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Chapter 27: Aristotelianism and its Alternatives

Section I: The Organisation of Knowledge at Commencement of the Scientific Revolution

One way of approaching the period of the Scientific Revolution is to examine how the field of natural knowledge was organised at the time and how it changed during the course of the period. This requires attention to how contemporaries envisioned this organisation in ideal terms and how the pursuit of natural knowledge was accomplished in practice. Ideal visions and actual practices interacted in complex ways, and both underwent considerable changes during the period. By tracking these changes one can obtain insight into the process of the Scientific Revolution itself and hints toward explaining why it occurred.

Of course, ideals of the organisation of knowledge were contested at the time, and different historians emphasise different aspects. The approach here starts from the recognition that in practice, and often in theory, the central category of natural inquiry was 'natural philosophy', 'the philosophy of nature', and that throughout most of the period under discussion here, one species of natural philosophy, Scholastic Aristotelianism, was dominant institutionally and in the cultural experience of educated men. The hegemony of Aristotelianism was reflected not only at the level of specific natural philosophical claims, but in the pervasive way in which Aristotelianism dictated an entire geography of knowledge. It framed the way in which virtually all disciplines were conceived, and related to each other, whether, like metaphysics or theology, they were superior to natural philosophy, or, like the various types of history or mixed mathematical fields, they were taken to be 'subordinate' to it. This fact is especially important, since Aristotelianism provided a template for the design of competing species of natural philosophy, and so the geography of knowledge it entailed tended to be replicated by competing systems of natural philosophy.

Aristotelian natural philosophy had many varieties, but considered as a general type had certain structural characteristics. These were impressed upon students of any variant. The structure of natural philosophical theorising characteristic of Aristotelianism also formed a template that was deployed in the construction of alternative types of natural philosophy. Christianised Aristotelianism (as well as its early modern competitors) purported to describe and explain the entire universe and the relation of that universe to God, as conceived in the particular version of theology embraced by a given author. The enterprise also involved, explicitly or implicitly, a concern with the place of human beings and society in that universe. So, Aristotelianism (and indeed all systems that came to contest its hegemony) rested on four structural elements. These were: (1) A theory of substance (material and immaterial), concerning what the cosmos consists in, what kinds of bodies or entities it contains: In the case of Aristotelianism we have the doctrines of matter and form articulating to his theory of the five elements, four terrestrial and one celestial. (2) A cosmology, an account of the macroscopic organisation of those bodies: In the case of Aristotelianism the finite, geocentric cosmos, a nest of concentric spheres of fifth element, bearing around the central, immobile earth, the stars, planets, sun and moon. (3) A theory of causation, an account of how and why change and motion occur: In the case of Aristotelianism the doctrine of the four causes needed for a complete explanation, material, formal, efficient and final (4) An epistemology and doctrine of method which purported to show how the discourses under (1), (2) and (3) were arrived at and/or how they could be justified, and how they constitute a system: In the case of Aristotelianism the doctrine of scientific method derived from the Posterior Analytics and other logical works, emphasising arriving at principles and causes by means of operating on particulars; and explanation of particulars by means of universal statements expressing causes and principles.

Additionally, at the basis of any system of natural philosophy resided one or more privileged images, metaphors or models. Accordingly, at the basis of all the varieties of Scholastic

Aristotelianism there resided a number of related metaphors, which we may anachronistically term biological in their content and tenor. [338] Aristotelianism fundamentally envisioned nature as a hierarchy of qualitatively different types of being, or substance, each individual member of which pursues natural inner directed goals during the course of its finite existence. All natural as opposed to artificially caused change takes the form a finite process toward the realisation of goals present initially as mere potential in the being undergoing change. This holds exactly the same for an acorn growing into an oak as for the natural motion of a falling stone, expressing its heaviness and moving toward the goal of rest, closer to the center of the earth, which is the center of the cosmos. This orientation is linked to Aristotelian natural philosophy's lack of concern with highly contrived experiment or with the teachings of human crafts and material practice. In these situations the natural processes of substances are interrupted, distorted, forced along paths unlike their natural trajectories of change. The likelihood of enriching natural philosophical knowledge in this manner is, accordingly, negligible.

Aristotle's [384-322 B.C.E.] concept of natural philosophy had important implications for the range of more narrow disciplines seeking knowledge of nature, from histories of animals and plants through mathematically articulated disciplines such as optics and astronomy. To understand them, we need first to consider two other knowledge domains from an Aristotelian perspective: mathematics and metaphysics. According to Aristotelians, natural philosophy deals with those things that change and exist independently of us. Natural philosophy studies the naturally occurring types of substances, as well as the causal relations binding them into an ordered whole or cosmos. Mathematics, by contrast, deals with those things that do not change but have no existence independently of us, since geometrical figures and numbers, despite the opinion of Plato [428-348 B.C.E.], exist only in our minds. Hence, for Aristotelians a natural philosophical account of something dealt typically with issues of matter and causation, whereas a mathematical account of something required a wholly different kind of explanation, invoking principles appropriate to the nature of mathematical entities, that is, figures or numbers.

Metaphysics, a more fluid term in the usage of Aristotelians, and subsequent philosophers, means in this simplified Aristotelian context the study of those things that exist independently of us and do not change. Literally meaning 'after physics' or natural philosophy, the term meant the broad, abstract prior analysis of the constitutive categories used in both natural philosophy and mathematics, as in the analysis of matter, cause, space or time, as well as issues about the ontological status and knowability of these general concepts.

We can now turn to the specialised disciplines Aristotle and his Scholastic followers recognised as subordinate to natural philosophy. The most important category of such disciplines were the 'mixed', or 'subordinate', mathematical sciences, such as optics, astronomy and mechanics, the study of the simple machines. These disciplines are intermediate between natural philosophy and mathematics. For example, for Aristotelians, the investigation of the physical nature of light and its physical properties would fall straightforwardly under natural philosophising, an issue of invoking appropriate principles of matter and cause. In contrast, the mixed mathematical science of geometrical optics 'investigates mathematical lines, but *qua* physical, not *qua* mathematical.' Geometrical optics studied ray diagrams, in which geometrical lines represented rays of light, and phenomena such as the reflection and refraction of light were dealt with in a descriptive, mathematical manner, which was, according to Aristotle, incapable of providing proper explanations, dealing with the physical nature, properties and causal behaviour of light.

The question of the relation between the mixed mathematical disciplines, on the one hand, and the 'superior' discipline of natural philosophy, which did the real explanatory work on this conception, was thus dominated by the entrenched Scholastic viewpoint. However, as the competition amongst differing approaches to natural philosophy heated up in the early

Seventeenth century, many natural philosophers hostile to Aristotelianism proposed a more central explanatory role for mathematics in natural philosophy, and sophisticated Scholastic Aristotelians also began to loosen the Aristotelian marginalisation of mathematics as non-explanatory.

