could discuss the birth, death, geographical distribution, and variation of organic species as ontological entities.

The integration of this functional, historical, and ecological approach to organisms with the physical history of the earth was a topic that slowly developed in Buffon's natural history over a forty-year period. As his survey of natural history encountered the issue of geographical variation, an issue necessarily forced into the foreground by his physical conception of organic species, the unusual arrangement of the *Histoire naturelle* first raised this issue with respect to the geographical variation of domestic animals.[67] In 1756, as he expanded his review to include the wild animals, Buffon suggested a causal mechanism responsible for this change of species. The differences created by climatic variations in the constituent organic molecules making up every living being presumably produced slight, heritable, and cumulative effects on the transmitted internal moulds that were transmitted to subsequent generations.[68] These reflections were considerably expanded in the ninth volume of the *Histoire naturelle* (1761), when Buffon finally treated the complex problem of the relations of the Old and New World quadrupeds. In these discussions he developed his theory of a historical degeneration of species over time to account for these geographical variations. By the middle 1760s, Buffon's theory of degeneration allowed him to carry out a considerable collapsing of mammalian forms into a few original stem-species that had altered into the other groups as they migrated from an originating site in northern Europe.[69]

6. *Buffon and evolution*

An older historiographic tradition has often discussed Buffon's concept of species degeneration in the light of later evolutionary reflections of nineteenth-century naturalists. It is indeed the case that the degeneration theory and the historical conception of species expounded in Buffon's immensely popular work raised to prominence a thesis of the gradual alteration of forms in history under the action of purely secular forces. Furthermore, Buffon's impact upon early French species transformists – Jean Baptiste de Lamarck (1744–1829), and Etienne Geoffroy St. Hilaire (1772–1844) – who succeeded him at the Muséum national d'histoire naturelle, the Revolutionary successor to the Jardin, illustrates lines of development from some of Buffon's ideas.[70] But to designate Buffon's species degeneration as an 'evolutionary' view is misleading and historically inaccurate. The changes of species, in spite of the significant breadth Buffon allowed species degeneration in his writings by 1766, was always an ontologically limited change, confined within the limits defined by the organizing internal mould. Primordial cat, canine, or bovine stem-species might fragment into the plurality of existing geographical variants, creating *genres physiques* or *familles* in his technical parlance, but never new kinds of creatures.

Buffon's theory of species degeneration was indebted to his growing awareness of the extent of geographical variation of forms. Located at the centre of Parisian natural history, he was in an ideal position to consider the expanding body of new information in the 1760s and 1770s from scientific expeditions to the New World, South Pacific, East Indies, and the northlands by French explorers and other European inquirers.[71] The full complexity of the issues raised by this material could only partially be considered by Buffon in his last published works – the *Histoire naturelle des oiseaux* (1770–83) which was part 2 of *Histoire naturelle*, and the supplementary volumes to the latter (1774–89). This new information expanded the problem of accounting for the geographical distribution of forms and forced to the foreground the problem of the origin of forms on the remote islands and continents of the South Seas. New information from the Old and New Worlds on the apparent extinction of large mammals related to the elephants and hippopotami, and further collections of remains of woolly mammoths from Siberia and America, required explanation.[72] Buffon's emphasis on historical processes and the physical connectedness of forms was to stimulate further bio-geographical analyses. The great bio-geographers of the late Enlightenment – Johann Reinhold Forster (1729–98), Eberhard Zimmermann (1743–1815), and Alexander von Humboldt (1769–1859) – if often critical of Buffon, all drew in important respects on his work.[73]

Buffon's most powerful synthesis of cosmological, geological, and biological issues was published in 1779, the year following the death of his rival Linnæus, in the fifth supplementary volume to the *Histoire naturelle* as *Des Époques de la nature*.[74] In this work, Buffon drew together his reflections on the history of the cosmos, the physical formation of the earth, the history of life, and the theory of climatic and geographical degeneration of organic beings. Claiming that natural and human history formed a single historical scheme, Buffon suggested a model of analysis that was expounded in more developed form by several others in succeeding decades.

Utilizing for his chronological scale the results of experiments on the cooling of various molten materials conducted at his forge in Montbard in the 1760s, Buffon presented a secular Genesis story divided into seven long historical epochs encompassing in the published edition 75,000 years from first formation of the earth from the sun to the present. The first of these epochs described the cometary collision with the sun and the consolidation of the planetary bodies, a sequence requiring 2,936 years. The second epoch, lasting 32,064 years, encompassed the history of the earth from its molten state through the consolidation of various minerals and strata, the formation of mountains, and the cooling of the surface of the earth to the point where water could remain in a non-vaporized state. The third epoch of 15,000 years' duration described a primeval ocean covering the globe in which the first aquatic animals and plants arose. In the fourth epoch, lasting until approximately 60,000 years from the first origins, the waters retreated and land emerged, with a period of vulcanism resulting from the central heat created by electrical matter in the earth. Epoch five (to 65,000 years) encompassed the origins of the larger land quadrupeds in the northern latitudes, arising from the clumping together by natural forces of the organic molecules into the first forms of each of the main species. This period was followed by a sixth epoch (to 70,000 years) in which the continents separated and the contemporary geography of the earth assumed its present shape, with migrations of animals to the tropical zones. Extinction of large quadrupeds also occurred in this period. It is in this epoch that the first humans appeared in Siberia, 'in the pure state of nature, without clothes, religion, or society except among widely dispersed families . . . '[75] Spreading and diversifying, these humans form the various geographical races as they cover the habitable world. The final epoch moves to the domain of recorded human (and biblical) history, the organization of society, and the progress of the arts and sciences. The continued cooling of the earth was extrapolated to an end of all life at 168,000 years from the first origins of the world.

Although these estimates would seem, by nineteenth-century chronologies at least, unduly limited, Buffon speculated much more freely in the manuscripts, estimating in one version at least 2,993,280 years to the present with an end of life at 7,000,000 years.[76] By eighteenth-century standards, these figures involved an enormous expansion of the accepted time scale, and they were supported by the first plausible empirical estimates of the age of the Earth.

The range of this first modern integrated scientific story of the origins of the world order and its contained inhabitants, connecting natural and human history to a general history of nature, suggests the conceptual scope of Buffon's version of natural history. Outrageous to many, the *Epoques* was, like his 1749 treatise, censured by the theologians of the Sorbonne. But in its unified, comprehensive, naturalistic analysis, it supplied a framework upon which his successors could develop more complex integrations of cosmology, geology, and the subsequent history of life.

