5 Aristotle (384-322 BC), His Natural Philosophy and Cosmology

The last Chapter, on theory-loading of perception and theory-loading of facts, ended the first section of this book, where we encounter a few introductory ideas to assist us in doing history of science in a better way. Now we enter Section Two of the subject, where we begin to do some historical work in the form of our first historical case study. We are going to look at the confrontation in the Scientific Revolution between the originally dominant, established world view, cosmology and astronomy, which was that of Aristotle, and the world view, cosmology and astronomy of the challengers, loosely called Copernican. To do this, we are going to put to work some of our ideas about not being Whiggish, for example, not considering Aristotle as stupid and the Copernicans as obviously right. We shall follow these people as they make and break facts, and make and break theories. We shall show that the making and breaking of facts and the making and breaking of theories are not historical phenomena that depend on true contact with the nature of reality -- the good guys making contact, the bad guys not making contact. These phenomena instead depend on people's personal, social, political and institutional tactics, and their ways and means of making and breaking facts and theories. That's why it makes for interesting history, instead of the mythical fairy tales of Whig history.

Let's turn now to Aristotle's Natural Philosophy, (which is what I am going to call his *system*, his *world view*, what some people might want to call his *science*). We prefer the term 'Natural Philosophy' for a reason that will become apparent below. One of the first things that strikes us about Aristotle's Natural Philosophy is that it is very much a coherent, and in some ways brilliant, drawing together of the assumptions and theories that are implicit in everyday descriptions of events and phenomena. In other words, if you speak an Indo-European language, as he did, and as we do, your everyday descriptions of the world, involve certain theories, some very close to those systematised in Aristotle's Natural Philosophy. Aristotle's Natural Philosophy is a kind of elaborate drawing together of those assumptions, rendering them explicit and systematic. So Aristotle really is a person that believes roses are red; that the redness is in the roses -- no funny modern physics here (cf. Chapter 4). To tell you that red doesn't exist would not have made sense to Aristotle or to any of his followers in the Middle Ages and Renaissance: everybody knows that red exists - and that it's in roses. Aristotle was also the kind of man who would take as a fact the very obvious statement that 'heavy bodies fall down when you drop them; that they fall down because they are heavy', and that every one of these words has and accurate physical meaning. He was the kind of person who would take seriously the very obvious 'fact' (the very well accepted report) that 'the sun rises in the east, passes overhead, and sets in the west'.

Aristotle's version of Natural Philosophy was the official, institutionalised framework for thinking about the nature of physical reality, and for doing science. It was the official philosophical and scientific framework amongst educated Europeans and in European universities from about 1300 up to, in many cases, well past 1650. Aristotle's followers in the 16th century -- and that meant most educated men -- disagreed with Copernicus and his followers not because the Aristotelians were stupid and the Copernicans were smart. Rather, they disagreed about the facts (reports) and about the theories that 'loaded' the reports. The historical problem is why did Copernicus' set of theories (and facts) come to replace Aristotle's theories (and facts), given that Copernicus was not obviously right (in touch with the real facts) and Aristotle was not

obviously wrong (out of touch with real facts that the others had magically got in touch with).

Now Natural Philosophy in general, as a cultural activity of a social elite, was an invention of the ancient Greeks in about the 6th to the 4th century BC. But of course not all the ancient Greeks believed in pursuing Natural Philosophy, just a very tiny, elite stratum of Greeks were ever interested in Natural Philosophy or ever "did" any Natural Philosophy. What was this Natural Philosophy was all about.

Well, as you know the ancient Greeks, or at least a few of them, were the creators of our Western philosophical tradition. The Greeks tended to view philosophy as having three main strands. One was political philosophy, which was supposed to show the educated man or the educated ruler, how reasonably to analyse and formulate political action. Then there was moral philosophy, ethics, which had to do with individual behaviour. And the other main branch of philosophy, for the Greeks, was Natural Philosophy and that's what we are mainly concerned with here in the history of science.

In order to have some idea of the scope and aims of Natural Philosophy for the Greeks, you have to understand that the ancient Greeks also created of a number of **technical sciences** (and here I *do* want to use the word *science*). These were narrow, technical, specialised areas of inquiry into specific aspects nature which they believed had to be consistent with, and controlled by, an overarching, systematic general Philosophy of Nature. In this book we are going to be concerned mainly with one of these technical specialties, one of these sciences invented by the Greeks, astronomy, and its changing relations with the dominant and challenging Natural Philosophies in the 16th and 17th centuries. The Greeks, as I say, invented some other sciences as well, for example, a field we would call anatomy, and, to some degree, a field we would call physiology, as well as optics, statics, a kind of acoustics, and most importantly geometry, which we might consider a science for these purposes. For us geometry obviously is not a natural science, but it is a discipline, and the Greeks certainly put it on a theoretical framework. They tended to see it as the science of real, three-dimensional space, a kind of natural inquiry, therefore. So the Greeks created these sciences, each of them a relatively narrow, fairly technical and specialised area of inquiry.

