The Reform Project

Progressive, enlightened voices from the Arab Muslim world

Towards a

Model Curriculum

For the reform of the educational syllabus

in the teaching of the humanities

[A] Courses

A1: The Historical Rise of the Scientific Method

(Samples)

COURSE A1 - THE ROUTE TO KNOWLEDGE: THE HISTORICAL RISE OF THE SCIENTIFIC METHOD

The following pages in these samples are intended to map out for the educator the general lines that a syllabus can take as it summarises the rise of the scientific method over history.

In this Course the educator can provide sample readings that illustrate the development of the scientific method as it developed over history and the stages of the advance, from the emergence in Greece and ancient India of rationalist explanations of nature, to the pioneering of the scientific method as it is practised today, passing through the following broad stages:

- Antiquity – early methodology and the emergence of natural science (SAMPLED)
- The Late Antiquity transition (SAMPLED)
- The Muslim world
- The rise of the scientific method in Europe
- The 17th century transformation

Module A1.1 - ANTIQUITY – EARLY METHODOLOGY AND THE EMERGENCE OF NATURAL SCIENCE

A1.1.1 – The culturally diverse origins of scientific endeavour

The educator will root the historical treatment of the rise of the scientific method back in deep antiquity. In this context the role of the Babylonians in evolving the first examples of a scientific astronomy, by their meticulous accumulation of data and a mathematical description of astronomical phenomena, should be given the appropriate significance [1] in that

> all subsequent varieties of scientific astronomy, in the Hellenistic world, in India, in Islam, and in the West – if not indeed all subsequent endeavour in the exact sciences – depend upon Babylonian astronomy in decisive and fundamental ways.[2]

Similarly, the educator can highlight the contribution of ancient Egypt ti technology and geometric precision, and feature ancient Chinese Mohist explorations of logic and opposition of fatalism.

But in tracing the rise of the scientific method, and the underlying rational theories of nature, the educator will be highlighting the achievement of the ancient Greeks in elaborating these theories and in formulating geometrical systems to represent the observable phenomena. This is not to be culturally chauvinistic: a notable feature of Greek learning was its openness to the achievements of others, and its readiness to give credit where credit was due. This is the mark of civilisational maturity and was also a distinguishing feature, for instance, of the best years of Arab Muslim science. An example of the attitude can be seen in the following passage from *Proclus Diadochus* (410-485 AD) commenting on the origins of geometry and mathematics:

> We must next speak of the origin of geometry in the present world cycle. For, as the remarkable Aristotle tells us, the same ideas have repeatedly come to men at various periods of the universe. It is not, he goes on to say, in our time or in the time of those known to us that the sciences have first arisen, but they have appeared and again disappeared, and will continue to appear and disappear, in various cycles, of which the number both past and future is countless. But since we must speak

[1] For instance, the Chaldean astronomer and mathematician Kidinnu calculated the value for the solar year, and his calculations are still in use in today's calendars.

[2] A. Aaboe, 'Scientific Astronomy in Antiquity', *Philosophical Transactions of the Royal Society.* 276, No. 1257, May 2 1974, pp. 21–42.

> of the origin of the arts and sciences with reference to the present world cycle, it was, we say, among the Egyptians that geometry is generally held to have been discovered. It owed its discovery to the practice of land measurement. For the Egyptians had to perform such measurements because the overflow of the Nile would cause the boundary of each person's land to disappear. Furthermore, it should occasion no surprise that the discovery both of this science and of the other sciences proceeded from utility, since everything that is in the process of becoming advances from the imperfect to the perfect. The progress, then, from sense perception to reason and from reason to understanding is a natural one. And so, just as the accurate knowledge of numbers originated with the Phoenicians through their commerce and their business transactions, so geometry was discovered by the Egyptians for the reason we have indicated. It was Thales, who, after a visit to Egypt, first brought this study to Greece…

The educator may usefully feature the essay by Proclus on this matter, where he provides the full panoply of the rise of geometry and mathematics, from Thales, to Pythagorus, Anaxagoras, and Plato, through to Euclid.[3]

While some scientific disciplines in the modern sense, such as chemistry, were only possible in the early modern era of precise instrumentation and experimentation, the Greeks were pivotal in establishing the culture of examining the constituents of the physical world. They sought a theory of matter that would furnish a rational explanation of the ways in which different substances could exist and how they could be combined or dissolved, and their establishment of the underlying unity of non-celestial matter had an important bearing on the subsequent development of alchemy and chemistry.

While the origins of experimentation or knowledge through observation is lost to deep pre-history, the role of observational science as a systematic method on the route to knowledge was something that first had to be established and defended. The educator may demonstrate this process taking place in the writings of the ancient Greek thinkers, in the contest between authority through sense observation or through rational speculation as fought out between, for instance, the Pythagoreans and the Eleatics whose founding figure, Parmenides, warned against placing trust in experimental science:

> Turn your mind away from this path of enquiry. Let not the habit engrained by manifold experience force you along this path, to make an instrument of the blind eye, the echoing ear, and the tongue. Rather, judge by reason.[4]

The educator may therefore usefully preface his instruction with a demonstration of the argumentation for the validity of some basic premises: that the material world exists, that it is divisible and that it is subject to change and time, as opposed to the monistic conception of an unchanging, ungenerated, indestructible whole, an eternal indivisible reality that is obscured by the artificially, arbitrarily defined, individualised appearances.

A1.1.2 – Pre-Socratics and the tussle between myth and reason

In particular, the educator will usefully feature the work of the *Pre-Socratic philosophers* of the archaic period (650-480 BC) since it was during this period that natural explanations for physical phenomena were first explored to replace mythical and religious explanations for phenomena that focused upon stories of sacred origins, or the mystical conceptions of the Eleatics. Out of their debates on the nature of matter – from the four 'roots' or elements of Empodocles to the infinitude of 'seeds' proposed by Anaxagoras – emerged the theory of atomism (the fundamental building block of science today) along with other ingredients significant not only in the development of science, but also of philosophical explanation more broadly.

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[3] See Cohen and Drabkin, *Op. cit.*, pp.33-38.

[4] For a succinct description of this phase, and a good source for the educator, see 'Parmenides and the attack on observational science' in Benjamin Farrington, *Greek Science, its Meaning for Us*, Penguin Books, London 1953, (Part One, Chapter IV, pp.53-62).

A1.1.3 – Atomism – an early but repudiated pre-echo of modern science

Two figures stand out in the rise of atomism as an explanation, *Leucippus* (5th century BC) – the effective founder of the theory that everything is composed entirely of various imperishable indivisible elements called *atoms* ('un-sliceables', 'un-cuttables'), and *Democritus* (c.460-c.370 BC) who developed the theory in greater detail.[5]

- At this point, the educator may find it useful to distinguish medieval Islamic atomism which, in the pen of an author such as al-Ghazali, fell subject to Ashʿarite theories of occasionalism, removing the possibility of secondary causation (for al-Ghazali, atoms were the only perpetual, material things in existence, and all else in the world was 'accidental' meaning something that lasts for only an instant. If contingent events are thus not subject to natural physical causes, nothing accidental could be the cause of anything else).

Samples of the Pre-Socratic theories of Leucippus and Democritus are scattered and fragmentary, but the educator may call attention to such passages as Aristotle's disapproving commentary on Democritus:

> Democritus believes that the nature of the eternal things is small substances infinite in number. As a place for these he hypothesizes something else, infinite in size, and he calls their place by the names 'the void' … and 'the unlimited'… He holds that the substances are so small that they escape our senses. They have all kinds of forms and shapes and differences in size. Out of these as elements he generates and forms visible and perceptible bodies. These substances are at odds with one another and move in the void because of their dissimilarity … And as they move they strike against one another and become tangled in a way that makes them be in contact and close to one another … The grounds he gives for why the substances stay together up to a point are that the bodies fit together and hold each other fast. … He thinks that they cling to each other and stay together until some stronger necessity comes along from the environment and shakes them and scatters them apart. He describes the generation and its contrary, separation, not only for animals but also for plants, *kosmoi*, and altogether for all perceptible bodies.[6]

While the influence of Aristotle made the four 'roots' (hot, cold, dry and moist) of Empedocles the dominant theory of the elements until the modern period, the theory of atomism as originated by Democritus and modified by Epicurus and his followers, remained a highly significant achievement which, when it assumed a completely quantitative form in the 19th century, rendered a fundamental service to science.