Consider geometrical astronomy, the exemplary case of a mixed mathematical science. It was routinely held to lack the explanatory power of natural philosophy because it did not deal with the material and causal principles of planetary motion, but merely with appearance-saving geometrical models. Thus, the fine details and elaborate geometrical tools of Ptolemaic astronomy fell outside any plausible realistic interpretation, and hence outside any natural philosophical gloss. However, the fundamental concepts of Claudius Ptolemy's [ca. 100-ca. 170] astronomy were clearly shaped by Aristotelian natural philosophy: the finite earth-centred cosmos, the distinction between the celestial and the terrestrial realms, the primacy of uniform circular motion. Therefore, it is quite clear that even in the relations of Aristotelian natural philosophy to Ptolemaic geometrical astronomy, there were linkages of a causal and matter theoretical nature that grounded the geometrical astronomy and linked it to its 'parental' natural philosophy. Admittedly this was a thin conceptual linkage, but nevertheless a real one. When, in the later sixteenth and early seventeenth centuries, Copernican astronomy came to be hotly debated, it was not as a set of new calculational fictions, but rather as a system with realistic claims about the physical structure and causal regime of the cosmos, implying the need for a framework of non-Aristotelian natural philosophy, a new theory of matter and cause, adequate to justifying its existence and explaining its physical mechanisms.

However, the fit of a natural philosophy over a mixed mathematical science could be much looser than the Copernican example implies. As just noted, under Aristotelianism geometrical optics consisted largely in geometric ray diagrams, their rules of construction and a set of canonical puzzles, such as the behaviour of mirrors, the rule governing refraction, the explanation of the rainbow and other curious optical effects. Broadly speaking, virtually any natural philosophical theory of matter could have been used to provide an explanatory 'voice over' for this science, from Scholastic 'propagation of species', through the transport of atoms or the propagation of neo-Platonic immaterial substances, to the mechanists' passage of light corpuscles or propagation of mechanical pressures or tendencies to motion in a medium. Only later, during the critical phase of the Scientific Revolution, in the optical work of Johannes Kepler [1571-1630] and René Descartes [1596-1650], was there sought a closer interaction between optical theorising and problem solving, on the one hand, and natural philosophical explanations, on the other. [339] That is, new natural philosophical theories of matter and cause were taken more intimately to control technical details in geometrical optics, and in turn, technical details in geometrical optics exerted pressure on the exact nature of those natural philosophical claims about matter and cause.

Section II: The Competing Programs of Knowledge 1590-1650

Between roughly 1590 and 1650 alternative natural philosophies corrosive of Aristotelianism proliferated. By the middle decades of the Seventeenth century the cultural dominance of Aristotelianism collapsed (although it continued to reign supreme in most universities for another generation). After 1650 the mechanist philosophy of nature, in several variants, became the dominant form, and, after a period of consolidation and institutionalisation in the third quarter of the seventeenth century, the mechanical philosophy was modified and partly displaced by the post-mechanist philosophy of Isaac Newton [1642-1727], in which the concept of force and of immaterial causal entities, such as gravity, played a renewed role. Seen this way, the Scientific Revolution is less a rupture from a decadent, 'Medieval' Scholastic Aristotelian to a new 'modern' Science, than an extended process of change and transformation in the pan-European culture of natural philosophy.

Many of the early challengers to Scholastic Aristotelianism had a basis in neo-Platonism, often tinged with magical, alchemical and Hermetical colourations and explicitly advertising utopian and irenic programs of religious, social and intellectual reform. For the sake of simplicity, historians of science often group the bulk of these challengers under the rubrics of 'the Chemical Philosophy' and the 'Magnetic Philosophy'. As for the Mechanical Philosophy, it was as much a response to the social, political, ethical and theological threats seemingly posed by these competitors as it was a direct challenge to Aristotelianism.

In the late Sixteenth and early Seventeenth century, Scholastic Aristotelianism, although widely challenged, was notably strengthened in many quarters. Aristotelianism found new life as the connective tissue of the rapidly rigidifying curricula of institutionalised forms of Protestantism and a militant post-Tridentine Catholic Church. Neo-Scholasticism, Protestant and Catholic, symbolised both sides' uncompromising preparation for the renewal of hostilities which brewed in the 'cold war' atmosphere of earlier sites of Reformation conflict, in Germany, the Low Countries and in France after the end of its Wars of Religion in 1598 and prior to the outbreak of the Thirty Years War in 1618.

The religious and political crisis of the period was important for the proliferation of alternative programs to Aristotelianism, and the eventual emergence of mechanism out of the competitive turbulence thus created. Educated men recognised an imperative to find, and install, the 'proper' system of natural philosophy, because it was believed that the 'correct' program for natural knowledge would provide much needed support for 'correct' religion, as well as a set of directives or for the improvement of both the moral and practical aspects of life. The fact that there was, of course, no consensus on correct religion casts a poignant light on this struggle and explains both its intensity and ultimate lack of closure.

We have already discussed the essentials of the Aristotelian program in Section I. Since there existed a wide variety of alternative natural philosophies, we are concerned here only with larger genera or families of related types of systems, and particularly with those families of systems which had wide and powerful followings and which consequently were seen to pose serious threats and alternatives to Scholastic Aristotelianism as a program for the organisation and pursuit of natural knowledge.

Chemical Philosophy

The Chemical Philosophy, like so many of the anti-Aristotelian alternatives in natural philosophy of the period, drew heavily from the resources of neo-Platonism, so vigorously recovered and studied in the Renaissance and Sixteenth century. It shared with other neo-Platonically influenced approaches to natural philosophy a view of the universe as an organism, a hierarchy of more or less animate parts, integrated by bonds of spiritual power and correspondence. Knowledge of this language of correspondences [340] could promote control over nature, and the modality for entering into this code was intuitive participation, aided by an appropriate spiritual and ethical state of the knower. Useful and edifying effects could be attained by manipulation of knowledge of the code of spiritual influences. Indeed, there is a special status and mandate for the human knower in these natural philosophies, because, according to their doctrine of correspondences between man, the microcosm, and the wider universe, the macrocosm, not only are humans capable of knowing nature completely, but this knowledge is expressible as ever improving levels of self-knowledge. Thus far many neo-Platonisms might go, although one needs to notice that some deeply imbued neo-Platonists, such as Kepler, eschewed macrocosm/macrocosm doctrine as well as the range of 'natural magical' applications seemingly available within this view.

What differentiated the program of Chemical Philosophy within this genre was the way it linked the more widely shared neo-Platonic ontology and commitment to the possibility of natural magic to its own particular concern with the content and value structure of chemical arts and practices, including especially the use of chemical knowledge in medicine. This in effect was the natural philosophical master stroke of Paracelsus [ca. 1493-1541], to whom the Chemical Philosophers of the critical period of programmatic conflict looked for inspiration. In the Chemical Philosophy the term alchemy, which could denote the range of mundane chemical crafts, was invested with the ontological and magical envelopes of neo-Platonism. 'Alchemy' in this sense became the axis around which to hang the content, and agenda of the program in so far as chemical concerns, practices, facts and metaphors were employed. So, in a telling example, Chemical Philosophers such as Robert Fludd [1574-1637] displayed their religious superiority over Scholastic Aristotelians by arguing that alchemy, in their interpretation, provided the key to understanding the process behind the account given in the Book of Genesis. God, too, was an alchemist and his creation was an alchemical process. Not only was alchemy here identified with a very high register of spiritual and ethical concerns, sublimated, as it were from its common connotation of mundane chemical craft and practice, but it was nominated as the key to nature and human destiny.

It is also the case that some projects and pursuits with which the Chemical Philosophy was associated could exist independently, outside the widening flow of fully fledged systems of Chemical Philosophy. For example a pedagogically systematised 'alchemy', aimed at dissemination and application of useful chemical knowledge, was developed by Andreas Libavius [1546-1616] and others early in the Seventeenth century, partly in a reaction to fully fledged, highly spiritualised neo-Paracelsian chemical philosophising . This sort of enterprise was very important in the development of a practical baseline of chemical knowledge and in systematisation of that body of knowledge.