III. FROM DEGENERATION TO THE DEVELOPMENT OF NATURE

Buffon's history of nature, in spite of its ambitious historicising intentions, was nonetheless framed within a degenerating model of history. Buffon's world system, no longer open to Newton's intermittent divine repairs, was necessarily running down, gradually cooling to the state that life would no longer be possible. In this same framework, species lose coherence, organisms become smaller, and life itself wears out. Human beings, through their arts and sciences, can resist this decay for a period, but even the human species must eventually lose in this conflict with the course of nature. In this important respect, Buffon remained more a Newtonian than a Leibnizian. Nature and its immanent forces governing matter lacked constructive, teleological directedness. It is on this theoretical point that his successors were to revise Buffon's insights. Rather than a degeneration of nature, the end of the century was to see the emergence of speculative histories of nature that postulated dynamic progress and development. It is in this framework that the first genuine transformist theories were proposed.

This change in the late eighteenth century from degenerating or steady-state to progressivist histories of nature was considerably indebted to the revival of vitalistic conceptions of life. This 'vitalist' revolution of the late Enlightenment was profound in its implications. It marked the crucial transition from the assumptions of the 'mechanical' philosophy to those of nineteenth-century philosophies of nature.[77]

The conception of the organism as governed by dynamic and constructive forces, challenged but never fully eliminated from medical discourse by the hegemony of the animal-machine theory of Descartes, had been continued into the eighteenth century through philosophical programs, such as the revived nature philosophy of Ralph Cudworth (1618–77), and also on the Continent in the medical 'animism' of University of Halle theoretician of medicine, Georg Ernst Stahl (1660–1774). Aspects of Stahlianism were incorporated in select centres of medical training – Halle, Montpellier, and Göttingen. British vitalism, derived from the medical theories of William Cullen at the University of Edinburgh and John Hunter in London, provided additional sources of these ideas. Although differing widely in specifics, these medical theories were united by the conclusion that the inert conception of matter assumed by Cartesian, and some versions of Newtonian, natural philosophies, was inadequate to account for important areas of biological function.[78] In place of mechanical models of the organism, living beings were re-conceptualized as governed by new powers within matter – *vis essentialis* (Caspar Friedrich Wolff); *Lebenskraft* (Friedrich Casimir Medicus, 1736–1808); *Bildungstrieb* (Johann Blumenbach); *sensibilité* (Théophile Bordeu, Paul Joseph Barthez); and 'matter of life' (John Hunter). This new reliance on vital powers became a prominent feature of the biomedical and philosophical literature of the late Enlightenment. The total effect of the vitalist revival was to reconstitute medical theory on vitalistic rather than mechanistic grounds. Living beings now constituted a metaphysically distinct domain, governed by special dynamic forces or principles that served to explain their primary biological functions. Methodologically, this appeal to vital forces took many different forms. Johann Blumenbach, for example, defended his notion of the *Bildungstrieb* on Newtonian methodological grounds, justified by abductive inference from phenomena. Marie-François Xavier Bichat (1771–1802) emphasised a phenomenological, rather than a realistic, conception of vital agencies. The primacy of force over matter in the Leibnizian and later Kantian tradition enabled some versions of these theories to escape the charge that they involved inserting occult forces into passive matter. Disseminated at mid century through the medical articles of Diderot's and d'Alembert's *Encyclopédie*, and through other writings of medically oriented *philosophes*, vitalism in its many forms was able to enter the literature of natural history in prominent ways by the end of the century.

Particularly in the Germanies, the link that developed between the concept of a developmental history of nature and the assumption that life is governed by inherent vital forces had important consequences. An influential application of vital forces in 1759 to account for embryological development by stages (epigenesis) by Caspar Friedrich Wolff (1733–94) marked an important break with the reigning eighteenth-century mechanistic theory of embryological formation (pre-existence theory),[79] This conception of embryological development under the action of vital forces was then extended to nature and to history by the end of the century, most generally in a broader philosophical statement by Johann Gottfried von Herder (1744–1803). In his massive *Ideen zur Philosophie der Geschichte der Menschheit* (1784–91), Herder synthesised the historical cosmology of Kant and Lambert with Buffon's epochal history of nature into a dynamic developmental history progressing, rather than degenerating, under the action of an inherent vital genetic force (*genetische Kraft)*, modeled on Caspar Wolff's embryological force. In his integration of cosmology, natural history, and human history into one grand schema, Herder envisaged a slowly advancing naturalistic system leading progressively to contemporary European society.[80] This raised a critical discussion within German philosophy over the epistemic status of vital forces and their relation to a developmental history of nature that was to pit Kant against Herder and his disciples in a conflict that in important respects opposed Linnæan and Buffonian conceptions of natural history against one another. It also raised questions over the limits of reason that had been brought into prominence by Kant's project for a 'critical' metaphysics.

The concept of nature as a system of interconnected processes and entities with a history developing with some kind of purposive plan under the action of teleological forces forms a prominent feature of natural history at the end of the century. The speculative, vitalistic developmentalism of Herder represented one form of this turn of events. The systematic, rational philosophy of nature set forth particularly by Friederich Schelling (1775–1854) and his disciples formed another.[81] In opposition to both stood the critical history of nature of Immanuel Kant (1724–1804).

1. *History or description of nature?*

Kant's entry into the field of natural history and his concern with functional questions of biology were a direct outgrowth of his annual academic lectures on physical geography and anthropology, offered regularly from 1757 until 1798.[82] In these lectures he had evidently treated the 'theories of the earth' of Burnet and Woodward, the *De telluris* of Linnæus, the *Protogaea* of Leibniz, and Buffon's *Histoire naturelle*. He also was aware of other biological issues being debated in his time that were to have implications for his larger epistemology.[83] The continuation of these lectures before and through the critical period provides a framework for reading Kant's statements on natural history and the classification of the sciences in his better known philosophical treatises. Tracing the impact of these inquiries on the development of Kant's thought as he moved from his earlier standpoint in *Popularphilosophie* to the critical perspectives of his mature philosophy forms a topic of current research.[84]