A1.1.4 – Epicurus and the pre-figuring of scientific methodology

Given that texts from these authors are sporadic, the educator may find it useful to focus on the work of *Epicurus* (341-271 BC), as found in his writings preserved in the works of later authors,[7] but particularly as expounded by his enthusiastic proponent Lucretius (99 BC-55 BC) in his didactic poem *De Rerum Natura* ('On the Nature of Things'). Lucretius' work was not only highly influential in the ancient world, but in fact delivered a second boost to the scientific method in 17th century Europe when, following the re-discovery in 1417 of the sole remaining manuscript of the *De Rerum Natura,* the work became a significant factor in the revival of atomism, and contributed in no small way to the scientific revolution in its deconstruction of many elements in the Aristotelian natural philosophy that had previously been dominant.[8]

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[5] As mentioned earlier, there are also contemporary works on atomism from Indian materialist philosophers of the Charvaka school whose skepticism promoted perception as the primary and proper source of unconditionally true knowledge, as well as the atomist perception of the Jains which of all the Indian schools most closely approximated to the ideas of the Greek Presocratics, by teaching that all atoms were of the same kind, producing different effects by diverse modes of combinations.

[6] Patricia Curd, Richard McKirahan, *A Presocratics Reader: Selected Fragments and Testimonia*, 2nd ed. Hackett, Indianapois, 2011, p.112.

[7] Such as the *Letter to Herodotus* contained in Dionysius Laertius *The Lives of the Philosophers,* Book X.

[8] In the view of Stephen Greenblatt the discovery of this manuscript "plucked from a thousand years of neglect, changed the course of human thought and made possible the world as we know it." It inspired artists such as Botticelli and thinkers such as Giordano Bruno; shaped the thought of Galileo and Freud, Darwin and Einstein; and had a revolutionary influence on writers such as Montaigne and

Lucretius' work deeply influenced scientific thinkers such as Pierre Gassendi[9], Robert Boyle and Isaac Newton. The educator may therefore usefully adopt the *De Rerum Natura* as an example of a pre-echo of modern scientific thought, and make selections from the following sections of the work:

- *The atomic theory* [Book I: 146-417]

  Here are described his four principles of the atomic theory: 1) nothing is created by divine power from nothing; 2) no entity is completely reduced to nothing, but only down to its atoms; 3) bodies are composed of invisible atoms (differentiated according to their atomic weight and emerging as new chemical substances based on their atomic structure); 4) there is empty space between atoms;

- *The composition of bodies* [Book I: 921-1117 and Book II: 100-108; 581-588 ff]

  After reaching three conclusions – 1) space is infinite; 2) matter is infinite: 3) there is no centre for the universe – the author goes on to give an explanation of the diversity of bodies: they are composed through random collision of the atoms.[10] This theory of diversity explaining identity constitutes a significant departure from the traditional understanding of diversity as some form of degeneration from a prior identity, back to which diverse entities are driven to return (as in Platonic or Aristotelian thought).

Syllabus Theme – On the Nature of Things

The educator will be able to provide an illustrative window on the achievements of the ancient world and some tantalising indications of the scientific potential of the Epicurean approach to the natural world by focussing on Lucretius' work *On the Nature of Things*, such as:

- the law of inertia (Book II 62-166; 184-332) – whereby unless retarded by a blow, objects are in constant motion (not proved until Galileo)
- the principle of universal natural law (Book II 718-729; 1067-1078) in which the same principles of behaviour that apply on earth apply the same everywhere in the universe
- the rain cycle (Book VI 495-523) - that rain comes from water that has evaporated from seas and lakes, due to the heat of the sun and the motion of the air, and is stored in clouds
- sound is caused by pressure waves in air (Book IV 524-614)
- earthquakes are caused by slipping fault lines (Book VI 535-551)
- animals and men evolved by natural selection (Book II 62 1150-1156; Book V 790-834; 855-859)
- there are other planetary systems and that there is no centre of the universe but many different solar systems with their own planets (Book II 1048-1089)
- the speed of light is finite (Book II 144-156; Book IV 183-216)
- intimations of a theory of relativity (Book I 459-463; Book II 308-332) arguing that motion is relative, and time does not exist except as the relation of objects and events to each other, and hence time is also relative to the observer

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Shakespeare and even Thomas Jefferson. See Stephen Greenblatt, *The Swerve, How the World Became Modern,* W.W. Norton, New York, 2011.

[9] The French Jesuit Fr Pierre Gassendi (1592-1655) is an interesting example of the possibilities of reconciling religious faith with materialist science, in particular Epicurean atomism, in that he was one of the first thinkers to formulate the modern scientific outlook of moderated skepticism and empiricism. His work on Epicurus' atomic theory was to have a significant influence on modern atomic theory.

[10] See Book II, 583-5: "There is none of those things which are in plain view before us which consists only of one kind of element, nothing which does not consist of various seeds commingled."

and even, as some have claimed,

- intimations of a form of quantum physics (Book II 216-293) with his theory of the 'swerve' whereby the atoms that are in eternal motion collide and veer off in new directions and thus randomly change their momentum or location.[11]

The philosophy of Epicurus constitutes an achievement of the scientific imagination, and his conception of a cosmos based on three fundamental principles: materialism, mechanism, and atomism, led to the conception of a complete and interdependent system, one based on an empiricist theory of knowledge, a description of nature, a molecular understanding of disease[12] and a naturalistic account of evolution and change. This striking 'modernity' of the vision of Epicurus will make for an interesting feature in the educator's course, illustrating how anciently rooted are the operative scientific ideas of the contemporary world.

Of particular importance for the educator are the beginnings of a methodology for investigation outlined by Epicurus in his work *Kanōn* ('ruler', 'yardstick'):

I – that the first concepts be seen, and that they not require demonstration;

II – that prior to an investigation, we are to have self-evident concepts, so that we might infer both what is expected and also what is non-apparent.

This method of 'using the phenomena as signs of what is unobserved' is the process of *inductive reasoning* from a small example to a larger explanation, a fundamental feature of the scientific process as the educator will demonstrate (see below *Module 2 – Preliminaries on knowledge acquisition*). Based upon the self-confidence that a rational view of phenomena could bestow, that the universe functioned without the aid of gods, and that religious fear was not a pious good but something damaging to human life, the Epicureans saw humans as free to seek their own natural well-being.[13] Seeing themselves as "fitted with the faculties of perception and reason which allow them to acquire reliable knowledge of the world about them,"[14] the optimism that this bequeathed them is entirely familiar to our current scientific age.

A1.1.5 – Early controversies on evolution: Aristotle and Lucretius

The educator may make an interesting illustration of the diversity of speculative thought in the ancient world by making a comparison with two competing views on the nature of living matter and the problem of change. In the writings of Aristotle, and in Lucretius' account of the teachings of Epicurus, we have two clear positions on the question of development and change: the one refuting the doctrine of chance or purposeless variations (out of a belief in the comprehensive part played by purpose in the workings of nature), the other giving a view of evolution based on

[11] The 'swerve' theory of Lucretius is particularly interesting in the light of the latest theories of quantum theory. Lucretius solved the conundrum of a mechanistic universe generating change and new forms by invoking the idea of a certain randomness in the motion of atoms (analogous to modern descriptions of the random onset of turbulence in fluids). The idea of such a minute veering, said to occur at no determinate time or place, evinced mocking critiques at the time of his writing, but now is less strange in the modern age of quantum physics. On this, see Epicurus' in *Stanford Encyclopedia of Philosophy*, https://plato.stanford.edu/entries/epicurus/#3 .

[12] Students of Epicurus developed this theory in detail. Asclepiades of Bithynia suggested that the human body is composed of molecules and void spaces, and that diseases are caused by alteration of form or position of a patient's molecules. On this see Yapijakis C. 'Hippocrates of Kos, the Father of Clinical Medicine, and Asclepiades of Bithynia, the Father of Molecular Medicine', *In Vivo* 23 (2009): 507-514.

[13] Lucretius famously put this sentiment into his verse: "When man's life lay for all to see foully grovelling upon the ground, crushed beneath the weight of Superstition, which displayed her head from the regions of heaven, lowering over mortals with horrible aspect, a famous man of Greece who was the first that dared to uplift mortal eyes against her, the first to make stand against her … bearing his prize, the knowledge of what can come into being, what can not, how each thing has its powers limited and its deep-set boundary mark. Therefore Superstition is now in her turn cast down and trampled underfoot, whilst we by the victory are exalted high as heaven. (*De Rerum Natura*, I, 66-67, 75-79).