Magnetic Philosophy

The Magnetic Philosophy grew from the work of one individual, William Gilbert [1544-1603], whose On the Magnet (1600) is arguably the most influential and impressive new natural philosophical gambit of the period. To call Gilbert 'the father of electrical or magnetic science' rather misses the point that his program involved a new natural philosophical agenda and content, built, it is true, on exploiting and metaphorically extending important experimental work he had done on the magnet and magnetic compass. Also indebted to a basically neo-Platonic view of ontology, Gilbert based his new system of nature on a new theory of the earth, according to which the earth's magnetism, which he established as a fact, is a form of quasi spiritual power. The earth's magnetic 'soul' is responsible for its spinning on its axis, and since other celestial objects similarly have magnetic 'souls', a host of celestial motions could be explained. Gilbert's aim here was to support a modified version of Tycho Brahe's [1546-1601] system of cosmology, and so win the glory for closing the Copernican debate. To establish this, Gilbert worked not on astronomical or cosmological questions, but on the structure and nature of the earth. He co-opted and reinterpreted the craft knowledge and lore of miners and metallurgists, to argue that lodestone is the true elemental nature of the earth; that the earth is a gigantic spherical magnet; and that, since magnetic force, even in a small magnet, is an immaterial, spiritual force, the magnetic nature of the entire earth amounts to a cosmic soul or intelligence—capable of moving, or at least spinning the earth. This natural philosophy, he claimed, showed the true nature of the earth, as opposed to the superficial mutterings of Aristotelians about earth, air, fire and water and their qualities. Similarly, he insisted that his knowledge was built on assiduous attention to experiments and to facts reported by craftsmen and artisans, and that it was productive of useful results, most notably improving the understanding and use of the magnetic compass in navigation.

Unlike the other grand programs the Magnetic Philosophy never had a very large and energetic cohort of identifiable advocates. It did inhabit certain institutional sites, particularly in England, where at Gresham College, for example, its mix of technical, navigational and natural philosophical concerns commanded a following. But Gilbert's challenge across the spectrum of natural philosophical discourse, from cosmology, to method, to basic ontology, to the example of dynamic interaction with a wide range of practical arts, won [341] many admirers in general, and not a few opponents on particular points, thus keeping the image of the Magnetic program alive well into the middle third of the seventeenth century.

We have already discussed, in the context of Aristotelianism, the role of central models or metaphors in a system of natural philosophy. Such images and metaphors could be drawn from a variety of cultural resources; from some especially valued craft; or, from the presumed guiding concepts of some field of natural knowing that held special value for the system's devotees. Moreover, because different natural philosophical programs selected different constitutive metaphors and models, the differing programs embodied and expressed certain values and interests at the expense of others. Values permeated a natural philosophical program through the image of humankind and of the aims of human activity conveyed by that system, and through the program being embedded in academic curricula or other institutional sites in relation to other value-laden discourses on politics, religion or society.

Mechanical Philosophy

Within systems of mechanistic natural philosophy the leading image was that of the world as a machine, drawn from the experience of the designers of mechanical philosophy with entertaining automata and complexes of simple machines. These were devices whose sources of motive power or motion lay without them, just as a machine-Nature required a transcendent God to maintain and control activity within it. They were devices whose intricate functions had solely to do with the geometrical disposition and relative motions of parts, just as was asserted of machine-nature. The mechanical philosophy resonated with the experience, technical and social, of philosophically sensitive and socially ambitious engineers and practical mathematicians, and with their practical engagement with the simple machines and their intellectual engagement with the traditions which theorised them, the works of Archimedes [ca 287-212 B.C.E.], the 'Medieval science of weights', and Sixteenth century attempts to link such 'mechanics' and a possible geometrical science of motion. But mechanism also resonated a Protestant (and Jansenist) stress on the will of the creator and the total dependence of mankind and Nature upon Him. To endorse mechanism was to place a high value on (alleged) geometrisation, on experiment (a machine is known by taking it apart and reassembling it), and upon a certain voluntarist relation of God to the world.

Similarly, Paracelsus' metaphorical elevation of alchemy, initiating the Chemical Philosophy program, illustrates again, as in the case of statics and mechanics in the mechanical philosophy, how rapid change in a science or craft and/or a shift in its social evaluation in some quarters, could have major implications for how a given school of natural philosophy was constituted and pursued, particularly through the avenue of the borrowing or rejection of privileged images or models. More broadly, just as mechanism battened upon and projected for elite culture the supposed meaning and promise of mechanics, so Chemical Philosophy was manufacturing natural philosophical capital out of the raw material of the mere existence of chemical crafts and craftsmen in the society. And, by extension, Magnetic Philosophy bespoke Gilbert's endorsement of the idea that the royal road to natural philosophical truth lay in the merged efforts of certain kinds of scholars, that is, himself rather than mere Scholastics, and certain kinds of craftsmen, that is, literate navigators, practical mathematicians and craft experts on the 'real' nature of the earth and its constituents.

It is clear then, that, advocates of the Chemical, Magnetic and Mechanical Philosophies shared two related constellations of sentiments antithetical to the survival of Scholastic Aristotelianism. They were a positive re-evaluation of the practical arts, and a diffuse cultural dissatisfaction, a feeling that Scholastic Aristotelianism was irrelevant to the intellectual demands of the age and to the new imperative for the man of learning to be a man of action as well. By the first decades of the seventeenth century, for each of the great prophets of the nascent programs—Mechanical, Magnetic and Chemical--there were thousands of others sharing the sentiment, and ready to listen, if not quite able to speak. However, this picture needs articulation. [344] To this point one might be forgiven for thinking that each program was internally coherent and homogenous and that, in so far as Aristotelianism was the target of the challengers' concerns, there really existed only two sides, Aristotelians and anti-

Aristotelians. In fact all the programs were internally complex and contested, at the same time that speakers for each program attacked the other programs. Competition was the keynote, within and across programs.

Competition and Polemics: Inside and Across Programs

For example, systems of mechanical philosophy were not published until the 1640s and mechanism was not widely established until after 1660. One reason was the almost total lack of consensus about the details of a mechanical philosophy of nature amongst the inventors of the program—Descartes, Thomas Hobbes [1588-1679], and Pierre Gassendi [1592-1655]. There was a similar internal complexity in the Chemical Philosophy program, where radical German Lutherans, self-proclaimed Rosicrucians, and sympathisers such as Fludd in England, jostled with other neo-Platonists of similar aim but diametrically opposed politics and religion, such as the renegade Dominican, Tommaso Campanella [1568-1639], following the tradition, and almost the fate, of Giordano Bruno [1548-1600].