As Kant's scientific reflections developed alongside his mature philosophy, he made an effort to reconcile his analysis of physical-geographic and natural-historical questions with the more general structure of his critical philosophy. Beginning with his 1775 summer lectures in anthropology, Kant introduced into his writings a technical distinction between a genetic history of nature that sought a causal connection between the situation at the present and events in the past (*Naturgeschichte*), exemplified particularly by Buffon's speculations and earlier 'theories of the earth,' and the Linnæan a-temporal classificatory description of natural objects (*Naturbeschreibung*).[85] In the wake of the conflicts with Herder and certain of his *Sturm und Drang* followers in the mid-1780s,[86] Kant developed these reflections further in important essays of the late 1780s, and in the *Kritik der Urtheilskraft* (1790). Herder's speculative synthesis was attacked by Kant severely in a series of reviews in 1785, and this critique was further elaborated in the conflict with Herder's admirer, the natural historian and ethnographer Johann Georg Forster (1754–94). In these controversies, Kant denied the status of a genuine science (*Wissenschaft*) to the 'history' of nature, to some extent agreeing with Newton, but on different conceptual grounds. *Naturgeschichte* was only an inquiry of Reason (*Vernunft*) in its speculative function, organized by a regulative idea of nature as a teleological system developing in time toward the final goal of human culture and moral freedom.[87] As Kant wrote in an important essay of 1788 generated by this controversy:

> This distinction [of history and description of nature] lies in the nature of things [der *Sachen Beschaffenheit*], and I demand nothing new, but merely the careful separation of one line of inquiry from the other. Because they are wholly heterogeneous, and if the one (description of nature [*Naturbeschreibung*]) appears as a science [*Wissenschaft*] in the full glory of a great system, the other (history of nature [*Naturgeschichte*]) can exhibit only fragments [*Bruchstücke*] or shaky [*wankende*] hypotheses. Through this distinction and presentation of the second as a separate science, even if for the present (and perhaps forever) it only can be realized in outline (and most questions perhaps only be answered with a blank), I hope to make sure that one does not accept a presumed insight into something in the one that simply belongs to the other.[88]

Within the restrictions of the critical philosophy, the conception of nature as a causal developing system creating changes over historical time, unifying geological and biological developments in the manner of Buffon and Herder, could only be an ideal construct, a guide into the classification, description, and mechanistic analysis of life. It could not be claimed to be a true story of the past in itself.[89]

In spite of these careful restrictions on the claims that could be made for such speculative organizing views, however, Kant's impact on the ensuing discussion was ambiguous. Some readers, typically dropping the purely regulative status of his formulations, read him through Herder's lenses, seeing Kant providing the framework for a comprehensive program for synthesising natural history and historical inquiry into a genuine science (*Naturwissenschaft*).[90] Others, more convinced of the epistemic limits placed upon historical knowledge of nature by

Kantian epistemology, confined their attention to a description of nature.[91] This emphasis on physiographic over physiogonic inquiry, and the conclusion that genuine scientific knowledge was to be confined to the analysis of empirically ascertainable patterns of distribution, rather than speculations about historical processes, was to be an important feature of the bio-geographical researches of Eberhard Zimmermann in his landmark *Geographische Geschichte des Menschen und der allgemeinen verbreiteten vierfüssigen Thiere* (1778–83).[92]

The project of Schelling's *Naturphilosophie*, first sketched out in his *Ideen für eine Philosophie der Natur* (1797) and his *Erster Entwurf eines System der Naturphilosophie* (1799), suggested, on the other hand, a more systematic combination of the description and history of nature. This tradition can be followed into British contexts through the writings of Samuel Taylor Coleridge and his medical disciple Joseph Henry Green (1791–1863).[93]

2. *French transformism*

The most direct development from Buffon's natural history to the theory of transformism took place at the Paris Muséum national d'histoire naturelle. This displayed a different form of interaction between the classificatory insights of Linnæus and his followers and the speculative, historical views of Buffon. Restored to a position of prominence in French life science at the Revolution, Linnæan methods and theories were even proclaimed as triumphant over the *ancien régime* natural history of Buffon in some quarters.[94] Sensing the necessity of rational systems but convinced of the value of the historical and bio-geographical insights of Buffon, many French naturalists made efforts to combine the two programmes.[95] Some chose to pursue the more speculative insights of the history of nature in this tradition. Exemplary among this group is Jean Baptiste de Lamarck. Originally encouraged to work in natural history by Buffon, Lamarck's first inquiries were in botany, exemplified by his *Flore françois* of 1778. In this work Lamarck sought to work out a true natural system of botanical arrangement.

Lamarck viewed the natural system in botany as an arrangement of plants in a continuous series, beginning with the least complex mosses and lichens, and ending in the complex flowering plants. This insight was then transferred to the zoological realm in part as the result of the radical reorganization of the Jardin du Roi into the Muséum National in 1793. Lamarck shifted career directions at this time from the study of plants to the study of the complex bloodless animals, which he proceeded to define on anatomical grounds as the 'animals without backbones'. Applying to these forms the same principle of the natural system he had developed in botany, he set forth in his lectures at the reorganized Paris

Muséum the presentation of the invertebrates as a natural sequence of forms arranged from the simplest polyps to the most complex squid and octopi. In his Muséum lectures of 1800 he first proposed that this natural order was also a dynamic historical order of genetic development of lower into higher forms, a thesis expanded in print in his *Considérations du corps organiques* (1802), the *Philosophie zoologique* (1809), and in a revised form in his major work, the *Histoire naturelle des animaux sans vertèbres* (1815–22). Drawing on contemporary French medical vitalism and his own work in phlogistic chemistry, Lamarck explained the ascending system of increasing complexity through the causation of the constructive powers of chemical and electrical fluids. These were able to create life spontaneously from matter and also were able to supply the efficient cause for the progress of life to greater degrees of organization. In these first truly transformist reflections, Lamarck denied the traditional fixity of organic species and proposed a general evolutionary picture of life that was to influence the nineteenth-century reflections in several important ways. Lamarck's Muséum colleague Etienne Geoffroy St. Hilaire developed somewhat similar reflections in laying out the evidence for a great 'unity of plan' uniting the vertebrates and invertebrates.

Developing matters in a different direction, Lamarck's fellow botanist at the Muséum, Antoine Laurent de Jussieu, proposed a 'natural' arrangement of plants that recognized their distribution into distinct natural groups, within which species could be arranged by a subordination of characters.[96] This principle was applied to zoology by the young Alsatian naturalist Georges Cuvier (1769–1832), who joined the Paris Muséum staff in 1795. Cuvier undertook a novel reclassification of the animal kingdom, dividing animals into discrete, disconnected major *embranchements* – molluscs, radiates, articulates, vertebrates – within which forms were arranged on the basis of the principle of the subordination of parts. Although generally critical of the speculative transformism of Lamarck and Geoffroy St. Hilaire,[97] Cuvier reflected his contact with the Buffonian tradition through his theory of the historical revolutions of the globe, developed in the preliminary discourse to his *Recherches sur les ossemens fossiles de quadrupèdes* (1812). As in Buffon's epochs, life displays a historical sequence, separated by major geological events, resulting in the extinctions of forms and different arrangements of fauna and flora at different historical epochs.