[14] James Warren, *The Cambridge Companion to Epicureanism*, Cambridge University Press, 1st Edition 2009, p.5.

chance combinations (an early form of the Darwinian theory of natural selection). The educator could adopt the following passages, for example, as themes for discussion:

Aristotle, *Physics* (II, 8):

> We must explain that nature belongs to the class of causes which act for the sake of something … certain things *necessarily* are and come to be … A difficulty presents itself: why should not nature work, not for the sake of something nor because it is better so, but just as the sky rains, not in order to make the corn grown, but of necessity? … Such are the arguments which may cause difficulty on this point. Yet it is impossible that this should be the true view … Where a series has a completion, all the preceding steps are for the sake of that … If man-made products are for the sake of an end, so clearly also are natural products … When an event takes place always or for the most part, it is not incidental or by chance. In natural products the sequence is invariable, if there is no impediment. It is absurd to suppose that purpose is not present because we do not observe the agent deliberating … If the purpose is present in art, it is present also in nature … It is plain then that nature is a cause, a cause that operates for a purpose.[15]

Lucretius, *De Rerum Natura* (V 783-877):

> Rightly has the earth won the name of mother, since out of the earth all things are produced … Since she herself formed the race of men, and almost at a fixed time brought forth every animal which ranges madly everywhere on the mighty mountains, and with them the fowls of the air with their diverse forms … Time changes the nature of the whole world, and one state after another must needs overtake all things, nor does anything abide like itself; all things change their abode, nature alters all things and constrains them to turn … One state after another overtakes the earth, so that it cannot bear what it did, but can bear what it did not of old … And it must needs be that many races of living things then perished and could not beget and propagate their offspring. For whatever animals you see feeding on the breath of life, either their craft or bravery, or their swiftness has protected and preserved their kind from the beginning of their being. … But those to whom nature granted none of these things, neither that they might live on by themselves of their own might … you may know that these fell a prey and spoil to others, all entangled in the faithful trammels of their own being, until nature brought their kind to destruction.[16]

Rationality in Greek medicine

As with experimentation and knowledge through observation, the originality of the Greeks in the sixth and fifth centuries BC in the field of medicine lay in the choice taken to develop a rational systemisation based on natural causes and free of magical, mythical or religious explanations. The educator may give an example illustrating this with the ‘sacred disease’[17] of epilepsy. Here the ‘father of medicine’ Hippocrates (460-370 BC) insisted, in opposition to popular demonology and magic, that the cause, treatments and procedures must be rationally based:

> This disease is in my opinion no more divine than any other; it has the same nature as other diseases, and the cause that gives rise to individual diseases. It is also curable, no less than other illnesses … Its origin, like that of other diseases, lies in heredity … This disease styled ‘sacred’ comes from the same causes as others, from the things that come to, and go from, the body … So there is no need to put the disease in a special class and to consider it more divine than the others … Each has a nature and power of his own; none is hopeless or incapable of treatment.[18]

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[15] See M. Cohen and I Drabkin, *A Source Book in Greek Science*, Harvard University Press, 1948, pp.395-98.

[16] See M. Cohen and I Drabkin, *Op. cit.*, pp.398-400. It should be noted, however, that the type of evolution described by Lucretius does not fully equate to modern theories of natural selection (it does not involve, for instance, a development from lower to higher forms through the mechanism of heredity).

[17] Epilepsy was regarded as the most mysterious of diseases, with its bewildering symptoms thought to be a punishment from the gods upon an individual. “Men”, Hippocrates lamented, “invent many and various things, and for this disease they assign the cause to a god...However, I hold that a man's body is not defiled by a god, the one being utterly corrupt the other perfectly holy. Nay, even should it have been defiled or in any way injured through some different agency, a god is more likely to purify and sanctify it than he is to cause defilement.” Hippocrates, *On the Sacred Disease*, 4,49.

[18] Hippocrates, *On the Sacred Disease*, 5,21. Cohen and Drabkin, *Op. cit.*, pp.473-4. For the full text of the work see W.H.S. Jones, *Hippocrates*, Vol. II, Loeb Classical Library, Oxford, Harvard, 1959.

This confidence of Hippocrates that no part of nature is more divine than any other, this incorporation of biological and medical problems within the framework of naturalistic systems of philosophy, constitutes the bedrock of scientific medicine, and the starting point for the progressive accumulation of human experience that has brought us to where we are today.

A1.1.6 - Aristotle and the triumph over Plato's Theory of Forms

As evidence of his all-embracing presence in scientific debate, then and now, demonstrates, Aristotle (384-322 BC) must occupy a prominent position in a syllabus illustrating the route to knowledge. His views on the physical sciences profoundly shaped medieval scholarship, and their influence extended well into the Renaissance (before ultimately being replaced by Newtonian physics). His influence has therefore been all-pervasive over history, and if modern science defines itself in many ways as an emancipation from his influence, this does not reduce this philosopher's pivotal role in setting the course for the rise of the scientific world-view.

Among his manifold pioneering achievements three basic elements stand out as pivotal in the advancement of human knowledge: 1) his repudiation of Plato's theory of Forms; 2) his innovation of an investigative method employing a formalised system of logical reasoning, and 3) his doctrine on causes, including final causes.

Against Plato's theory of Forms

Aristotle was pivotal in his rejection of Plato's theory whereby non-physical (but substantial) forms (or ideas) represent the most accurate reality there is, and that what mankind perceives is merely a pale reflection of reality.[19]Aristotle instead insisted that the world itself is real, and the reality or substance of things lies in their concrete, apparent forms (*'phainomena'*), which constitute the vital starting point for the accumulation of scientific knowledge. This was a signal contribution to the destiny of science and human knowledge. "Ironically", as a historian of science observes,

> his achievements are not often appreciated by contemporary scientists, because his greatest contributions lay in influencing certain raging debates about fundamentals that we now take for granted. It must be emphasised – even though modern readers can scarcely grasp how something so obvious to them could ever have been hotly debated – that Aristotle advanced society enormously and strategically simply by insisting that the physical world is real.[20]

He argued that mankind can learn the truth by 'experience' of the workings of this world (the Latin translation of this term is *experimentum*, from which we get the all-pervasive scientific term 'experiment'). Aristotle's approach is expressed in a language remarkable for the familiarity of its tone to a modern reader, and even today his work informs to a greater or lesser extent scientific activity in almost every field of study.[21]

[19] Plato believed that there was another realm of existence where objects he called 'forms' or 'ideals' – prototype objects that fully embodied that which was reflected (imperfectly) in earthly objects such as men, tables, and rocks – existed. This realm was thought to be inaccessible to normal human action He believed that before birth our souls resided in this other realm and had contact with all of these 'ideals' and that when, on Earth, we encountered things that bore some (faulty) resemblance to these perfect ideals, we remembered them. For which reason we could see the ideal of man in each man, the ideal of table in each table, and so on.

[20] Hugh Gauch, *Scientific Method in Practice,* Cambridge University Press, 2003, pp.47-48.

[21] The contrast of his material and empirical concept of the physical world with the essentially theoretical and theological concept may be seen in the following passage from Plato: "Now that which has come into existence must needs be of bodily form, visible and tangible; yet without fire nothing could ever become visible, nor tangible without some solidity, nor solid without earth. Hence, in beginning to construct the body of the All, God was making it of fire and earth. But it is not possible that two things alone should be conjoined without a third; for there must needs be some intermediary bond to connect the two … If the body of the universe could have been a plane without depth, one middle term would have sufficed to bind together the extremes and itself. But in fact the world was to be solid, and solids must always be conjoined not by one middle term, but by two. So God inserted water and air between fire and earth, and made them all, so far as was possible, proportional to one another, air being to water as fire to air, and water to earth as air to water." Plato, *Timaeus*, Section 31-2.

A1.1.7 – Aristotle and the ordered categorisation of investigative method

It is a mark of the service Aristotle rendered to humanity that, due to his exhaustive labours, a world of a disorganised *mélange* of significant, anecdotal or superficial knowledge was classified, categorised, evaluated and turned into an organised, accumulative, *scientific* understanding of phenomena. To bring this about Aristotle elaborated a formal system of logical reasoning – the study of how arguments are constructed – a methodology concerning causality and a systematic way of studying the natural world. He demonstrated that any investigation must work according to a system of concepts and propositions organized hierarchically and based upon the 'experience' of the essential nature of the objects of study. By so doing, operative principles may be extracted that will be productive of causal explanations for other universally applicable truths in related areas of the investigation.[22] Aristotle thus provided posterity with the basic building blocks of a consistent logical approach to knowledge.

His system has come down to us in a collection of works on logic, the *Organon* (meaning 'instrument', 'organ'). To illustrate Aristotle's contribution to the scientific method the educator may usefully take two signal works from this collection, the *Prior Analytics* and the *Posterior Analytics*, as discussion pieces for the classroom.

- *The Prior Analytics (Book I, Chapters 4-7)*

With this work Aristotle develops from the ground up a system of logic based on the examination of two statements, called the *major premise* and the *minor premise,* with the aim of determining whether or not a third premise, the *conclusion* follows from them. When the *conclusion* is a valid logical consequence of the *major and minor premise,* Aristotle calls this logical structure a *syllogism*, which he describes as

> a deduction in a discourse in which, certain things being supposed, something different from the things supposed results of necessity because these things are so.[23]

The purpose of this system is to distinguish between one group of valid conclusions and another group of fallacious claims that do not follow from the given premises, thus establishing beyond doubt the validity of a proposition, upon which other conclusions and propositions may be built.