There were two other dimensions of complexity. First there was a tendency on particular issues for unstable alliances to be made across programs. For example, Kepler assailed the danger and meaninglessness of Fludd's natural philosophy, running along lines parallel to those pursued by Father Marin Mersenne [1588-1648], the mentor of the mechanists. At virtually the same time, the young Descartes, a future mechanist coming under the tutelage of Isaac Beeckman [1588-1637], could ponder the attractions of Rosicrucianism whilst joining with Beeckman in attempting to co-opt and rewrite much of Kepler's neo-Platonically achieved corpus of technical results in optics and celestial mechanics. Secondly, as the natural philosophical crisis of the early seventeenth century unfolded, there emerged a tendency for some proponents of each program to reach for a more sanitised, cooled down version of their own programs in the hope of winning inter and intra programmatic support. Francis Bacon's [1561-1626] entire project revolved around stealing the fire of more radical and politically and religiously dangerous natural philosophical positions, and domesticating them for his project of a top-down reform of knowledge under State control. [345] In the Chemical Philosophy program, Johannes Baptista van Helmont [1579-1644] stood for a transformed and sanitised alchemical natural philosophy, for a toning down of the potential excesses -- religious, psychological and political -- of Paracelsianism, without sacrificing its stress on 'experience' or the chemical key to nature. The same drift toward a common basis in somewhat sceptically assessed 'experience' and an intent, at the very least, to side step dogmatism, is the keynote of Gassendi's construction of his version of mechanical philosophy.

But, whilst we focus on competition within and across programs, we need to bear in mind an important condition and premise for competition to occur. This competition took place in a common arena, because all the players recognised they were in a shared domain of natural philosophising. Whilst the prophets of the Mechanical and Chemical Philosophies all overtly rejected Scholastic Aristotelianism, they remained to varying degrees dependent upon its vocabulary and conceptual grammar. Scholastic Aristotelianism still dominated the educational system. All educated men were exposed to one or another version of neo-Scholastic Aristotelianism as their first version of what natural philosophising in general was about, prior to the possibility of developing any sort of alternative. In other words all natural philosophers had a shared set rules of engagement for the construction and advocacy of their own programs and for attacks upon competitors. Attending to this point will aid our understanding of the ways and means of natural philosophical contention in the period of programmatic competition and emergence of mechanism. Just as importantly, it will help us to understand the further history of this process of natural philosophical change, in which natural philosophising simultaneously became more differentiated from other realms of philosophy, whilst also tending to dissipate into more narrow scientific disciplines.

Each Program was capable of stimulating new developments, discoveries of fact, albeit conditioned by the natural philosophy in question, and of fomenting developments in existing subordinate 'sciences' from within their respective frameworks of explanation. Aristotelianism itself could still provide deep conceptual orientations for narrow specialist pursuits. Aristotelian concepts continued to nourish physiological and anatomical researches, of which those of William Harvey [1578-1657], extending the deeply Aristotelian 'comparative anatomy' program of Hieronymus Fabricius [ca. 1533-1619] at Padua, are only the best known. Aristotelians continued to contend about experimental discoveries and instruments well into the middle of the Seventeenth century. The novelties in Gilbert's work have been mentioned already and the manner in which Kepler's, optical, astronomical and celestial mechanical discoveries were shaped by his version of a neo-Platonic philosophy of nature will be touched on below. Chemical philosophy was not bereft of new claims that were quite plausible to a wide range of contemporaries, as illustrated by Paracelsus' iatrochemical treatments and later by van Helmont's chemical novelties, such as the beginning of the construction of the concept of 'gas'.

Mere competition to produce discoveries is only part of the story, because the various programs were vigorously involved in attempting to appropriate the discoveries of others, or to negate them. Appropriation was tactical; that is, if a discovery or claim was particularly significant in the architecture of a competing program that claim had to be appropriated, down played, reinterpreted or neutralised in some fashion. So, Descartes was happy to appropriate Harvey's epochal, yet clearly Aristotelian based discovery of the circulation of the blood and motions of the heart, radically altering the latter (to the point of arguably contradicting it) to fit his mechanistic program in physiology. From the Chemical program Fludd endorsed the discovery of his friend Harvey, but invested its meaning with mystical connotations in ways that only committed aficionados of his natural philosophy could appreciate. Matters could become quite entangled in tactical cross fire, however. Gassendi, one of the early mechanists, was understandably eager to refute Fludd's interpretation of the meaning of the circulation, but went on to reaffirm, against Harvey (and Descartes) the Galenic pores in the septum of the heart on the basis of first hand witnessing of anatomical facts! For Gassendi it was this Galenic claim that vindicated a sense of the identity of venous and arterial blood, a claim typical of Harvey's position.

Descartes' extended strategic encounter with Gilbert's work on magnetism illustrates all the above points. What was novel in Gilbert's experimentation was co-opted by Descartes without the addition of a single new experiment. For Descartes the nub of the encounter lay elsewhere. Gilbert's natural philosophical exploitation of the magnet was dictated by his concern to establish a novel system of Magnetic natural philosophy of distinctly neo-Platonic flavour and embodying and supporting a modified Tychonic cosmology. This was the 'significance' of the magnet work that had to be appropriated, reframed, and tamed to the imperatives of Descartes' program. Gilbert's natural philosophising of the magnet was too important and impressive a gambit in the natural philosophical field to be ignored by his natural philosophical competitors. So, Descartes efforts were directed at re-glossing Gilbert's experimental work [346] in mechanistic terms, rather than at extending the number and type of magnetic experiments. Descartes devoted considerable attention to preserving and capturing the 'cosmic' significance of magnetism, the keynote of Gilbert's system. He replaced Gilbert's story of the cosmos making and binding role of the spiritual magnetic force with a mechanist's story of an equally cosmic magnetism which was now the purely mechanical effect of a species of corpuscle of particular, and peculiar, shape and size, moving in and through suitably configured aggregations of ordinary 'third matter'.

Perhaps the most profound level at which this strategic battle was carried out was where entire disciplines and their value structures were at stake. We have seen how mechanism was in a sense woven on the metaphorical basis of the promise and presumed value structure of mechanics and its practitioners. Similarly, the Chemical philosophy depended for both technical and value orientation on the notion of a spiritualised yet practically productive alchemy. In this energised and articulated spiritual form, alchemy powerfully expressed moral-psychological aspirations, a search for redemption through esoteric knowledge and successful practice. These powerful sentiments were partially shared, and certainly co-opted in the programs of Bacon, Descartes and their later seventeenth century followers. For mechanists the nature and 'control' of alchemy was therefore a particularly strategic issue. In Bacon, Descartes and their mechanist followers the values and aims which Paracelsianism and later the Chemical philosophy invested in alchemy were co-opted, sanitised of radical political and religious resonances and made acceptable to intellectually progressive but socially conservative elites, a ready audience for the mechanical philosophy. Alchemy itself was de-spiritualised and reduced to applied mechanistic matter theory, whilst the search for personal justification and social benefit would now be achieved through proper method and well grounded results, rather than esoteric insight and wisdom.

This same competitive pattern of production of novel experiments and facts, accompanied by inter and intra programmatic scrambles to deflect, co-opt or reinterpret claims, runs right through the mid-Seventeenth century, a period of increasing focus on instrumental and experimental exploration. So, the international sensations produced by Evangelista Torricelli's [1608-1647] 'barometer' and later by Robert Boyle's [1627-1691] air pump were not simply events about making (and transferring) an instrument, and finding (and replicating) one given, agreed set of facts. Mechanists, Aristotelians and surviving descendants of Chemical philosophy contended over what the facts were, what they meant, how the instruments behaved and indeed therefore about what the instruments actually were. In modern parlance, inter and intra programmatic differences led to debates about the 'theory-loading' of the facts; the theory-loading of the instruments; and, the implications of both to the meta-theories, that is, natural philosophies, held by the different protagonists. This situation has two important consequences for the discussion of the shifting organisation of knowledge, one dealing with historical method, and one related to the next stages in the process we are describing.