The end of the century also saw a growing emphasis upon more limited, professionalised inquiries. The quantity of materials available to workers at the major museums demanded specialized expertise and division of labour. The reorganization of the Paris Muséum at the Revolution into twelve professorships, each with responsibility for a separate domain of natural history, formed a new disciplinary model of organization of the inquiries which had traditionally constituted natural history, setting the stage for a wider disciplinary fragmentation of the subject.[98]

The change of focus from the natural history of the opening of the century to the botany, zoology, geology, comparative anatomy, and physiology at its end represented the triumph, at least within the professional organizations of science, of the more narrowly conceived experimental work of Kölreuter, Gärtner, and Spallanzani, the detailed inquiries into microscopic structure by Réaumur and Bonnet, the comparative anatomy of Daubenton, the ornithological studies of Mathurin Jacques Brisson (1723–1806), and the detailed local faunal studies of Eberhard Zimmerman, over the more speculative and theoretical tradition represented by Buffon.[99]

IV. FROM NATURAL HISTORY TO ANTHROPOLOGY

In terms of its general philosophical impact, the speculative tradition of natural history was important and even transformative for some prominent lines of philosophical reflection of the late Enlightenment. The willingness of natural historians and philosophers conversant with natural history – Herder, Kant, Rousseau, Monboddo, and Kames – to discuss the philosophy of the human sciences in relation to the work of the great philosophical natural historians of the century carried with it profound implications. No other area of inquiry more seriously threatened to undermine the philosophical project of Enlightenment philosophers, exemplified by David Hume's programme of 1739[100] to develop a secular 'science of man' that was to be built upon the concept of a uniform human nature presumed to serve as a secular foundation for politics and ethics. To this enterprise was opposed the evidence for the great variety of types, customs, beliefs, and geographical variations within the human species revealed by the expansion of natural history, employing the very process of empirical inquiry Hume had recommended.[101] The redefinition of 'anthropology' and the refocus of attention on the questions related to the 'natural history of man' in the latter part of the Enlightenment reflect this new level of concern. Kant, for example, inaugurated his own lectures on anthropology in 1772, splitting these off his lectures on physical geography. Furthermore, he was concerned to distance his project of a transcendental and 'moral' anthropology from the growing ethnographic and physical approach generated by the work of the philosophical physicians and natural historians.[102] His former student Johann Herder, on the other hand, openly sought to replace formal philosophical treatment of human beings with a cultural and historical anthropology and ethnography, explicitly developing on the reflections of Buffon, Rousseau, and the philosophical physicians.[103]

The impact of natural history on these philosophical developments in the human sciences can be followed through an examination of the question of the unity of the human species. Linnæus's struggles in the major revisions of the *Systema naturae* of 1744, 1748, 1758 and 1766, generated by the welter of reports of man-like apes, aborigines, feral children, and curious man-like creatures with tails living in the woods or in underground caves, revealed the issues besetting a classificatory approach to the question.[104] The massive quantity of new information on the geographical variations of the human species, summarized in the reports of naturalists accompanying major voyages of exploration in the latter half of the century, further complicated the assumed unity of human nature. If novel animals and plants seemed to form distinct species confined to distinctive fauna regions, could not human beings also be considered to form the same plurality of species? More closely in touch with the conclusions of the natural history of the day than Hume, Jean-Jacques Rousseau saw the solution to the great philosophical questions of ethics and politics in a 'conjectural history', describing the development of human beings to the state of civilization from more primitive 'men of the woods', apparently constructing his account of the original state of humanity upon the contemporary reports of the orang-outang of Borneo.[105] Whether Rousseau intended his treatise as a literal 'historical' account of the rise of human beings is a major interpretive issue in the text itself. For those who read Rousseau in a literal sense, it was not the discovery of a constant human nature that supplied the key to the moral and political questions of his age. Rather, the solution lay in a historical transformation of human nature, accompanied by a parallel physical transformism, in which man-like apes were changed over time into civilized humans. This historical account, claimed Rousseau, promised to resolve 'an infinity of moral and political problems which the philosophers cannot resolve'.[106]

For those unwilling to countenance Rousseau's slow transformation of human nature, the discoveries in natural history of the end of the century challenged the unity of the human species itself. Growing immediately from the efforts by naturalists to discriminate specific faunal and floral regions in response to the new bio-geographical data of the second half of the century, the period was presented with two competing interpretations that vied for acceptance. One interpretation, following Buffon's views, defended the unity and essential identity of the human species over time but admitted the possibility of permanent historical 'degenerations' within the species under the impact of differing climatic conditions, resulting in the production of permanent historical varieties within the human species. This concept underlay the concept of 'race' developed explicitly by Kant and Johann Blumenbach in the 1770s.[107] The other possibility, given its most influential scientific statement by the French naturalist

Jules Joseph Virey (1775–1847) in 1800, concluded that human beings formed distinct species, either created independently or derived separately by historical transformation from apes.[108] Although polygenism – the thesis of multiple species of human beings – was a venerable theory, dating particularly from the Pre-Adamite theory of Isaac de la Peyrère in the seventeenth century,[109] the new polygenism of the end of the century was developed on new grounds. It now claimed strong empirical warrant, and it was supported by the arguments of important natural historians. The 'anthropology' of the new century was forced as a result to deal with a wide range of issues generated by these speculations of the natural historians.

By the close of the century, natural history had clearly been transformed from a propaedeutic discipline, located among the sciences of memory in Bacon's classification of the sciences, into a dynamic programme of related researches, pursued at major scientific institutions and prosecuted with narrowing focus on detailed areas. It had also developed its own methodologies and forms of analysis distinct from those of the physical sciences. In this form it deeply affected the nineteenth century in both scientific and philosophical dimensions.

NOTES

1 See *The Cultures of Natural History*, eds. N. Jardine, J. Secord, and E. Spary (Cambridge, 1996).

2 William Ashworth, 'Emblematic Natural History of the Renaissance', in *The Cultures of Natural History*, eds. Jardine et al., 17–37; 'Natural History and the Emblematic World View', in *Reappraisals of the Scientific Revolution*, eds. D. C. Lindberg and R. S. Westman (Cambridge, 1990), 303–32.

3 See Vladimir Jankovic, *Reading the Skies: A Cultural History of English Weather, 1650–1820* (Chicago, IL, 2000), chs. 4–5. See also Lesley B. Cormack, '"Good Fences Make Good Neighbors": Geography as Self-Definition in Early Modern England', *Isis* 82 (1991), 639–61; David Elliston Allen, *The Naturalist in Britain: A Social History* (London, 1976), esp. ch. 1.