The syllogism is a vital tool for establishing clarity and the possibility of a neutral ground, with consistent rules on which a constructive discussion can take place, and one which binds the disputants or competing evidence into a framework that does not allow for recourse to extraneous, irrelevant or un-testable argumentation. Aristotle's achievement in digging the foundations for logical discourse was so successful that it remained virtually unchallenged until the 19th century.

The educator will be able to demonstrate from this work the four forms of categorical syllogism (universal affirmative, universal negative, particular affirmative, particular negative), each based on a general statement (the major premise) and a specific statement (the minor premise), from which the conclusion is deduced, as illustrated by the formula – *if A = B, and B = C, then A = C* – and the example *All humans are mortal* (major premise); *All Greeks are humans* (minor premise); therefore *All Greeks are mortal* (conclusion).

[22] The educator may access an informative discussion on this in 'Aristotle's Biology' in *Stanford Encyclopedia of Philosophy at* https://plato.stanford.edu/entries/aristotle-biology/#AriSci .

[23] *Prior Analytics*, A.1, 24b 18-22. See A. Jenkinson, *Aristotle, Prior Analytics* https://ebooks.adelaide.edu.au/a/aristotle/a8pra/ .

- *The Posterior Analytics (Books I and II)*

We now know how to derive true conclusions from true premises but are left with the question of how to find true premises as the foundational principles of a given science. In the *Posterior Analytics*, the educator may illustrate how Aristotle addresses this question by applying the syllogism as a demonstrative tool to explain a physical phenomenon. Too often, as Aristotle lamented, people made assumptions about things loosely based on their own uncritical experience:

> We suppose ourselves to possess unqualified scientific knowledge of a thing, as opposed to knowing it in the accidental way in which the sophist knows, when we think that we know the cause on which the fact depends, as the cause of that fact and of no other, and, further, that the fact could not be other than it is.[24]

Aristotle's definition of the task of knowledge acquisition is precise: it is to determine the *cause* of a phenomenon. Grasping the cause means that we understand *that* a phenomenon is; *why* it is; *whether* it is; and *what* it is.

To do this, Aristotle defends the method of demonstration from axioms and first principles known with certainty and uncontestable. In *Book I* he demonstrates how these primary and universal principles constitute the starting points of knowledge and how these must be established by *inductive reasoning* since "all learning and teaching by means of argument proceed from pre-existent knowledge" and "we must get to know the primitives [premises] by induction; for this is the way in which perception instils universals". The discipline Aristotle imposes here is important, since without establishing these first principles we are left with infinitely long explanations and circular reasoning on the one hand or, on the other hand, the negativity of skepticism. This was a vital step in the establishment of the foundations of the progressively accumulating edifice of science.

Scientific proof or demonstration, for Aristotle, consists in deriving a conclusion syllogistically from these more basic truths, and from *Book II* the educator will be able to demonstrate Aristotle's application of the syllogism's *deductive reasoning* process as it works out in explaining natural phenomena. It is this combined process of induction-deduction: the establishment of general principles or definitions, and the deductions made from those principles checked against further observations, which creates for Aristotle a cycle that progressively improves precision in understanding.

An important product of the *Posterior Analytics*, as the educator may lay out, is how Aristotle demonstrates that the sciences are independent of one another; they are neither arranged hierarchically nor is there some 'universal science' or wisdom under which fall all the specialised branches of science. His encyclopaedic vision provided the first comprehensive categorization of knowledge into different fields such as physics, poetry, zoology, logic, rhetoric, politics, and biology (which he effectively invented as a scientific discipline and bequeathed its first taxonomical framework[25]) – pre-figuring the necessary specialisation of the modern scientist.[26]

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[24] *Posterior Analytics*, Book I, Part 2. See G. Mure, *Posterior Analytics* https://ebooks.adelaide.edu.au/a/aristotle/a8poa/index.html .

[25] Aristotle's detailed categorisation of the animal world was so thorough and largely accurate that Darwin wrote that the intellectual heroes of his own time "were mere schoolboys compared to old Aristotle." (Darwin , Letter of February 22, 1882).

[26] Even though Aristotle's classification system has been replaced, much of his method remains in use in modern nomenclature.

A1.1.8 – The debate on final causation

The second feature of Aristotle's work which the educator may wish to focus on is the issue of *final causation* since this has had important ramifications throughout history and remains a theme productive of strong debate.

Aristotle noted how his predecessors lacked a complete understanding of a phenomenon due to their ignorance of the interrelated causes (*plural*) that underlie it, and that this ignorance was hampering their attempts to understand *why* something exists. He argued that in order to fully understand something, one has to understand it in light of *all* of its constituent causes, which he explained as being four in number, as expounded in his work *Physics* (Volume II section 3):

> (1) that out of which a thing comes to be and which persists;
>
> (2) the form or the archetype, i.e. the statement of the essence, and its genera;
>
> (3) the primary source of the change or coming to rest;
>
> (4) the end or 'that for the sake of which' a thing is done.

That is, the *material cause* (the material out of which the object is made); the *formal cause* (the shape of the object in question); the *efficient cause* (the primary source working upon or actively producing the object; and the *final cause* (the purpose for which the object was created).

It was this *final cause*, Aristotle argued, that which lay at the end of the process, which could answer the question of why something existed. While the material, formal and efficient causes still inform contemporary analysis of phenomena, it is this final cause that has historically been the feature most subject to controversy. This is because Aristotle identified final causes not only in artefacts, but also in *natural phenomena*. He believed that plants and animals, as well as their constituent parts, had their own final cause or *telos* ('end' purpose). Aristotle was clearly conscious of the difficulty of understanding how a non-intelligent thing like nature could act intelligently, and imagined nature

> as a sort of artist who deliberates and makes a choice among appropriate means toward the end which he proposes to himself…. In the last analysis Aristotle conceives the artist as a particular case of nature.[27]

Aristotle was thus identifying this end neither as anthropocentric, nor as due to the actions of a creator, but as something immanent in nature. In so doing he was attempting to moderate the wholly mechanistic explanation put forward by the Atomists, whereby the operation of elemental physical processes was purposeless and accidental. Aristotle felt that material and efficient causes on their own fail to account for the characteristic regularity of the final form of phenomena. He was thus seeking a holistic explanation, so that the final cause or purpose determined the formal cause of the phenomenon or organism, that the end somehow steered the process along the way to its own realization.

While Aristotle was keen to remove the psychological or personal element from his causes (even where he talks of an artisan fashioning something he focuses on the effect of the 'knowledge' of the artisan, not of its 'intention'), nevertheless, this purposeful or 'teleological' view became enmeshed with theological discussion, and throughout the medieval period it held close to a Neoplatonist perspective, reinforced by the scriptural emphasis on divine providence and on the conception of God as the *telos* of the entire universe.[28]

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[27] Étienne Gilson, *From Aristotle to Darwin and Back Again, A Journey in Final Causality, Species, and Evolution*, (tr. J. Lyon), Ignatius Press, San Francisco, 1984, pp.12-13.

[28] Later scholastics turned away from this thoroughly teleological position, seeing the world more as an expression of inner indeterminacy and freedom than as a goal-seeking activity. For the nominalists, led by William of Ockham, final causality was simply a name given to the efficient cause considered as producing an effect. It was this position that bore fruit in the denial of final causality by early modern scientists such as Galileo and Francis Bacon.

➢ *DISCUSSION POINT – Final causality and Darwinian evolution*

To emphasize the relevance to the modern student of the historical trajectory to knowledge, the educator may find it useful to include a discussion on Aristotle's final cause as it appears in the contemporary world, and how it continues to be debated, albeit in a form that diverges from the medieval scholastic perspective.

For instance, in the field of biology, Darwin's non-teleological explanation to account for the current form of natural phenomena (indicated by the full title of his work: *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life)* has become the majority position adopted by scientists. Some have argued that this, in its way, is teleological in that natural selection describes a movement toward better adaptation and well-being. They nonetheless do not adduce an entity directing that movement and note that evolution cannot adapt teleologically to conditions that might occur sometime in the future.[29]

The implications of the final cause debate will make for lively classroom exchange, and in designing the discussion the educator will gain much from works such as Étienne Gilson's *From Aristotle to Darwin and Back Again*[30] where the author highlights how the last word has not been said on the problem of final causality highlighted by Aristotle. Basic questions, for instance, remain in the 'struggle for existence' which evolutionary scientists adduce as the driver of change:

- What does it mean to struggle if not to seek an end? And if living things seek ends, then in what respect has Aristotle been refuted when he claims that "nature acts for an end"?
- Is Darwinism ultimately teleological in that the struggle for existence, the desire or tendency of living things to stay alive and reproduce, is itself a teleological explanation?[31]
- Can evolution and biology tell us why a non-teleological nature would generate and sustain teleological beings? Have scientific discoveries on chance mutation resolved the problem of discerning a mechanism for this process?[32]
- Has contemporary evolutionary science and theories on 'the selfish gene' reversed Aristotle's slogan that "generation is for the sake of substance, not substance for the sake of generation"?[33]

Aristotle's definition on the causes is pivotal for modern science and if – in an age without the modern technical tools of scientific investigation or the accumulation of centuries of data and speculation, or the knowledge of vast eons of time for adaptations to take place – his fourth and final cause is scientifically inoperative, a new and constructive consensus is emerging in the modern debate between science and faith.