Firstly, recent scholarship about mid Seventeenth century experimentalism can easily mislead the non-reflective reader. Much has been asserted, correctly, about how natural philosophers were now merely seeking well attested, trustworthy, and atheoretical 'matters of fact'. These, it is said, became the touchstone of any claim or argument. Matters of fact were experimentally mediated, and it was hoped, available to be repeated and witnessed by other savants. From this it is further inferred, incorrectly, that the old culture of natural philosophy and its conflicts had been displaced with the sudden birth of something like 'modern experimental science'. No such rupture took place in the mid Seventeenth century, nor indeed later, as we shall see in Section IV below. Close study reveals that no claimed matter of fact failed to be theory-laden, and that the more significant a matter of fact was taken to be for natural philosophical contention, the more theory-laden, from contending sides, it tended to be. Talk of matters of fact was indeed endemic and was part of the operational etiquette of the new scientific societies and academies. However, as recent studies of the Royal Society of London and the Florentine Accademia del Cimento reveal, talk of matters of fact was the preferred rhetorical icing on still theory-loaded cakes, or claims, which, additionally, were the stalking horses of competing natural philosophical programs, or, of competing agendas within one program.

The second point is that the process of programmatic competition by means of production of experimental novelty and attendant battles over co-optation and reinterpretation, which gained such momentum in the mid Seventeenth century, was to have large consequences for the organisation of knowledge. For it is this process that led, in a largely unintended manner, to the further dissipation of natural philosophy into more narrow and autonomous experimental disciplines. We shall see the outcome of this process in Section IV below, but its early stages may be summarised as follows, based on what we have already canvassed. Competition within and across programs lent extra force and imperative to the doing of experiments and the exploration of instruments and experimental hardwares.

Experimentation was not some disembodied impulse or idea. It was an increasingly weighty aspect of the battle within and across natural philosophical programs. Different programs had favoured different domains of experimentation, and specific strategies for deflecting or co-opting the experimental work of competitors. Overall this competition drove the idea that the criteria of success were novelty, fruitfulness and productiveness. [347] When after about 1660 the mechanical philosophy became the broadly consensual view, buttressed by a loosely Baconian rhetoric about experiment, utility and progress, this process occurred within a more narrow ambit of natural philosophical competition. This, as it were, allowed diversion of energy from battles over natural philosophical systematics toward engagement with rapidly thickening domains of specific experimental and instrumental expertise.

Next we need to consider how this competition and turbulence affected the already existing disciplines, especially the mixed mathematical sciences. Here again we need first to consider the common rules of engagement that structured how Aristotelianism as well as its challengers dealt with these mature and now quickly developing subordinate sciences. Just as within Aristotelianism one had to take a position on how it linked to and commanded the existing subordinate knowledge seeking traditions, so any system of natural philosophy had to establish some pattern of privilege and exclusion amongst the available subordinate traditions. A natural philosopher had to set priorities amongst them, and link them conceptually to his natural philosophy, meaning that at least some central concepts of the subordinate science were derived from the natural philosophy in question. This created a pattern of linkages characteristic of a particular natural philosophy. The practice of a subordinate science under the aegis of a particular natural philosophy was coloured by the nature of the conceptual linkage.

We noted above that in the early Seventeen century, as the competition amongst differing approaches to natural philosophy intensified, some natural philosophers hostile to Aristotelianism insisted on a more central explanatory role for mathematics in natural philosophy, and that some Scholastic Aristotelians also began to revise the Aristotelian marginalisation of mathematics as non-explanatory. These changes, reflecting a burgeoning of the mixed mathematical sciences and their emancipation from the Aristotelian epistemological straightjacket, are central to the shifts in the organisation of knowledge that occurred during the Seventeenth century. Some areas within the mixed mathematical sciences of astronomy and optics became particular objects of contest and more intense inquiry. They became the targets of heated inter-system competition, which involved in every case a dual process of change: in the subordinate science in question, and in the natural philosophies contending to exploit and dictate to the science in question. In this way, as in the case of new experimental domains, there was unintended promotion of trajectories toward relative independence from natural philosophy, to which we shall return in Section IV.

So, for example, Kepler practised geometrical optics under, and in the service of, a neo-Platonic conception of light with brilliant results in the theory of the camera obscura, theory of vision, and, to some degree, the theory of refraction and the telescope. Descartes, in emulation of Kepler's technical optical achievements but in competition with his neo-Platonic natural philosophical program, practised geometrical optics under his peculiar form of a mechanical conception of light, achieving a simple and workable version of the law of refraction and a general theory of lenses. Conversely, essential details of Descartes' mechanistic system were shaped by the experience of his optical work. Practicing optics and advancing their respective natural philosophies, Kepler and Descartes moved freely between optical findings, contrivances and problems and profoundly consequential natural philosophical claims. In sum geometrical optics, the mixed mathematical science of the Scholastics, was evolving under these pressures into a much more obviously physical cum mathematical discipline, in which issues of matter and cause were not eschewed as many Aristotelians preciously advocated. The appropriate contemporary term here is that optics was becoming a 'physico-mathematical' discipline, and one with which certain innovative natural philosophers hoped to establish heavy traffic in their own favour.

The greatest example of these phenomena in the era of natural philosophical conflict is provided by the debate on Copernican theory in astronomy. In discussing Aristotle's notion of mixed mathematical sciences, we noted earlier that Copernican astronomy became a critical issue, not as a set of calculational fictions, but rather as a theory making realistic claims about the physical structure of the cosmos and the causes acting within it. Under the rules of engagement that we have been discussing, this meant that realist Copernicanism required for its sustenance, always and everywhere, new anti-Aristotelian natural philosophies. There was no realist Copernicanism without an appropriate natural philosophical envelope or carrier beam. Descartes literally staked the truth of his natural philosophy on the truth of his version of a physically explained Copernicanism. The same cosmological 'hydrodynamics' that explained his vortices, explained the higher registers of his theory of light as well, and hence, he hoped, articulated onto his dazzling achievements in geometrical optics. This sort of two way dynamic linkage between realist Copernicanism and radically anti-Aristotelian programmatics in natural philosophy is obvious in Kepler's work on planetary orbits, the physical causes of planetary motion and the architecture of the Copernican universe. The overall tendency, again as in optics, was toward a physicalisation of certain astronomical questions, which Kepler specifically recognised with his category of 'celestial physics'. The old mixed mathematical science of Ptolemaic astronomy was passing, not simply as a particular theory, but the very genus 'astronomy as mixed mathematics' was giving way to physico-mathematical disciplines of astronomy and celestial mechanics, an outcome occluded and halting in the turbulence of the mid-Seventeenth century, but quite clear in the wake of the reception of Newton's work two generations later.

One final stunning development of this period needs to be discussed, Galileo Galilei's [1564-1642] 'new science' of the mechanics of falling bodies, projectiles and pendula. The significance of this science is often misunderstood, and indeed it does not routinely fit the picture drawn so far of the emergence of physico-mathematical disciplines out of mixed mathematical precursors. But on close inspection it can be fitted into the account of the shifting organisation of knowledge offered here. Galileo's mechanics, first of all, was not some simple version of Newton's physics to come. Rather it was a sui generis, and novel first instance of new species, classical mechanics, and as such is also a prototypical case of the sorts of physico-mathematical disciplines we have been discussing.