4 See Allen, 'Natural History in Britain in the Eighteenth Century', *Archives of Natural History* 20 (1993), 333–47, for an overview of the social history dimensions. See also W. P. Jones, 'The Vogue of Natural History in England, 1750–1770', *Annals of Science* 2 (1937), 332–56.

5 A primary title citation list generated by computer gives 685 works with these terms in the title, including duplicates and new editions.

6 Francis Bacon, *Preparative Towards a Natural and Experimental History: Aphorisms on the Composition of the Primary History*, in *Works*, eds. J. Spedding, R. L. Ellis, and D. D. Heath, 14 vols. (London, 1857–74), 4: 253.

7 On the concept of 'style' in science, see symposium in *Science in Context* 4 (1991), 223–447.

8 Harold Cook, 'Physicians and Natural History', *Cultures of Natural History*, eds. Jardine et al., 91–105; Andrew Cunningham, 'The Culture of Gardens', in same, 38–56; Karen M. Reeds, *Botany in Medieval and Renaissance Universities* (New York, NY and London, 1991).

9 Allen, *The Naturalist in Britain*, ch.1.

10 Daniel Roche, 'Natural History in the Academies', in *Cultures of Natural History*, eds. Jardine et al., 127–44; Alice Stroup, *A Company of Scientists: Botany, Patronage, and Community at the Seventeenth-century Parisian Royal Academy of Sciences* (Berkeley, CA, 1990), esp. ch. 6.
11 Allen, *Naturalist in Britain*, ch. 1: 'Natural History in Britain'.
12 See Paula Finlen, 'Courting Nature', in *Cultures of Natural History*, eds. Jardine et al., 57–74, for the early background of this tradition.
13 On this notion of the natural history museum as a centre of geographical control, see Bruno Latour, *Science in Action* (Cambridge, MA, 1987), ch. 6, and Emma Spary, *Utopia's Garden: French Natural History from Old Regime to Revolution* (Chicago, IL, 2000), ch. 2.
14 Christopher Fox, 'How to Prepare a Noble Savage: The Spectacle of Human Science', in *Inventing Human Science: Eighteenth Century Domains*, eds. C. Fox, R. Porter, and R. Wokler (Berkeley and Los Angeles, CA, 1995), 1–30.
15 Scott Atran, *Cognitive Foundations of Natural History* (Cambridge, 1990), chs. 6–7; James L. Larson, *Reason and Experience: The Representation of Natural Order in the Work of Carl von Linné* (Berkeley, CA, 1971), ch. 1; and Phillip R. Sloan, 'John Locke, John Ray and the Problem of the Natural System', *Journal of the History of Biology* 5 (1972), 1–53.
16 John Ray, *Synopsis methodica animalium quadrupedum et serpentini generis* (London, 1693) 53, 60; *Synopsis methodica avium & piscium*, ed. W. Derham (London, 1713).
17 Gunnar Broberg, '*Homo sapiens*: Linnaeus's Classification of Man', in *Linnaeus: The Man and His Work*, ed. T. Frängsmyr (Berkeley, CA, 1983), 156–94, and P. R. Sloan, 'The Gaze of Natural History', in *Inventing Human Science*, eds. Fox et al., 112–51.
18 On the spread of linnæanism, see Frans Stafleu, *Linnaeus and the Linnaeans: The Spreading of Their Ideas in Systematic Botany, 1735–1789* (Utrecht, 1971); Allen, 'Natural History in Britain,' esp. 342–3; Lisbet Koerner, 'Carl Linnaeus in His Time and Place', in *Cultures of Natural History*, eds. Jardine et al., 145–62.
19 For an exception see J. L. Larson, 'An Alternative Science, Linnæan Natural History in Germany, 1770–1790', *Janus* 66 (1979), 267–83.
20 The most theoretically interesting of these are Linnæus's *Oratio de telluris habitabilis incremento* (Leyden, 1744); and the dissertations of Isac J. Biberg, *De Oeconomia naturæ* (Uppsala, 1749); H. C. D. Wilcke, *De Politia naturae* (Uppsala, 1760); and Christian Hoppius, *Anthropomorpha* (Uppsala, 1760). Linnæus is estimated by Stafleu to have had over 186 pupils under his immediate supervision during his teaching career at Uppsala between 1741 and 1776 (Stafleu, *Linnaeus and Linnaeans*, 143).
21 Jean-Jacques Rousseau, *Lettres élémentaires sur la botanique* (Paris, 1789), first appearing as letters in J. J. Rousseau, *Collection complète des oeuvres de J. J. Rousseau* (Geneva, 1782). The first publication as a separate monograph is in the English version edited by Thomas Martyn as *Letters on the Elements of Botany, Addressed to a Lady* (London, 1785), to which had been added twenty-four additional letters by Martyn explaining the Linnæan system.
22 Carl von Linné, *Praelectiones in ordines naturales plantarum*, eds. J. C. Fabricius and P. D. Giseke (Hamburg, 1792).
23 J. C. Beaglehole, 'Eighteenth Century Science and the Voyages of Discovery', *New Zealand Journal of History* 3 (1969), 107–23. On the work of Harrison and longitude, see *The Quest for Longitude*, ed. W. J. H. Andrewes (Cambridge, MA, 1996).
24 See Michèle Duchet, *Anthropologie et histoire au siècle des lumières* (Paris, 1995), chs. 2–3; Alan Frost, 'The Pacific Ocean: The Eighteenth Century's "New World"', *Studies on Voltaire and the Eighteenth Century* 152 (1976), 779–822; Sloan, 'The Gaze of Natural History,' esp. 133–9.
25 On the concept of centres of creation, see Larson, *Interpreting Nature: the Science of Living Form from Linnaeus to Kant* (Baltimore, MD, 1994), 27.