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[29] "Natural selection adapts populations to conditions that prevailed in the past, not conditions that might occur in the future. There is a common misconception that organisms can be adapted to future conditions, or that selection can look ahead in the sense of anticipating environmental changes during future generations. This is impossible. Evolution is always a generation behind any changes in the environment". See Jon C. Herron and Scott Freeman, *Evolutionary Analysis*, Pearson, Harlow, 2013.

[30] Étienne Gilson, *Op. cit.*

[31] Charles Darwin himself hints at a teleological explanation for the evolution of the species: "Authors of the highest eminence seem to be fully satisfied with the view that each species has been independently created. To my mind it accords better with what we know of the laws impressed on matter by the Creator, that the production and extinction of the past and present inhabitants of the world should have been due to secondary causes, like those determining the birth and death of the individual. When I view all beings not as special creations, but as the lineal descendants of some few beings which lived long before the first bed of the Silurian system was deposited, they seem to me to become ennobled." Charles Darwin, *On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life*. London: Murray [1st ed.] 1859, p.489.

[32] The scientists' case against a final cause on the basis of Darwinism is described by Stephen Jay Gould: "Although organisms may be well-designed, and ecosystems harmonious, these broader features of life arise only as consequences of the unconscious struggles of individual organisms for personal reproductive success, and not as direct results of any natural principal operating covertly for such 'higher' goods … By taking the Darwinian 'cold bath', and staring a factual reality in the face, we can finally abandon the cardinal false hope of the ages – that factual nature can specify the meaning of our life by validating our inherent superiority, or by proving that evolution exists to generate pass as the summit of life's purpose." S..J. Gould, *Introduction to Carl Zimmer,* in *Evolution: The Triumph of an Idea,* New York, Harper Collins, 200, p.xiii.

[33] *Posterior Analytics*, 640 a 18–19.

This debate looks again at the ancient philosopher's category, and understands his final cause as denoting a purpose not in a designed sense, but in a *functional* sense. This consensus is one that no longer adopts a wholly antagonistic position to evolution by natural selection for, as the Austrian cardinal Christoph Schönborn outlines,

> there is more affinity between evolutionary theory and classical immanent teleology of Aristotle and St Thomas Aquinas … than there is between evolutionary theory and the deistic conception of God and the static conception of living things implicit in Paley's mechanistic "watchmaker" arguments.[34]

The educator will find the contemporary debate on final causality, as it is being played out in the Christian West with respect to Darwinism, highly productive and stimulating for students – both as evidence of the living relevance of the groundwork of ancient thought on the route to knowledge, and as source material for an application of the argumentation to the Islamic context.

Aristotle and the development of scientific method

In terms of the rise of the scientific method, the educator can explain how Aristotle's role was principally one of defining the process of *interpreting* results, rather than one of accumulating research evidence in the modern sense. Modern science is more thoroughly empirical in its search for new data and more efficiently explains contingent facts, whereas Aristotle worked on *a priori* assumptions, on 'necessary' propositions. He was thus less interested in the nitty-gritty of dissecting natural phenomena than in perfecting an intellectually and logically coherent holistic system of explanation. Modern science also works inductively, beginning with observations and working *toward* general principles, whereas Aristotle's system is deductive *from* general principles, since the ultimate purpose of his demonstrative techniques was to explain how a mass of available data fits together.

Aristotle's focus on establishing and refining the basic *concepts* of science nevertheless proved cumbersome and limiting as the rapid accumulation of new discoveries, particularly in physics and chemistry, demanded new methodologies to accommodate them. The development of new techniques, oriented toward the quantitative verification of hypotheses and the specification of physical laws, could no longer fit harmoniously into his method for deriving first principles in the empirical sciences.

Even so, if his methodology fails to meet the standards of modern science, Aristotle is to be recognised as having provided mankind with the foundations of a consistent, disciplined approach to knowledge, an important tool for explaining phenomena and events, a validation of the empirical sciences and the earliest features of the classical model of scientific enquiry.[35]

[34] Christoph Schönborn, *Forward* to Étienne Gilson, *Op. cit.* The "watchmaker" analogy – a frequent device in philosophical discussions on purpose – was most famously formulated by William Paley in his 1802 work *Natural Theology, or Evidences of the Existence and Attributes of the Deity collected from the Appearances of Nature*. In this work he argued that if a pocket watch were found in a field, it is most reasonable to assume that someone dropped it and that it was made by at least one watchmaker, not by natural forces. This analogy played a prominent role in the 'argument from design,' where it was used to support arguments for God as the intelligent designer of the universe.

[35] Hugh Gauch estimates that "Aristotle got 70 % of scientific method right. His contribution is impressive, especially for a philosopher-scientist living more than two millennia ago." H. Gauch, *Op. cit.* p.48.

- *CURRICULUM THEMES - Early methodology*

By highlighting the above issues with illustrations from the original texts, the educator can establish for the student the domain for investigation and the structures and methodology of enquiry that the ancient world bequeathed to posterity. In particular the following themes may be explored to lay the groundwork for the route to knowledge:

- The multiple cultural origins of scientific observation and the role of the ancient Greeks in organising and categorising inherited knowledge and in establishing a framework for the understanding of phenomena;
- The emergence of natural explanations for physical phenomena among the Pre-Socratic Greek philosophers;
- The defense of sense perception and experimentation in the face of opposition from the Eleatics;
- Aristotle and the confirmation of physical reality as the appropriate subject of study;
- The rise of atomism as a foundation for scientific explanation of phenomena;
- The system of Epicurus and the pre-figuring of modern scientific methods;
- Aristotle and the establishment of the investigative method:
    - a) The invention of the syllogism
    - b) The application of the syllogistic method to the natural world
- Aristotle's four causes and the debate on final causation;
- The defense of change and early controversies on evolution
    - a) Final causality and Darwinian evolution
- The achievements and limitations of ancient science.

A1.1.9 – The relationship of philosophical thought to the promotion of science

The educator can thus establish for the student how the legacy of the ancient world to science is not merely a matter of antiquarian interest. In reality the period bequeathed substantial advances in factual knowledge across a full range of scientific disciplines, important investigations of scientific problems (especially those related to change and its causes) and a recognition of the importance of undertaking empirical research.

The *Module A1* thus establishes the fundamental building blocks of the early scientific method. By paradigmatically focusing on two authors – Epicurus and Aristotle – it sets the scene for the operative attitudes to science. The importance of these two thinkers for the *Model Curriculum* is that, in very broad terms, Epicurus signified *what* to study, and Aristotle demonstrated *how* to study. The schools of thought focusing on the work of these thinkers furnished the foundational basis for subsequent developments on the route to knowledge.

The educator can establish that the role of the ancient Greek philosophers, working in the axial age between a theological and a material conception of the world, was not merely one of accumulation; while men had been observing phenomena thousands of years before the Greeks, and must have had practical and intuitional knowledge of the principles involved, what the ancient Greeks bequeathed above all was a means to sort out the theoretical implications of this practical knowledge, and present the resulting body of knowledge as a logically coherent system.[36] As a result their work has an astonishing contemporary flavour. Reading the writings of these ancient authors

> we find ourselves on the threshold of modern science. Nor should it be supposed that by some trick of translation the extracts have been given an air of modernity. Far from it. The vocabulary of these writings and their style are the source from which our own vocabulary and style have been derived.[37]

Most importantly the educator, in focusing on the elements featured above, can demonstrate how the scientific vision, founded upon a material conception of reality, is not a cultural peculiarity of the contemporary West that may be taken or left aside at will, but something that is deeply rooted in mankind's story, and in the long record of his speculation as to the nature of things. It is a joint enterprise of humanity on the route to knowledge.

Further reading

Science in the ancient world

Aaboe, 'Scientific Astronomy in Antiquity', *Philosophical Transactions of the Royal Society.* 276, No. 1257, May 2 1974, pp. 21–42.

M. Cohen and I Drabkin, *A Source Book in Greek Science*, Harvard University Press, 1948. (Available online at https://archive.org/details/in.ernet.dli.2015.279430)

Patricia Curd, Richard McKirahan, *A Presocratics Reader: Selected Fragments and Testimonia*, 2nd ed. Hackett, Indianapois, 2011.

Benjamin Farrington, *Greek Science, its Meaning for Us,* Penguin Books, London 1949, 1953.

Hugh Gauch, *Scientific Method in Practice,* Cambridge University Press, 2003.