Galileo's mechanics was largely autonomous of specific natural philosophical systematics and contestations. [348] Galileo was not a system builder, and the truth of the matter is that the mechanical philosophers who embraced Galileo's mechanics could do so only rhetorically. Neither Gassendi, Descartes nor Hobbes integrated it into his system. This does not mean, however, that natural philosophical conflict was not part of its genealogy. It certainly grew from within the natural philosophical combat—the agenda and hopes of Sixteenth century anti-Aristotelian devotees of the science of the simple machines. Indeed it was in some ways the long hoped for culmination of the Sixteenth century search for an anti-Aristotelian 'new science' of motion and mechanics. Nor did Galileo's mechanics offer some easily repeatable formula, method or algorithm for churning out additional new physico-mathematical sciences. It was an ideal or inspiration for the existence of powerful and autonomous physico-mathematical disciplines. But, it was sui generis in that it consisted in a hierarchical conceptual edifice of levels where theoretical construction was entwined with appeals to experiment, both real and imagined. Classical mechanics, subsuming the domain of celestial physics, would become the master discipline in Eighteenth and Nineteenth century physical science; but Galileo's mechanics was only a first instance of the species, and had all physico-mathematical and experimental disciplines arisen so remotely from natural philosophising, we would be faced with a very different history than next transpired.

Section III: Consolidation of Hegemonic 'Experimental Corpuscular-Mechanism

The last two generations of the Seventeenth century were marked by a closure of the excessive natural philosophical turbulence just described and the emergence and dissemination of varieties of the mechanical philosophy, which had been melded in slightly differing ways with a doctrine of method, loosely attributable to Bacon, emphasising experimental grounding, tentative theorising, exploitation of instruments and possible technological and other socially useful benefits. As we have seen, there existed little consensus amongst the first generation of mechanists. Generically, however, mechanism had triumphed and the internal differences were damped down by leading advocates, such as Boyle and Huygens, so that, for example, Boyle's controversies with Hobbes reflect Hobbes' continuing, and increasingly unfashionable drive for a personal hegemony amongst the family of mechanists.

At the core of the mechanistic hegemony in natural philosophy resided a consensus about epistemology and methodology, reflecting selected aspects of the thought of Bacon, Descartes and Gassendi. All mechanists restricted explanations to matter in motion [themselves differently conceivable whilst still accountably 'mechanistic'], and they conceded that the detailed corpuscular mechanical models adduced to explain particular classes of phenomena necessarily had only a hypothetical and probable character. To a large degree the emphasis, following Bacon's rhetoric, was on raw accumulation of sound matters of fact; but, the ultimate aim was to produce mechanical explanations by advancing hypothetical models of the corpuscles and their arrangements and motions held responsible for the facts in question. This view permeated the established mechanical philosophy of the later Seventeenth century both in England and on the continent. One way to view this result is to say that the admitted variety of detailed corpuscular-mechanical explanations and models drove the overall legitimatory rhetoric of mechanists in the direction of something recognisable to moderns as a modest sceptical empiricism, albeit that corpuscular-mechanical ontology was never abandoned as the regulative ideal of acceptable scientific discourse.

When we add to this picture the mechanists' endemic endorsement of a mathematical approach to nature (with the possible exception of the circle of Boyle) and the Baconian discourse of utility and social progress, we arrive at the popular vision of triumphant mechanism—experimental, mathematical and aimed at utility. This kind of simple glossing, however, misses the nuance of what these three characteristics involved. The gloss hides the fact that mechanical philosophy was experimental, mathematical and oriented toward utility in a largely rhetorical or declaratory sense: It aimed at useful results but actual achievements in this regard were sparse. It was not mathematical in any essential sense, but borrowed the gloss of the genuinely physico-mathematical disciplines growing up within it. It was not experimental in the sense of possessing some genuinely unique, transferable and efficacious experimental method. [349] Experiment varied from domain to domain, as we have seen, whilst mechanism parroted a rhetorical mandate and imperative to 'perform experiments' and 'appeal to experiments to ground claims'.

Given these clarifications, we can indeed say the following: The fact that natural philosophy--meaning the dominant mechanistic philosophy--now called itself 'experimental' and 'mathematical' entailed that the organisation of the branches of philosophy inherited from Scholastic Aristotelianism were under stress. Natural philosophising, according to Aristotelians, was not supposed to be based on experiment or oriented toward utility, nor mathematicised in any significant way. Tensions and forces productive of even further shifts in the organisation of knowledge were now in play and we turn, finally, to these.

Section IV: Rising Disciplinary Differentiation & Restructuring of Natural Philosophy by Late 17th Century

The further restructuring of the disciplines seeking natural knowledge, consequent upon the rise of experimental corpuscular mechanism, had three salient and interrelated features. Firstly, natural philosophy, meaning of course the now dominant experimental corpuscular mechanism, was increasingly differentiated as a cultural undertaking from other realms of philosophy, such as metaphysics, ethics and epistemology, as well as from direct articulations with theology. One reason was that natural philosophy increasingly concerned itself with specific instances of practice, of experiment, and with new and curious observational reports, as well as with a declaratory rhetoric of mathematicisation and material utility. The other branches of philosophy did not concern themselves with such matters. This tended to give the new experimental mechanistic natural philosophy a more strongly defined, and indeed modern looking, character, compared to the intellectual ecology of natural philosophising under Aristotelianism or even its strongly systemic challengers in the earlier Seventeenth century. To the superficial observer it may seem as though finally 'Modern Science' was being born out of the ruins of a defunct culture of natural philosophising.

The situation, unfortunately, is not quite that simple for two reasons. First, as we have seen, the triumphant experimental corpuscular mechanism can hardly be dubbed 'modern science'. Secondly, the particular constitution of experimental corpuscular mechanism itself led to our second process: For there began to unfold a tendency, taking a century or more for its full effects to be visible, for natural philosophy itself to dissipate and dissolve into an ever enlarging set of relatively autonomous, heterogeneous, conceptually and practically differentiated disciplines of more narrow scientific inquiry. By the late Eighteenth century this led to the virtual dissolution of the five hundred year long European culture of systematic natural philosophising. Finally, alongside these developments there was also set in train in the mid and later Seventeenth century the emergence of new, sweeping disciplines concerned with the terrestrial environment and its history—new forms of natural history, natural theology, as well as novel theories of the structure and genesis of the earth itself. These too became major natural knowledge-seeking preoccupations in the Enlightenment. The hegemonic mechanical philosophy of the later Seventeenth century was the axis around which these developments revolved and they in turn portended the eventual demise of natural philosophy by the later Eighteenth century. We turn therefore to more detail on each of these processes.

Under Scholastic Aristotelianism the enterprise of philosophy, including natural philosophy, metaphysics, ethics, epistemology and method, exhibited a certain unity, or at least consisted in a network of strong mutual articulations. Additionally, all but the most radical forms of Scholastic Aristotelianism were designed to articulate intimately with whatever version of Christianity counted as orthodox for the followers of that particular species of Aristotelianism. This remained true under the conflict of natural philosophical programs in the early and mid Seventeenth century. Descartes' system of mechanical philosophy—to take the most elaborately worked out version of the genre—reflected on its own novel terms this sort of unification of philosophical endeavour. Descartes' own version of Cartesianism (for there existed many variants) had its own highly elaborate dualist metaphysics, explicit epistemological and methodological concerns and an extension to ethics by virtue of a mechanistic physiology and medicine leading to a therapy for the passions of the soul. Its potential linkages to theology were made clear in the central machinery of its metaphysics, although, to be sure, the nature of these linkages both attracted adherents, mainly Catholic, and repelled others, mainly Protestant, of differing theological temperaments.