26 See Janet Browne, *The Secular Ark: Studies in the History of Biogeography* (New Haven, CT, 1983), chs. 1–3.
27 René Descartes, *Principles of Philosophy*, trans. V. R. Miller and R. P. Miller (Dordrecht, 1983), Pt. 4, princ. 44, p. 203.
28 Descartes, *Principles*, Pt. 3, princ. 45, pp. 105–6.
29 Paolo Rossi, *The Dark Abyss of Time: The History of the Earth & the History of Nations from Hooke to Vico*, trans. L. G. Cochrane (Chicago, IL, 1984), ch. 7.
30 William Whiston, *A New Theory of the Earth, From its Original, to the Consummation of All Things* (London, 1696).
31 Isaac Newton, *Opticks: or, A Treatise of the Reflections, Refractions, Inflections and Colours of Light*, 3rd edn. (London, 1721), Qu. 31, 350–82. See Rossi, *Dark Abyss*, ch. 8, 41–49. See also David Kubrin, 'Providence and the Mechanical Philosophy: The Creation and Dissolution of the World in Newtonian Thought. A Study of the Relations of Science and Religion in Seventeenth Century England' (unpublished PhD dissertation, Cornell University, 1968), chs. 8–11.
32 Important eighteenth-century works on the theory of the earth in the period before Buffon's writings include John Woodward's influential, *An Essay toward a Natural History of the Earth and Terrestrial Bodies* (London, 1695; 2nd edn., 1702; Latin, 1714; 3rd English edn., 1723; French edn., Amsterdam 1735); Leibniz's 1693 prospectus of his later *Protogaea* in *Histoire de l'Académie Royale des Sciences*, Année MDCCVI . . . (Paris, 1707), 10–11; Louis Bourguet's 'Mémoire sur la théorie de la terre', in his *Lettres philosophiques sur la formation des sels et des cristaux* (Amsterdam, 1729); and Henri Gautier's *Nouvelles conjectures sur le globe de la terre* (Paris, 1721). On the general character of the pre-Buffonian context see François Ellenberger, 'Les sciences de la terre avant Buffon: bref coup d'oeil historique', in *Buffon 88: Actes du Colloque international 1988*, ed. J. Gayon (Paris, 1992), ch. 21, 327–42; Gabriel Gohau, 'La "Théorie de la terre", de 1749', in the same, ch. 22, 343–520, and François Ellenberger, 'A l'aube de la géologie moderne: Henri Gautier (1660–1737),' Pt. 1, *Histoire et nature* 7 (1975), 3–58; Pt. 2, *Histoire et nature* 9–10 (1976–7), 3–142.
33 I emphasize that my concern here is with the genetic history of the earth, and not with actualist theories of geology as they were developed by Gautier and others.
34 For an alternative view, see Paolo Casini, 'Buffon et Newton', in *Buffon 88*, ed. Gayon, ch. 19, 299–308.
35 Stephen Hales, *La Statique des végétaux et l'analyse de l'air*, trans. G.-L. L. Buffon (Paris, 1735).
36 Roger, *Buffon*, chs. 5–6; and Lesley Hanks, *Buffon avant l'Histoire naturelle* (Paris, 1966).
37 Isaac Newton, *La Méthode des fluxions, et des suites infinies* [trans. G.-L. L. Buffon.] (Paris, 1740).
38 A complete listing of these papers is to be found in 'Bibliographie de Buffon', compiled by E. Genet-Varcin and Jacques Roger, in Buffon, *Oeuvres philosophiques*, ed. J. Piveteau (Paris, 1954), 513–75.
39 See Michael Heyd, *Between Orthodoxy and the Enlightenment: Jean-Robert Chouet and the Introduction of Cartesian Science in the Academy of Geneva* (The Hague, 1983), esp. ch. 7.
40 Lorraine J. Daston, *Classical Probability in the Enlightenment* (Princeton, NJ, 1988).
41 Jacques Roger, *Buffon: A Life in Natural History*, trans. S. L. Bonnefoi (Ithaca and London, 1997), ch. 6. See also Sloan, 'From Logical Universals to Historical Individuals: Buffon's Conception of Biological Species', in *Histoire du concept d'espèce dans les sciences de la vie*, eds. J. Roger and J.-L. Fischer (Paris, 1987), 101–40 at 109–18.
42 Roger, *Buffon*, ch. 9.
43 See William H. Barber, *Leibniz in France, from Arnauld to Voltaire; a Study in French Reactions to Leibnizianism, 1670–1760* (Oxford, 1955). See also Sloan, 'L'hypothétisme de Buffon: sa

place dans la philosophie des sciences du dix-huitième siècle', in *Buffon 88*, ed. Gayon, 207–22.

44 Gottfried Wilhelm Leibniz, 'Third Paper' and 'Fifth Paper', in *The Leibniz-Clarke Correspondence*, ed. H. G. Alexander (Manchester, 1956), 25–6, 90.

45 Jean-Henri-Samuel Formey, *La belle Wolfienne* (The Hague, 1741); Emerich de Vattel, *Défense du Système leibnitien contre les objections et les imputations de Mr. de Crousaz*. ... (Leiden, 1741); and especially Jean des Champs, *Cours abrégé de la philosophie wolffienne, en forme de lettres*, 2 vols. (Amsterdam and Leipzig, 1743–7).

46 Letter of Claude Hélvetius to Mme du Châtelet, December, 1740, as quoted in *Les Lettres de la Marquise du Châtelet*, ed. T. Besterman, 2 vols. (Geneva, 1958), 2: 36n.

47 Linda G. Janik, 'Searching for the Metaphysics of Science: The Structure and Composition of Madame Du Châtelet's *Institutions de Physique*, 1737–1740', *Studies on Voltaire and the Eighteenth Century* 201 (1982), 85–113.

48 Du Châtelet, *Institutions de physique* (Paris, 1740), ch. 6, §102, p. 119.

49 Descartes, *Le monde de René Descartes ou traité de la lumière*, in *Oeuvres*, eds. C. Adam and P. Tannery, 11 vols. (Paris, 1897–1910), 11: 36–7. See James E. McGuire, 'Boyle's Conception of Nature', *Journal of the History of Ideas* 33 (1972), 523–42; and Jean Ehrard, *L'idée de nature en France dans la première moitié du XVIII siècle* (Paris, 1970), ch. 2: 'Le mécanisme universel'.

50 Ehrard, *L'idée*, ch. 3: 'Impulsion ou attraction?' On the revival of the nature philosophy of the Cambridge Platonists in the early decades of the century, see Roger, *The Life Sciences in Eighteenth-Century French Thought*, ed. K. R. Benson, trans. R. Ellrich (Stanford, 1997), 336–53.

51 Gottfried W. Leibniz, 'On Nature Itself, or On the Inherent Force and Actions of Created Things', *Acta eruditorum*, Sept. 1698, as trans. by L. E. Loemker in Leibniz, *Philosophical Papers and Letters*, 2nd edn. (Dordrecht, 1969), 498–508.

52 Du Châtelet, *Institutions*, ch. 7, §161, 174. Compare this definition to that in Buffon's 'De la nature, première vue', *Histoire naturelle, générale et particulière avec la description du cabinet du roi*, 14 vols. (Paris, 1749–67), 12: iii–xvi (1764), reprinted in *Oeuvres phil.*, 31–35 at 31.