Aristotle

A. Jenkinson, *Aristotle, Prior Analytics* https://ebooks.adelaide.edu.au/a/aristotle/a8pra/

G. Mure, *Posterior Analytics* https://ebooks.adelaide.edu.au/a/aristotle/a8poa/index.html

W. D. Ross, *Aristotle's Prior and Posterior Analytics: A Revised Text with Introduction and Commentary,* Oxford: The Clarendon Press, 1949.

(Studies)

Anagnostopoulos, G. (ed.), *A Companion to Aristotle*, Malden, MA: Wiley-Blackwell, 2009.

'Aristotle's Biology' in *Stanford Encyclopedia of Philosophy* https://plato.stanford.edu/entries/aristotle-biology/#AriSci

'Aristotle on Causality' in *Stanford Encyclopedia of Philosophy* https://plato.stanford.edu/entries/aristotle-causality/#Con

David Bronstein, *Aristotle on Knowledge and Learning, The Posterior Analytics*, Oxford, Oxford University Press, 2016.

Étienne Gilson, *From Aristotle to Darwin and Back Again, A Journey in Final Causality, Species, and Evolution,* (tr. J. Lyon), Ignatius Press, San Francisco, 1984.

Armand Marie Leroi**,** *The Lagoon: How Aristotle Invented Science***,** Penguin Books, New York, 2015.

Christopher Shields (ed.), *The Oxford Handbook of Aristotle*, Oxford: Oxford University Press.

[36] Benjamin Farrington, *Op. cit.*, p.24.

[37] Benjamin Farrington, *Op. cit.*, p.163.

Epicurus & Atomism

- Dionyius Laertius, *The Lives of the Philosophers*, Book X.

C. Bailey, (tr. and annot.), *Epicurus, The Extant Remains*, Loeb Classical Library, Oxford, 1926. Available online at: https://archive.org/stream/EpicurusTheExtantRemainsBaileyOxford1926_201309/Epicurus-the-Extant-Remains-Bailey-Oxford-1926#page/n1/mode/2up

C. D. Yonge, *Diogenes Laertius : The Letter of Epicurus to Herodotus*, Book 10, Sections 35-83. http://www.attalus.org/old/diogenes10b.html

- Lucretius, *De Rerum Natura*, ('On the Nature of Things')

R. Latham, *Lucretius – On the Nature of the Universe*, Penguin Classics, 1951 (and reprinted many times).

W. H. D . Rouse, *Lucretius – On the Nature of Things* (English and Latin text), Loeb Classical Library, Harvard University Press, 1992.

(Studies)

'Ancient atomism' in *Stanford Encyclopedia of Philosophy* https://plato.stanford.edu/entries/atomism-ancient/

Bailey, C. *The Greek Atomists and Epicurus, A Study*, Russell & Russell, New York, 1926.

'Democritus' in *Stanford Encyclopedia of Philosophy*, https://plato.stanford.edu/entries/democritus/#2Stephen Greenblatt, *The Swerve, How the World Became Modern*, W.W. Norton, New York, 2011.

B. Inwood, L. Gerson, *The Epicurus Reader*, Hackett, Indianapolis, 1994.

'Epicurus' in *Stanford Encyclopedia of Philosophy*, https://plato.stanford.edu/entries/epicurus/#3

Tim O'Keefe – *Epicureanism* (Ancient Philosophies), Routledge, Abingdon and New York, 2010.

Part 1 – *Metaphysics and physics* - Atoms and the void, emergent and sensible properties, cosmology, mechanistic biology, the nature and functioning of the mind, death, and freedom of action.

Part 2 – *Epistemology* - Arguments against scepticism, ideas on sensations, preconceptions and feelings.

'Leucippus' in *Stanford Encyclopedia of Philosophy* https://plato.stanford.edu/entries/leucippus/

James Warren (ed.), *The Cambridge Companion to Epicureanism* (Cambridge Companions to Philosophy) 1st Edition, 2009.

Chapter 4 – *Epicurean atomism* (Pierre-Marie Morel)

Chapter 4 – *Epicurean empiricism* (Elizabeth Asmis)

Hippocrates

W. H. S. Jones (tr), *Hippocrates*, Vol. II, Loeb Classical Library, Oxford, Harvard, 1959. Available online at https://archive.org/stream/hippocrates02hippuoft#page/126/mode/2up

(Studies)

Yapijakis C. 'Hippocrates of Kos, the Father of Clinical Medicine, and Asclepiades of Bithynia, the Father of Molecular Medicine', *In Vivo* 23 (2009): 507-514.

Module A1.2 - THE LATE ANTIQUITY TRANSITION

In this Module the educator will illustrate the core features of what came to dominate the philosophical and theological world view of the Middle Ages in Europe and the Muslim world. This period of 'Late Antiquity' witnessed the transition from a largely material explanation of phenomena to one that included a stronger focus on theological explanations that will be more familiar to the Muslim student. It saw the conception of creation as a force *within* nature develop into one of the action of a *demiurge* ordering the material of nature, and the transformation of this *demiurge* into an individualised, monotheistic divinity *transcending* the material world. The impact of this development fundamentally altered the intellectual trajectory of humanity and defined its course up until the rise of the scientific method that we understand today.

A1.2.1 - Technological advance and the focus on empiricism

The material and conceptual foundations of science in the ancient world were carried over into subsequent eras beginning with the Hellenistic period (320 BC ff) and extending into Late Antiquity (c.250 AD to c.650 AD). As advances were made there were adjustments to be made to Aristotelian assumptions,[38] but on the whole Aristotle's legacy remained the intellectual arena in which these sciences were conducted.

During this time there was a development towards specialisation in the sciences and a greater focus on experimentation, which promoted refinement in the construction of mechanical devices and medical instrumentation.[39] The educator may take the physician philosopher *Galen* (c129-200 AD) as a useful example of the development in an age of transition. While, in common with his contemporaries (and thinkers for many centuries afterwards), he retained the perception of a decline having taken place in the quality of science since the classical period, he remained optimistic about progress, and illustrated this in his assertion that the highest-level, most reliable kind of knowledge is arrived at through "scientific demonstration". He believed that the Empiricist position, avoiding any statement about unseen entities and basing itself entirely on experience (*empeiria*), would lead to the correct therapeutic result.[40] Importantly, this optimism remained even if there were matters on which he claimed he could only advance what was "plausible": here the attempt to gain knowledge is still worthwhile, even if it is not of direct, immediate practical value. In a sense, it prefigures the purpose of pure research for the sake of knowledge that defines modern science.[41]

A1.2.2 - Explorations on the concept of a 'soul'

Scientific and mechanist explanations notwithstanding, what is noticeable already in the works of Galen is an increased focus on the issue of the essence of 'ensouled' or animate creatures and their parts, or the conception of a "world soul" extending throughout matter. Galen the scientist expressed himself unable to adjudicate on this more strictly philosophical issue, but the intellectual climate of the age indicates the waxing influence of Plato's later thought, particularly in the *Timaeus* dialogue, on the nature of being and the causes of the material world.

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[38] On this, see Samuel Sambursky, *The Physical World of Late Antiquity*, Princeton University Press, 1987, pp.ix.-xi.

[39] "With the rapid development of the special sciences we find a keen interest in what we call 'scientific medicine'. For the first time human cadavers were regularly and systematically dissected. This fact, together with the refinement of mechanical instruments, contributed to the advance of surgery." See Cohen and Drabkin, *Op. cit* p.467.

[40] Historians point to a remarkable example of an experimental procedure to determine the irreversibility of the flow of urine from the kidney to the bladder in Galen's *On the Natural Faculties*, I, 13. (see Cohen and Drabkin, *Op. cit.*, pp. 481-2).

[41] "The goal of basic research and the advancement of scientific knowledge for the sake of knowledge. The applicability of that knowledge is irrelevant … The scientist is essentially the seeker after knowledge that is systematically acquired and systematically explored. His first obligations are towards knowledge itself." Willy Lens, 'Basic versus applied research', *International Journal of Psychology* 22 (1987) 453-461.

The system, as later crystallised by Plotinus, was characterised by three levels: the *One*, the *Intellect* and the *Soul*. The One is the principle of being, the First Cause, not a being in itself but *beyond* being, both the creative principle of being and the teleological end of all existing things, the principle of totality. Its power emanates onto two things:

I. the *Nous* ('pure Intellect' or 'Reason'), which is the motionless, creative *demiurge* that organises the material world into a perceivable state;

II. the immaterial *World-Soul*, inspired and permeated by the *Nous*, an active force of desire, with the power to perform two functions:

   a) embrace individual souls that allow themselves to be informed by the *Nous*, and desire the universal substances (forms);

   b) embrace individual souls that turn aside from the universal and move downward and lose themselves in the particular, corporeal realm of the senses and the finite as animals, plants or humans. Upon the disintegration of the organism, it rejoins the realm of separate substances (or forms), after passing through a series of progressive purifications. [42]

Aristotle had given definition to this *demiurge* as the 'Unmoved Mover'[43] and the Late Antique period is marked by a state of flux concerning the workings of this Unmoved Mover – as to which elements in nature were to be considered teleologically governed, and which elements governed by physical causation as a 'by-product' of a design authored by a divine intelligence.