For the Greeks, and also for the thinkers of the Middle Ages, Renaissance and Scientific Revolution, what one wanted was a true Natural Philosophy, a general theory of Nature that would encompass, control and explain the basic ideas in all of these more narrow fields of science, and so show how they were all related, all part of one overarching correct vision of the world. In other words, the field of Natural Philosophy was much wider and deeper than any of these other fields that they also invented. They conceived of Natural Philosophy as providing an overarching, systematic theory, within which the narrow sciences would be practiced. The question--in Greek times, and again in the period of the Scientific Revolution--was, which version or system of natural philosophy was the true one.

We no longer look at the various branches of natural science in this way. Certainly, since the late 1700's and since the 1800's, science has been divided into too many specialties for anyone to overview all the sciences and say, “I am a Natural Philosopher and I will dictate the general terms of all sciences in an overarching and correct philosophy of nature”. Some older Universities in Britain and Europe and even in the United States, have chairs of ‘Natural Philosophy’ but they are now in physics departments, there are no ‘Natural Philosophers’ to fill those positions, rather scientists in one or another sub-branch of physics -- quantum physicists or solid state physicists,

or perhaps astro-physicists. There simply is not 'Natural Philosophy' anymore, since the early 19th century at least. There is no systematic theoretical explanation that covers all the sciences to dictate what they should do.

But, in the Scientific Revolution of the 16th and 17th century, the field of Natural Philosophy was still alive as a social and cultural battlefield, and the **main debate** was not about astronomy or optics, or anatomy or physiology, or geometry or mathematical physics, which was being pieced together. It was about Natural Philosophy. The main debate was concerned with which specific system of Natural Philosophy, if any, was going to replace Aristotle's -- which system or version of Natural Philosophy was true, if Aristotle's was not, and of course many still defended Aristotle. So the Scientific Revolution did not destroy Natural Philosophy as a cultural game and field of struggle. The later efflorescence of the sciences and their proliferating sub-branches did that but not until after the Scientific Revolution, not until the late 1700s actually. So the field of Natural Philosophy is still with us in the period that we're studying -- Copernicus, Kepler (d.1630), Galileo (d.1642), Descartes (d.1650) and Newton (d.1727) were all Natural Philosophers with differing answers to the question of which system was true, above and beyond their knowledge of various specialised sciences of the day.

If you were in the Natural Philosophy business, like some of the ancient Greeks, and like Medieval and Renaissance University lecturers (and as were the contending participants in the Scientific Revolution), what did you have to do?; what was your job, what were your aims? Well, to be a Natural Philosopher, to be part of the game, you had to give systematic answers to four questions:

(1) What kind of stuff is nature made out of? What kind of matter is there?

(2) How is the matter organised into a cosmos? How is it organised, and that's a question of cosmology. It is one thing to know what the matter is, maybe it's bricks: the universe consists of bricks. It's another question to know whether it's in a split level brick veneer, or in a rambling ranch house or to know, in short, how is it organised.

(3) How or why, do things happen? That is the question of *causation*.

(4) A question that only evolved slowly in the early Greek tradition for it did not exist in the beginning of their Natural Philosophical tradition, but it was there at the end, with people like Aristotle and his teacher Plato. This is the question of how do you know your answers to (1), (2) and (3), and how do you know they are correct? So Natural Philosophy had to include within itself, an answer to the question of what its basis was - How did it know the answers to questions (1), (2) and (3). And one important part of that answer was given by Aristotle: "*I know the answers to (1), (2) and (3) because I have a scientific method that has given me the answers*" .

(Interestingly, even though Natural Philosophy no longer exists today as a cultural form and social institution, that last question (4) still lives on amongst philosophers of science and Whig historians of science, who believe that they key to understanding science and its history is to trace the nice, triumphant development and application of 'the scientific method'. We heard a little about this in Chapter 3 and later in Chapters 9 to 11 (section 3) we are going to learn (a) that ideas of scientific method never have and never can actually work to produce scientific knowledge -- science is done in different, more socially and politically interesting ways -- and (b) that ideas of scientific method have always served to legitimise and prop up opinions derived in various other manners).