53 Leibniz, *Protogaea: De l'aspect primitif de la terre et des traces d'une histoire très ancienne que renferment les monuments mêmes de la nature* (Latin and French text), trans. B. de Saint-Germain, ed. J.-M. Barrande (Toulouse, 1993), 13.

54 See, for example, des Champs, *Cours abrégé*, letter 20, 1: 235–77 at 236–7.

55 Des Champs, letter 19, 1: 232.

56 An important exception to this is Benoît de Maillet's Epicurean-inspired *Telliamed, ou Entretiens d'un philosophe indien avec un missionaire françois sur la diminution de la mer* (Amsterdam, 1748), written between 1698 and 1718 and circulated in manuscript. On the history of the text see Albert V. Carozzi, 'Introduction' to *Telliamed or Conversations Between an Indian Philosopher and a French Missionary on the Diminution of the Sea*, trans. and ed. A. V. Carozzi (Urbana, IL, 1968), esp. 5–24.

57 Bourguet, 'Memoire sur la theorie de la terre,' *Lettres philosophiques*, 177–220. On Bourguet see François Ellenberger, 'Louis Bourguet', *Dictionary of Scientific Biography*, ed. C. C. Gillispie (New York, NY, 1970–80): *Supplement* (1978) 15: 52–9. On Buffon's relation to Bourguet, see Roger, *Buffon*, 99–103.

58 Many of Buffon's distinctions on these issues are closely similar to those in des Champs, *Cours abrégé*, letter 21, 1: 248–61 at 248–51. See also letter 19, 1: 223–34.

59 Buffon, 'Premier discours (2): de la manière d'étudier et de traiter l'histoire naturelle', *Histoire naturelle* 1, 3–62 (repr. in *Oeuvres phil.*, 7–26 at 23–5); translated as *From Natural History to the History of Nature: Readings from Buffon and His Critics*, trans. and eds. J. Lyon and P. R. Sloan (Notre Dame, IN, 1981), 89–128. For discussion see Roger, *Buffon*, ch. 2.

60 Buffon, 'Premier discours', in *Oeuvres phil.*, 23–4.
61 Hume, *Enquiry Concerning Human Understanding* (1748), ed. T. L. Beauchamp in the *Clarendon Edition* (2000), especially Pt. 3. There is no direct evidence that Buffon had read either this treatise or the *Treatise on Human Nature* of 1739–40.
62 Roger, *Buffon*, 426.
63 On Buffon's 'actualism' in this period see Gohau, 'La 'Théorie de la terre' en 1749', in *Buffon 88*, ed. Gayon, 348–51.
64 Buffon, 'De la nature: première vue', *Histoire naturelle* 12 (in *Oeuvres phil.*, 31).
65 Buffon, 'L'Asne', *Histoire naturelle* 4 (1753) (in *Oeuvres phil.*, 353–8 at 355). See also the earlier 'De la Reproduction en général', *Histoire naturelle* 2 (1749) (in *Oeuvres phil.*, 238–64 at 238). On Buffon's species concept, see Sloan 'From Logical Universals,' 101–40; Jean Gayon, 'L'individualité de l'espèce: une thèse transformiste?' in *Buffon 88*, ed. Gayon, 475–89; and Paul L. Farber, 'Buffon's Concept of Species', *Journal of the History of Biology* 5 (1972), 259–84.
66 'Espèce: histoire naturelle', in *Encyclopédie*, 5: 956–7.
67 Buffon, 'La Brebis' and 'La Chèvre', *Histoire naturelle* 5 (1755); see *Oeuvres phil.*, 359.
68 Buffon, 'Le Cerf', *Histoire naturelle* 6 (1756).
69 Buffon, 'De la dégéneration des animaux', *Histoire naturelle* 14 (1766); see *Oeuvres phil.*, 394.
70 See especially Pietro Corsi, *The Age of Lamarck*, trans. J. Mandelbaum (Berkeley, CA, 1988), esp. ch. 1.
71 Buffon's source for much of this information was Antoine François Prévost d'Exiles, *Histoire générale des voyages, ou, Nouvelle collection de toutes les relations de voyages qui ont été publiées jusqu'à présent*, 20 vols. (Paris, 1746–70), a work appearing almost in parallel to the *Histoire naturelle.*
72 Claudine Cohen, *Le destin du mammouth* (Paris, 1994), chs. 4–5; John L. Greene, *The Death of Adam: Evolution and Its Impact on Western Thought* (Ames, IA, 1959), ch. 4.
73 See Larson, *Interpreting Nature*, ch. 4, and also, 'Not without a Plan: Geography and Natural History in the Late Eighteenth Century', *Journal of the History of Biology* 19 (1986), 447–88.
74 Buffon, *Des Époques de la Nature* in *Histoire naturelle*: Supplément vol. 5 (Paris, 1778), as in Buffon, *Les époques de la nature* (critical edn.), ed. J. Roger (Paris, 1962), 2–3, (reissued Paris, 1988), 4. See also *Oeuvres phil.*, 117–229 at 117–8. The work actually was published in 1779.
75 Buffon, *Époques*, Sixième époque, 212 (Roger edn., 192; *Oeuvres phil.*, 183).
76 See the exhaustive discussion of these chronologies in the introduction to the Roger edition of *Époques*, lx–lxvii.
77 I am deeply indebted for some of these insights to Peter Hanns Reill's *Vitalizing Nature in the Enlightenment* (University of California Press, 2005), although we disagree on the degree to which Buffon can be classed as a 'vitalist'. See also John Zammito, *Kant, Herder, and the Birth of Anthropology* (Chicago, IL, 2002), ch. 8; François Duchesneau, *La Physiologie des lumières: empirisme,modèles et theories* (The Hague, 1982), chs. 8–10; and Roger, *Life Science*, 336–53.
78 On the distinction between 'mechanistic' and 'materialistic' Newtonianism, see Robert E. Schofield, *Mechanism and Materialism: British Natural Philosophy in an Age of Reason* (Princeton, NJ, 1970).
79 See Shirley A. Roe, *Matter, Life and Generation: Eighteenth-Century Embryology and the Haller-Wolff Debate* (Cambridge, 1981).
80 See Zammito, *Kant, Herder, and the Genesis of Kant's Critique of Judgment* (Chicago, IL, 1992) ch. 9; Owsei Temkin, 'German Concepts of Ontogeny and History around 1800', *Bulletin of the History of Medicine* 24 (1950), 227–46; Reill, 'The History of Science, the Enlightenment

and the History of "Historical Science" in Germany', in *Beiträge zur Geschichtskultur* 5 (1991), 214–31, esp. 222–28.