A1.2.3 – Plotinus and 'Neo-Platonism' – its influence on the trajectory of science

For Galen, writing just before the intensifying synthesis of Plato and Aristotle (later to be termed 'Neo-Platonism') championed by Plotinus, the purpose of the *demiurge* was still the most important, but not the only, cause of natural phenomena, since the properties of nature interacted with the *demiurge* and acted as a limitation to it.

For historians of science the influence of Neo-Platonism, as it worked through the Late Antique period, is seen as both restricting and stimulating. On the one hand its mystical ingredients, its affiliations with astrometry and alchemy and the belief in the ultimate unity of the cosmos, had a retarding and confusing influence on scientific thinking,[44] but on the other hand it could be a stimulus to original approaches and reassessments of canonical science.

A1.2.4 – From 'Unmoved Mover' to creator deity

Aristotle's concern with the Unmoved Mover, as the cause of all the motion in the universe, had been focused on the metaphysical necessity of the perpetual motions of the heavens. Although conceived primarily as a final cause and a constant 'inspiration' towards perfection existing in a state of 'stasis' and untouched by change and imperfection, rather than an efficient cause, nevertheless, as the concept of an immaterial substance became less attractive as an explanation, the speculation as to the nature of the Unmoved Mover inexorably gravitated towards singularity and towards an active, individualised creator *deity*.[45] With this, the trajectory of divinity as a force *within* nature (as with the pre-Socratics) to a mediating force between the seen and the unseen (as with Plato and Aristotle), to finally a divinity that stands, unseen, *above* nature and creating *ex nihilo*, was completed in the Late Antique period.

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[42] Majid Fakhry – *A History of Islamic Philosophy*, 3rd edition, Columbia University Press, 2004, p.23.

[43] Aristotle develops this argument in Book 8 of the *Physics* and Book 12 of the *Metaphysics*, "that there must be an immortal, unchanging being, ultimately responsible for all wholeness and orderliness in the sensible world".

[44] Samuel Sambursky, *Op. cit.*, pp.ix.-xi.

[45] This can be seen already in Aristotle himself when he posed the question "whether we have to suppose one such [mover] or more than one, and if the latter, how many", and his conclusion that "the rule of many is not good; one ruler let there be".

In a pre-echo of later contests, Galen contrasts the Greco-Roman conception with what he terms the 'Mosaic philosophy' of a creation *ex nihilo* in which the deity's will is the only relevant cause to which there is no limitation:

> It is precisely this point [i.e. that God could have made a man out of a stone if he had wished to do so] in which our own opinion and that of Plato and the other Greeks who follow the correct method in natural science differ from the position taken by Moses. For the latter it seems enough to say that God simply willed the arrangement of matter and it was presently arranged in due order; for he believes anything to be possible with God, even should he wish to make a bull or a horse out of ashes. We, however, do not hold this; we say that certain things are impossible by nature and that God does not even attempt such things at all but that he chooses the best out of the possibilities of becoming … We say thus that God is the cause both of the choice of the best in the products of creation themselves and of the selection of the matter.[46]

It is against this background of transition to a more theologically imbued conception of the world that the so-called '*Theology of Aristotle'* emerged. Despite the name it was essentially a paraphrase of Books IV, V and VI of the *Enneads* (Porphyry's a digest of the teachings of the philosopher Plotinus) which focused on the *One*, the *Intellect* and the nature, immortality and workings of the *Soul*. It was thus based on the Platonic system but with adjustments made to aid compatibility with Revelation. Due to the Arab Muslim philosophers' interest in Aristotle, the work was translated under his name[47] and incorporated, erroneously, into the corpus of 'Aristotelian' literature. As such it was to have a complicating, distorting influence on the subsequent development of Arab Muslim philosophy.

A1.2.5 - Ptolemy and the structure of the heavens

An important work in the history of the route to knowledge, with a similarly distorting influence, was the influential work on astronomy by *Claudius Ptolemy* (100-170 AD) called the *Great Treatise*, a work that, due to its influence over subsequent periods, was later dubbed *Megistē* ('greatest' – *Al-Māġest* in Arabic). This sole surviving, comprehensive ancient treatise on astronomy collated the observations of 800 years (dating back to the first mathematical approaches to astronomy of the Babylonians) and produced a geometric model, the influence of which can be seen in the names given to the constellations in the northern sky today. In contradistinction to competing models of the earth (such as the ancient Semitic model of the flat disk encircled by waters and surmounted by a dome-like sky[48]), Ptolemy adopted the spherical thesis of Eudoxus (c.410-c.347 BC) that was featured in Plato and Aristotle – that is, one of a motionless sphere standing at the centre of seven rotating spheres containing the sun, moon and five planets. This was likely due to its hoary antiquity as an explanation and its support from the above Greek luminaries.[49]

[46] Galen, *De Usu Partium,* 11.14. Galen went on to criticise the 'Mosaic cosmogony' and rejected its reliance on divine miracles. See S. Benko, *Pagan Rome and the Early Christians,* Indiana University Press, 1986, p.143.

[47] The work was translated in the 9th century by the Christian Ibn Naʿīma of Emesa for Al-Kindī. See the Arabic text in 'Abd al-Raḥmān Badawī, افلوطين عند العرب *Plotinus apud Arabes: Theologia Aristotelis et Fragmenta Quae Supersunt*, Maktabat Al-Nahḍa al-Miṣriyya, Cairo 1955, p.6.

[48] This model first appears in Akkadian and Ugaritic texts. Aristotle demonstrated its error by noting that "quite a small change of position to south or north causes a manifest alteration of the horizon" whereby one observes different sets of stars in the night sky depending on where one is located, which would not be the case if the earth was flat. (Aristotle, *On the Heavens,* Chapter 14).

[49] Sumerian incantations of the late second millennium BC make references to 'seven heavens and seven earths' and remained in currency throughout the period up to the era of the Greeks (and beyond). On this see Wayne Horowitz, *Mesopotamian Cosmic Geography*, Eisenbrauns, Indiana, 1998, pp.211; 214; 217. In antiquity 'seven' was a mystical number because of the seven planets visible in the sky.

In doing so, however, he failed to adopt the geocentric thesis of Aristarchus of Samos (c. 270 BC)[50] and Seleucus of Seleucia (b. 190 BC), and fails to mention them as an alternative explanation, or indeed take seriously any other model.[51] As a result, the prestige and authority of the work, with its concept of the 'seven heavens', heavily influenced other cultural traditions, all of them acknowledging Greek primacy,[52] and remained the canonical explanation in both the Christian and Muslim worlds up until Copernicus.[53]

Ptolemy's argument for the spherical shape of the Earth is made by observation:

> it can be seen that the Sun, Moon, and other stars do not rise and set at the same time for everyone on earth but always first for those who live to the east and later for those who live to the west. For we find that the phenomenon of eclipses, and especially lunar eclipses, which occur everywhere at the same time, are not recorded by everyone is happening for them at the same hours, that is, the same intervals from their noon. Instead, the hours recorded by the more eastern observers are always later than those recorded by the more western observers. And since the difference of the hours is found to be proportional to the distances between the places, someone could appropriately suppose that the surface of the earth is spherical.[54]

But his argument for the non-rotation of the earth is made by appeal to logic:

> Some people think … that nothing could it disprove them if they were to suppose, for instance, that the heaven were motionless and the earth were turned around the same axis from the west to east approximately one turn each day … But what has escaped their notice is that while nothing would prevent this from being the case for the sake of the phenomenon concerning the stars … this kind of thing can be seen to be altogether ridiculous from those things which concern us … For suppose we concede to them that unnatural things are so … they would have to admit that the turning of the earth was the simply most violent of all the motions around it for it to make so great a revolution in a short time … Neither clouds nor anything else which is flying or thrown could be shown to be passing to the east because the earth would always move faster and overtake their motion to the east. Therefore everything which the earth leaves behind would seem to be displaced towards the west.[55]

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[50] The work is not extant, but Archimedes (c.287 – c.212 BC) describes it thus: "Aristarchus has brought out a book consisting of certain hypotheses, wherein it appears, as a consequence of the assumptions made, that the universe is many times greater than the 'universe' just mentioned. His hypotheses are that the fixed stars and the sun remain unmoved, that the earth revolves about the sun on the circumference of a circle, the sun lying in the middle of the orbit, and that the sphere of the fixed stars, situated about the same centre as the sun, is so great that the circle in which he supposes the earth to revolve bears such a proportion to the distance of the fixed stars as the centre of the sphere bears to its surface." *Psammites* (Chapter 1 Sections 4-5). Plutarch also refers to it in passing: "Ought the Earth … be understood to have been devised not as confined and at rest, but as turning and whirling about in the way set forth later by Aristarchus and Seleucus, by the former only as an hypothesis, but by Seleucus beyond that as a statement of fact?" (*Platonic Questions,* Query VIII).