However, by the closing decades of the Seventeenth century, it was becoming clear that the long standing ideal of the unity of philosophy was beginning to unravel, with the major strands of philosophical endeavour drifting toward relative autonomy, as separate communities of discourse emerged, no longer coded to a core of natural philosophising. This dissipation is reflected in the fate of the Cartesian system. It had been relatively unified in the hands of its original designer. But it was rich in newly minted problems, such as that of the relations between ontologically distinct immaterial minds and corpuscular-mechanical bodies; the nature and grounds of human knowledge of the corpuscular-mechanical natural world; and the theological bearings of any given version of mechanism. Amongst Descartes' contemporaries and interlocutors, such as Gassendi, Hobbes and Antoine Arnauld [1612-1694], one sees a growing tendency to debate in isolation from natural philosophical and technical scientific issues, matters related to the dualist metaphysics of matter and soul, ethics and epistemology. In this way increasingly distinct realms of discourse began to appear around issues in epistemology; dualist ontology, method and ethics, where serious, sustained and technically informed concerns with science and natural philosophy were relatively small.

One can also trace this process by examining particular traditional categories such as 'substance' or 'cause', noting shifts in the locus and style of discussions about them. Corpuscular mechanism had dissolved the Aristotelian notion of a substance as something with an essence that upholds its properties and behaviours. The properties that Aristotelianism and common sense had attributed to material things became bifurcated: only matter, its motions and combinations could exist in the physical world, while the realm of everyday sensory properties and qualities of material things were relegated to the human mind. The increasingly autonomous epistemological discourse of British philosophers such as John Locke [1632-1704], George Berkeley [1685-1753] and later David Hume [1711-1776] would be addressed to the entanglements of this position. To a large extent the debate was carried on apart from significant concern with technical developments in sciences and natural philosophy. A similar evolution of autonomous philosophical concerns can be traced in the post-Cartesian debates about causation.

[352] As to the long term dissipation of natural philosophising into a host of more narrow 'scientific' specialisms, two overlapping developments need to be examined: Some of these represented the final stages in the long process of transmutation of the old mixed mathematical sciences, a process in train by the late Sixteenth century and hastened by the conflict and turbulence of the clash of large schools of natural philosophy in the early Seventeenth century. Others of these narrow 'science-like' disciplines were novel, new births out of the womb of natural philosophy, especially in its experimental corpuscular mechanical form. By the late Eighteenth century, both tendencies contributed to the virtual dissolution of the culture of unitary, systematising natural philosophy.

First the evolution of what originally were the mixed mathematical fields. We have seen how the mixed mathematical sciences emerged from their Aristotelian cocoon, where they were held to be non-explanatory and were subordinated to Aristotelian natural philosophical categories. In the period of natural philosophical turbulence, they became objects of contest and more intense inquiry, and began an unintended trajectory toward relative independence. The large scale historical trajectory of any such field obviously eluded the control of any given natural philosophy and consisted in the interplay and concatenation, over time, of the ways it was linked to, and thus practiced under, competing natural philosophies. As these fields became more self-consciously oriented to physical and causal explanation, this interplay and concatenation led to the emergence of more independent looking physico-mathematical disciplines. For example, the larger history of geometrical optical inquiry would show this character in the early modern period. We have already discussed how Kepler and Descartes simultaneously advanced technical optics as well as their respective larger natural philosophical programs. Now, in the latter half of the Seventeenth century the process of working physico-mathematically upon optics extended from Kepler and Descartes to Hobbes, Christiaan Huygens [1629-1695], Robert Hooke [1635-1703], Newton and a host of others. By the time of Newton and Huygens there had developed a great density of new phenomena and claims, and instrumental/practical applications which also set further problems. A domain of physical and mathematical expertise crystallised, where optical work floated quite a bit more freely than ever before from the demands of any given natural philosophical system or even the generically hegemonic mechanical philosophy.

Newton's optics is often misread in this connection. It is either taken as the point of origin of physical optics, or, even more implausibly, as the working exemplar for the development of other mathematical-experimental sciences, much as Galileo's mechanics often is, as noted earlier. But, Newton's optics fits into a larger process of formation of a relatively autonomous physico-mathematical domain of optics. Additionally, just like Galileo's mechanics, it carried no algorithmic instructions for its replication in other domains of phenomena. Both of these misreadings are aided by a quite relevant and true fact; that Newton's optics was strongly shaped by his own particular brand of post-mechanist natural philosophy of forces and aethers, and it grew up, as we would expect, in dynamic relation to shifting nuances in that natural philosophy. This reminds us of the heroic optical/natural philosophical wranglings of Descartes and Kepler. But Newton's properly optical results and claims were fed into an even more dense and crystallised domain of optical science than those of Kepler and Descartes had been, and that is an equally important aspect of its nature.

Other key cases of this process are the development of classical mechanics from Galileo and the emergence with Kepler and the triumph of realist Copernican mechanical philosophy of at least a problematic of 'celestial mechanics' if not quite a new discipline. Newton was to synthesise parts of these developments, not invent them de novo. Other related but complex stories could be told of how certain parts of the traditional mixed mathematical disciplines of statics and hydrostatics had passed through the natural philosophical gauntlet of mechanism and become more physico-mathematical in character, only to be further absorbed into the highly sophisticated mainly Continental mechanics of the early Eighteenth century.

In sum, this growth and transformation of the mixed mathematical sciences helped alter the complexion and centre of gravity of natural philosophy. By the late Seventeenth century natural philosophy was in one sense more centrally about such matters; but, simultaneously there was also a marked tendency for natural philosophy itself to dissipate into what are just beginning to manifest the character of successor fields. The emergent physico-mathematical fields, always somewhat distinct from natural philosophy, more and more absorbed questions previously treated in natural philosophy. In both these ways this physico-mathematical focus also drove natural philosophy away from other branches of philosophy, from metaphysics, epistemology, morals.

The second dimension of the dissipation of natural philosophy into more narrow disciplines relates to a set of new experimentally based domains, not grounded in the classical subordinate sciences, and not mathematicised until much later, if at all. These include the study of heat, electricity, magnetism (in the sense of going beyond the starting points of Gilbert) and pneumatics, or the physical side of chemistry concerned with the manipulation and properties of gases. [356] Gaston Bachelard [1884-1962] and latterly Thomas Kuhn [1922-1996] first drew attention to the historical and epistemological issues posed by these developments. They pointed out that these sciences did not arise from the application of one unified scientific method to different areas. Rather they stressed the heterogeneity of these developments, their dispersion in time, and the idea that each case marked the establishment of a sui generis basis for a limited scientific practice against the backdrop of a now rejected pre-scientific approach. They were correct in all but the latter claim, which calls in effect for the creation of these fields by the process of local ruptures from the pre-existing, 'pre-scientific' realm of natural philosophy.

In fact quite the opposite is the case, for these new 'experimental sciences' formed out of the evolving matrix of late Seventeenth and Eighteenth century natural philosophy and not over against it in a sequence of destructive revolutions or ruptures. What happened was a function of the dynamics of change in the organisation of knowledge we have been discussing. We have already seen, in Part II, how natural philosophies competed to explain and possess particular instruments, experiments and classes of phenomena. Because different programs had different favoured areas of experimental exploration and demonstration, yet had to take some account of what competitors are doing, the programmatic competition encouraged the proliferation of experimental domains and depth of engagement with them—meaning operationally the multiplication of claims, hardwares and practices. Competition also promoted the idea that the criteria of natural philosophical success are novelty, fruitfulness and productiveness. And, in turn, these criteria drove on specialist exploration and focus.