81 On the distinctions between these two programmes, I am particularly indebted to Peter Reill's *Vitalizing Nature in the Enlightenment* (see note 77).

82 Kant's anthropology lectures were separated from the physical geography lectures in 1772–3.

83 On Kant's sources see Erich Adickes, *Kants Ansichten über Geschichte und Bau der Erde* (Tübingen, 1911). For a recent analysis of Kant's relations to Buffon, see Jean Ferrari, 'Kant, lecteur de Buffon', in *Buffon 88*, ed. Gayon, 155–63.

84 Zammito, *Kant and Herder*, esp. chs. 3, 7. See also my 'Preforming the Categories: Eighteenth-Century Generation Theory and the Biological Roots of Kant's *A-Priori*,' *Journal of the History of Philosophy* 40 (2002), 229–253.

85 Kant, 'Von den verschiedenen Racen der Menschen', in Ak 2: 429–43. An English translation of the revised 1777 version of this prospectus is given in 'Immanuel Kant, "Of the Different Human Races"', trans. J. M. Mikkelsen, in *The Idea of Race*, eds. R. Bernasconi and T. Lott (Indianapolis, IN, 2000), 8–26.

86 On the Herder conflict, see Zammito, *Genesis*, chs. 8–9.

87 See Rudolf A. Makkreel, 'Kant and the Interpretation of Nature and History', *Philosophical Forum* 21 (1989–90), 169–81.

88 Kant, 'Über den Gebrauch teleologischer Principien in der Philosophie'(1788), in Ak 8: 157–84 at 162, translation my own. The first full English translation of this text is found in 'On the Use of Teleological Principles in Philosophy', in *Race*, ed. R. Bernasconi (Malden, MA, and Oxford, 2001), 37–56.

89 See esp. Kant, *Kritik der Urtheilskraft*, Pt. 2, §80 (Ak 5: 417–22); translated as *Critique of the Power of Judgment*, trans. P. Guyer and E. Matthews, ed. P. Guyer, in *Works* (2000).

90 See, for example, Christoph Girtanner, *Ueber das Kantische Prinzip für die Naturgeschichte: ein Versuch diese Wissenschaft philosophisch zu behandeln* (Göttingen, 1796).

91 This seems to be important for understanding the primarily physiographic approach of Alexander von Humboldt. On this see J. A. May, *Kant's Concept of Geography and Its Relation to Recent Geographical Thought* (Toronto, 1970), 75–9. However, others have seen Humboldt as deeply interested in the integration of description and history of nature. See on this Michael Dettlebach, 'Introduction' to Alexander von Humboldt, *Cosmos*, trans. E. C. Otté (Baltimore, MD, 1997), 2: (esp.) xxix–xxxviii.

92 See Larson, *Interpreting Nature*, ch. 4.

93 See discussion and relevant Green texts in Richard Owen, *The Hunterian Lectures in Comparative Anatomy, May–June 1837*, ed. P. R. Sloan (Chicago, IL and London, 1992), 307–21.

94 Pietro Corsi, *The Age of Lamarck*, ch. 1; Spary, *Utopia's Garden*, ch. 5. Linnæus's botanical system had already been established in practice at the Jardin in the 1770s, but was most deeply influential on the provincial academies until the Revolution. See Pascal Duris, *Linné et la France, 1780–1850* (Geneva, 1993).

95 See Georges Cuvier, 'Prospectus', *Dictionnaire des sciences naturelles . . . par plusieurs professeurs du Jardin du Roi*, 60 vols. (Strasbourg and Paris, 1816–30), 1: vii. On the complex history of this text, first issued in part in 1804–5, see Corsi, *Age of Lamarck*, 220–1.

96 Antoine-Laurent de Jussieu, *Genera plantarum . . . secundum ordines naturales disposita . . .* (Paris, 1789).

97 Toby Appel, *The Cuvier-Geoffroy Debate: French Biology in the Decades before Darwin* (New York, NY, 1987).

98 See Appel, *Cuvier-Geoffroy Debate*, 13–19 and 'Appendix A,' 238–40; On the history of the Muséum, see symposium *Le Muséum au premier siècle de son histoire*, eds. C. Blanckaert et al. (Paris, 1997).

99 Larson, *Interpreting Nature*, ch. 3.
100 David Hume, *A Treatise of Human Nature* (1739–40), eds. D. F. Norton and M. J. Norton (Oxford, 2006), Introduction, 4–6 (SBN xx). On Hume's subsequent struggles with polygenecism, see John Immerwahr, 'Hume's Revised Racism', *Journal of the History of Ideas* 53 (1992), 481–6. See also Zammito, *Kant, Herder*, ch. 5.
101 See Peter J. Marshall and Glyndwr Williams, *The Great Map of Mankind: Perceptions of New Worlds in the Age of Enlightenment* (Cambridge, MA, 1982), ch. 9.
102 Zammito, *Kant, Herder*, esp. 292–307.
103 Zammito, *Kant, Herder*, ch. 8.
104 See Sloan, 'The Gaze of Natural History,' 121–6. Linnæus first proposed his new species *Homo troglodytes* in the tenth edition of the *Systema naturae* of 1758.
105 See Rousseau, *Discours sur l'origine et les fondemens de l'inégalité parmi les hommes*, in *Oeuvres*, 3: Note X, 208–14. See also Francis Moran, 'Pongos and Men in Rousseau's *Discourse on Inequality*', *Review of Politics* 57 (1995), 641–64; and R. Wokler, 'Anthropology and Conjectural History in the Enlightenment', *Inventing Human Science*, eds. Fox et al., 31–52.
106 Rousseau, *Discours*, 192.
107 See Robert Bernasconi, 'Who Invented the Concept of Race? Kant's Role in the Enlightenment Construction of Race,' *Race*, ed. Bernasconi, 11–36.
108 Julien-Joseph Virey, *Histoire naturelle de genre humain, ou, recherches sur les principaux fondements physiques et moraux, precedées d'un discours sur la nature des êtres organiques*, 2 vols. (Paris, 1801), 1: 91. On Virey, see especially C. Blanckaert, 'J. J. Virey, observateur de l'homme (1800–1825)', in *Julien-Joseph Virey: naturaliste et anthropologue*, eds. C. Benichou and C. Blanckaert (Paris, 1988), 97–182.
109 Richard H. Popkin, *Isaac la Peyrère (1596–1676): His Life, Work and Influence*, (Leiden, 1987), ch. 9.