[51] Precursors to this departure from the traditional model were the model of the rotation of the earth on its own axis proposed by Heraclides of Pontus (c. 390– c.310 BC) and the non-geocentric thesis of Philolaus (c.470 to c.385 BC) who posited earth and other heavenly bodies – including the Sun – as orbiting something else.

[52] For example, the Indian astronomer Varāhamihira (505-587 AD) in his *Brihat-Samhita* wrote: "The Greeks, though impure, must be honoured since they were trained in sciences and therein excelled others" while the astrological treatise *Garga Samhita* gives the following evaluation: "The *Yavanas* (i.e. Ionians) are barbarians, yet the science of astronomy originated with them and for this they must be reverenced like gods".

[53] For a useful pedagogic scheme on the world according to Ptolemy, see Kerry Kuehn, *A Student's Guide Through the Great Physics Texts, Volume I: The Heavens and the Earth,* Springer, Wisconsin 2015, pp.41-60. The Qur'ān, for instance, references both cosmological models. See T. Tesei, 'Some Cosmological Notions from Late Antiquity in Q 18:60–65: The Quran in Light of Its Cultural Context', *Journal of the American Oriental Society* 135.1 (2015), pp.19-32.

[54] Ptolemy, *Almagest,* Chapter 4.

[55] Ptolemy, *Almagest,* Chapter 7. We have seen this type of argument rehearsed recently in Saudi Arabia in *Model Curriculum Part I* above (section: *The educational results on the ground - the denial of heliocentrism*) in which Sheikh Bandar al-Khaibari refutes the rotation of the earth, as he demonstrates here::https://www.youtube.com/watch?v=_Xn3G7kx2A4

A1.2.6 – The limitations of ancient science

Just as the period of antiquity saw the foundations laid for the understanding of the physical world, the Late Antique period witnessed the transition from a largely material conception to one that included a stronger focus on theological explanations. It saw the conception of creation as a force *within* nature develop into one of the action of a *demiurge* ordering the material of nature, and the transformation of this *demiurge* into an individualised, monotheistic divinity *transcending* the material world. In this period the naturalist explanation of phenomena championed by figures of antiquity such as Epicurus lost ground since its doctrine on the fortuitous clash of atoms conflicted with divine providence.[56]

This development had a theologically productive, but scientifically restricting, influence over the following centuries as it pitched the empiricist position against the consideration of the workings of unseen entities. As such it defined the nature of the tussle between philosophy and theology throughout the mediaeval period.

A second, ultimately restricting, development was the establishment of the model of the earth and the universe put forward by Ptolemy which, albeit an improvement on earlier models of earth as a flat disk, bypassed available current geocentric theses and posited a motionless sphere standing at the centre of seven rotating spheres containing the sun, moon and five planets .This Ptolemaic system heavily influenced other cultural traditions and remained the canonical explanation in both the Christian and Muslim worlds until it was convincingly refuted by Copernicus in the 16th century.

Nevertheless, while the Late Antique period saw scholar scientists using their pagan classical heritage selectively by preferring organisation, conciseness and practicality over theoretical elaboration, there were original contributions. In fields such as medicine, astronomy, mechanics and biology this era added considerably to the accumulated heritage of the ancient world[57], and if, as historians note, Greek science was not everywhere soaring to its greatest heights,

> it would have taken a fine eye in the first two or even three centuries of the Christian era to detect any decline … [for it] flourished deep into the critical period of late antiquity as a monument to the persistence of the Greek rational spirit. [58]

The educator may usefully focus on this period as an important starting point for the development of the relationship of Arab Muslim philosophy with scientific endeavour in the Middle Ages. The educator may therefore develop the following themes:

- The continuation and accumulation of scientific endeavour in the Late Antique period, without fundamental changes to the Aristotelian framework;

[56] The objection was that if the soul consisted merely of atoms which after death remained in the material world, then human bodies could not enter the afterlife, and could therefore not partake of eternal bliss as a reward for virtue, nor eternal damnation as a punishment for sins. Taken from Dirk Rohmann, *Christianity, Book-burning and Censorship in Late Antiquity: Studies in Text Transmission*, De Gruyter, Berlin, 2016, pp.173-4. A footnote (p.174) gives the quote from Augustine *Util. Cred.* 4.10:"if someone were suppose it is true and to be believed that the soul consists of atoms and after death is dissolved into the same atoms and perishes, because Lucretius wrote it. For he is no less miserable if he is convinced in so great a matter that this error is true, however much Lucretius, whose books have deceived him, imagined that" .

[57] An example of original contributions to scientific endeavour in this period can be seen in the tone of the Byzantine thinker *John Philoponus* (c.490-570 AD) as he refutes a cardinal theory in Aristotle's *Physics* on motion and impetus: "This view of Aristotle is completely erroneous, and our view may be completely corroborated by actual observation more effectively than by any sort of verbal argument. For if you let fall from the same height two weights, one many times heavier than the other you will see that the ratio of the times required for the motion does not depend solely on the weights, but that the difference in time is very small." (See D. Lindberg, *The Beginnings of Western Science*, p. 305). Philoponus argued here that an object moves and continues to move because of an energy imparted in it by the mover, and ceases the movement when that energy is exhausted. His theory was admired by Ibn Sīnā and Al-Bitrūjī, but deplored by supporters of Ashʿarite Occasionalism, such as al-Ghazālī. This remarkable challenge by Philoponus to Aristotelian physics is not only significant in itself for the time, but also pre-figured the modern concepts of inertia, momentum and acceleration in classical mechanics. Galileo cited Philoponus substantially in his works, and Galileo's famous experiment on gravity – by releasing two weights from the Tower of Pisa – was effectively a repeat of this observation.

[58] M. Clagett, *Greek Science in Antiquity*, (Chapter Nine: Science and Spiritual Forces in Late Antiquity). Dover Publications, New York. Publishing, 1955, p.115.

- The emerging tussle between the Greco-Roman and the Judaeo-Christian conceptions of the origins of matter and the diversity of phenomena;
- The emerging theories of 'ensouled' or animate creatures and their parts, and the conception of a "world soul" extending throughout matter;
- The development of the conception of creation: from a force within nature, to a *demiurge* ordering the material of nature, towards an individualised, monotheistic divinity transcending the material world;
- The development of theories on an immortal soul and its fate in the afterlife, from Neo-Platonism to Judaeo-Christian revelation;
- The scientific limitations of the Late Antique period: their technological and conceptual causes;
- The importance of understanding the world of Late Antiquity as the conceptual arena in which Arab Muslim philosophy and science developed.

Further reading

'Abd al-Raḥmān Badawī, افلوطين عند العرب *Plotinus apud Arabes: Theologia Aristotelis et Fragmenta Quae Supersunt*, Maktabat Al-Nahḍa al-Miṣriyya, Cairo 1955.

S. Benko, *Pagan Rome and the Early Christians*, Indiana University Press, 1986

M. Clagett, *Greek Science in Antiquity*, (Chapter Nine: Science and Spiritual Forces in Late Antiquity). Dover Publications, New York. Publishing, 1955

M. Cohen and I Drabkin, *A Source Book in Greek Science*, Harvard University Press, 1948. (Available online at https://archive.org/details/in.ernet.dli.2015.279430)

Majid Fakhry, *A History of Islamic Philosophy*, 3rd edition, Columbia University Press, 2004

W. A. Heidel, *The Heroic Age of Science: The Conception, Ideals, and Methods of Science among the Ancient Greeks*, Baltimore 1933

Wayne Horowitz, *Mesopotamian Cosmic Geography*, Eisenbrauns, Indiana, 1998.

Kerry Kuehn, *A Student's Guide Through the Great Physics Texts, Volume I: The Heavens and the Earth*, Springer, Wisconsin 2015.

David Lindberg, D.*The Beginnings of Western Science: The European Scientific Tradition in Philosophical, Religious, and Institutional Context, prehistory to A.D. 1450*. University of Chicago Press, 2007.

D. Rohmann, *Christianity, Book-burning and Censorship in Late Antiquity: Studies in Text Transmission*, De Gruyter, Berlin, 2016

Samuel Sambursky, *The Physical World of Late Antiquity*, Princeton University Press, 1987.

T. Tesei, 'Some Cosmological Notions from Late Antiquity in Q 18:60–65: The Quran in Light of Its Cultural Context', *Journal of the American Oriental Society* 135.1 (2015),

Plato

B. Jowett, T*he Dialogues of Plato, Volume 3: Timaeus & Other Dialogues*, Sphere Books, London1970. Online edition: https://ebooks.adelaide.edu.au/p/plato/p71ti/index.html