We have also noted, just now, how in the case of the mixed mathematical sciences, as they matured toward more autonomous physico-mathematical sciences, there crystallised sets or constellations of related instruments and practices. Moreover, we have seen how conceptual frameworks in these areas became detached from their original sources in competing natural philosophies and began to assume more consensual characters, or at least became less hostage to the immediate demands of one or another overbearing natural philosophical system. This same dynamic was to occur in the emerging new experimental areas, aided by two crucial considerations: First of all there was the existence of a relatively greater degree of natural philosophical consensus, initially under experimental corpuscular mechanism, and then under the Newtonian enrichment thereof with a return to appeal to non-material causal agencies in nature. Secondly there was the rhetoric of experimental method built into mechanical philosophy with its mandate and imperative to experiment at all costs.

Once mechanism had largely triumphed, and also donned a somewhat sceptical and empiricist method rhetoric, the process of domain formation and relative separation from natural philosophical systematics and competition was greatly favoured. Each domain of experimental inquiry acquired more hardware, findings and protocols whilst simultaneously its language of explanation, originally derived from natural philosophy, became more of a local, regional explanatory dialect with diminishing organic relation to the ongoing business of natural philosophy, which was dissipating on other fronts as well. Some historians, rather in the style of Bachelard and Kuhn, mistakenly select out one or another moment in these processes and declare a moment of origin for the science in question, but what was really at stake was a long term process in the dynamics of natural philosophy. This dynamics could easily be illustrated in the cases of the study of heat or electricity, where by the mid-Eighteenth century there were quite obvious disciplinary bodies of theory, experiment and practitioners, in the latter case, self proclaimed 'electricians'. But a century earlier only sporadic bits and pieces of fact, hardware, claim and counter-claim representative of these areas had floated in the natural philosophical combat of the day. In between lay the process we have been describing. It displays just that gradually gathering density of hardwares, results, procedures and local explanatory languages, with concomitant distancing from natural philosophical systematics and struggle, through which natural philosophy was to dissipate, and specialisms emerge, both physico-mathematical, and de novo experimental. Natural philosophy, differentiating itself from ethics, metaphysics and epistemology, was itself literally falling apart and evolving into a more modern looking ecology of scientific specialisms.

Finally we turn to the new discourses of natural history, natural theology and theories of the earth. These did not quite have the same scope as traditional natural philosophising, but compared to, say, human anatomy or the new physical optics, were of breathtaking, natural philosophy-like range and aim. They did continue to draw upon dominant natural philosophical approaches, Cartesian and Newtonian, but, their development again signals an evolutionary fragmentation of natural philosophy into a more complexly structured constellation of enterprises. They developed tremendous empirical richness, drawing upon and further shaping new forms of fact and information gathering and exchange. In addition their very natures and rationales demanded that they maintain dense (and accordingly endemically disputed) articulations with theology, as well as the dominant natural philosophical accounts.

[357] The focus of these developments was from the mid seventeenth century a new sober, empirical, and arguably 'Baconian' natural history, which arose with surprising suddenness simultaneously with the mechanical philosophy. It decisively displaced the previously endemic discourse of natural history, which took its original bearings from Aristotelian histories of animals and plants and Pliny's natural history, but which had developed in the Renaissance many Platonist characteristics. The key to this Renaissance natural history was the belief that every kind of thing in the cosmos possessed multiple hidden meanings and hence that natural history knowledge involved learning as many of these hidden meanings as possible. Any species of animal, for example was just one aspect of a complex web of metaphors, symbols and emblems. This form of natural history strongly articulated with neo-Platonism and hence with many instances of the Chemical Philosophy program. In the new natural history this play of meanings dropped away. Emphasis was placed on particular specimens and reports; on careful local reporting of matters of fact. Against the efflorescence of signs and symbols, it affirmed that words are just tools, conventional signs, and that the natural historian must work methodically to collect matters of fact, to be expressed in sober, unpoetic, careful language. In this spirit the Royal Society of London banned the older 'emblematic' type of natural history.

In tandem with the new natural history there emerged a new natural theology. Here the premise was that nature and its contents, animals and plants, their characteristics and behaviours have been designed for optimal harmony and utility by an all powerful, all wise Creator. As such, they display to careful, pious observation in natural history the beautiful and benevolent design of their Creator. Typically, what was judged good, useful and harmonious in terms of Divine design was assessed from a human, indeed European Protestant point of view, because 'man' holds a special place in this creation as God's adjutant, responsible for further cultivating, developing and exploiting nature, thus 'completing' its divine design. Natural theology accorded with the value structure of the mechanical philosophy, and both in turn framed the cultural space in which the new earth histories could be contrived.

The new theories of the earth were not focused on the history of the cosmos at large, but on the local drama of earth history, still taken as largely co-extensive with human history, as taught in the Bible. That the Book of Genesis still seemed plausible to the vast majority of intellectuals in no way necessarily entailed simplistic textual literalism. As far as earth and human history were concerned the Bible contained truths requiring further rational and empirical explication and elucidation. That was the role of disciplines such as Chronology, and the embryonic forms of biblical criticism, but above all elucidation was sought from the realm of natural philosophy. The new, set piece, speculative theories of the earth were intended as special vehicles of this natural philosophical explication; that is, a kind of specialised derivative of natural philosophising was devoted to this function. The discourse was structured by the problem of showing which system of natural philosophy permitted the most plausible earth history to be constructed consistent with, and elucidating of Genesis. Thomas Burnet's [ca. 1635-1715] Sacred Theory of the Earth [1681], the first of the new large earth histories follows this strategy. But Burnet differed from the growing wave of his competitors and successors—such as John Woodward [1665-1728], William Whiston [1667-1752] and others—in three key respects. All the later theories deployed Newtonian rather than Cartesian natural philosophical principles; they all took serious notice of the accruing natural history data, for example, concerning fossil distribution, stratigraphy or the distribution of land forms; and all spoke for a divinely created, providentially maintained, harmonious earth, after the Noachian flood. Burnet's opening foray into earth history had, by contrast, relied on Cartesian principles, largely ignored the natural history facts and retailed an increasingly 'old fashioned' view of the earth as in decay. The overriding point here, again, is that a specialisation of intellectual pursuits was occurring, deriving from the body of natural philosophy but furthering its dissipation and fragmentation. It should also be noted that in the cases of natural theology and the theories of the earth, the old imperative to articulate natural philosophy to one's favoured version of theology was being fragmented or indeed parcelled out as the task of new successor disciplines.

In sum, then, it was the heightened natural philosophical contention and conflict of the early and mid-Seventeenth century that put in train developments, intended and unintended, that eventually re-wrote the earlier Scholastic Aristotelian organisation of knowledge. This occurred during the late Seventeenth and early Eighteenth century, as the culture of natural philosophising was both set off from other branches of philosophy, and itself beginning to dissipate into derivative, more narrow, semi-autonomous disciplines or domains of inquiry into nature. The successor disciplines developed complex relations to each other and to religion, as well as to the dimming cultural ideal of unified natural philosophical understanding. Subsequently, in the course of the Enlightenment and Nineteenth century, they evolved into entities approximating to, or at least pregnant with, recognisably modern forms.

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