There is one other thing that you need to know about Natural Philosophy in general, before turning to Aristotle's particular Natural Philosophy: What differentiated Natural Philosophy, and Natural Philosophers from everything else that was happening either in Greek society, or in its neighbouring or slightly older cultures (say the Near East or Egypt)? It was that the Greeks, in their Natural Philosophies, viewed the universe as more or less a self-contained whole. In fact, the word *cosmos* signifies this. Physical reality is a self-contained whole. And that assumption has a real sting in its tail, because this implies that even if there are supernatural beings, gods, and let us hope, goddesses, -- if there are such things -- they do not interfere with the self-contained physical system which is the cosmos. So, Natural Philosophy was not necessarily atheistical; there might be supernatural beings, but the idea was to try to explain things existent in the world *without* bringing the gods in, as it were, from the outside, from 'supernature' from the supernatural realm. This contrasts quite strongly with the deeply religious and mythical world-visions characteristic of those older civilisations, and indeed of Greek and Roman civilisation, leaving aside the small elite of Natural Philosophers . (What this all meant for Natural Philosophy in the Christian society of Europe in the Middle Ages, Renaissance and Scientific Revolution we will mention in a moment and explore in various details throughout this book!)

So, for example, in Aristotle there is virtually no supernatural being, and certainly no concept of the personal creator God of the Judeao-Christian type at all. In fact, when Aristotle's Natural Philosophy was brought into Europe in the 11th to 13th centuries it had to be supplied with a God. A vision of the Christian (Catholic) God had to be put on top of Aristotelian Natural Philosophy. Other Greek systems of Natural Philosophy had dealt with Gods and the supernatural in similar ways. One school that competed with Aristotelianism in the ancient world was the school of Atomists, who believed nature is an infinite system of atoms and empty space. (By the way their atoms are nothing like our modern ones. Theirs were solid little pieces of hard matter that could not be broken apart. Ours are complex systems of sub-particles energy distributions really). Now the Atomists had gods and goddesses, but their gods and goddesses were made out of atoms, so they were already **in** the universe -- not *super*natural. Moreover, as a matter of fact, according to some of the Greek Atomists, the gods and goddesses lived way off at the end of the universe, perhaps at a sort of "restaurant at the end of the universe" and they care much about our destinies. The moral of that, because ancient Atomism is in large measure a moral philosophy as well, is don't worry about things: don't worry about the Gods punishing you for your sins, for example; and don't worry about what happens when you die.You don't go to the dreary Greek 'underworld'. Your body falls apart into its constituent atoms and you are gone -- that's all. In the view of the Atomists' there is no God to save you. There are gods but they won't save you, or can't save you. So that's what I mean by no supernatural interventions. The cosmos is a self-contained whole, for the Atomists, and for Aristotle in his own way, and we humans are to find our understanding and meaning of life and the cosmos within that naturalistic setting.

Let's turn now to Aristotle's Natural Philosophy, commencing with his *cosmology,* his answer to the question of how everything is organised. This is the least innovative part of his version of Natural Philosophy because he took it over directly from Plato and the school of Plato, where this cosmology had been worked out in the generation or two earlier. But note, Aristotle's cosmology became the cosmology of the European Middle Ages and the European Renaissance, at least for educated people. The core idea of Aristotle's cosmology has a simple abbreviated name in some of the history books; it's called the '*two-sphere cosmos* ' (cf. T.S.Kuhn, *The Copernican Revolution*) because

the first thing that you see about it is that it consists of two spheres. One sphere, poised at the centre of the whole system -its centre corresponds with the centre of the cosmos - -is the earth. The second larger sphere is called the *sphere of the fixed stars* and the idea is that the stars are affixed to the inner surface of this sphere. Only the stars are so affixed, not the sun and the moon, not the planets, (and only five planets were known at the time - Mercury, Venus, Mars, Jupiter and Saturn). (fig 1)

These stars never move in relation to one another--they seem 'fixed'-- and so it is reasonable to assume that they are indeed fixed. The big sphere turns from east to west, completing one revolution every 24 hours. This means that from the surface of the central earth, the stars are seen at night moving from east to west in large arcs above our heads with some stars rising in the east and setting in the west; some stars so high in the sky from whereever you are that they simply seem to go in circles every night and don't rise or set. In fact they seem to circle a point which must be the 'pole' of the axis of rotation of the sphere of the fixed stars. These initially plausible concepts lead onto other apparently 'factual' accurate findings. If you go to Northern Greece, you see a slightly different set of stars than if you go down to Southern Egypt. Why? Because you are walking along the curved surface of the spherical earth, and you are getting a slightly different plane of vision cutting in two the sphere of the fixed stars. There are many different facts that can be explained in this way and that's why the smart postgraduate students of Plato's Academy, put this together in the generation before Aristotle.

What about the sun the moon and the planets? This is where the trouble starts and this trouble is called *astronomy,* because one can give a very general account of the cosmology of sun, moon and planets--what they do--but their motions present certain problems. In order to solve those problems reasonably accurately we have to be technical, using complicated mathematical models of these objects motions. Getting technical about those problems is called doing astronomy. In the next Chapter we will look at how some of the Greeks did astronomy, but for now we shall look at the basic, that is cosmological, story. The basic picture in cosmology is that the sun, the moon and the planets occupy the regions between the earth and the sphere of the fixed stars. Take the sun, for example. Everyday it travels from east to west around the earth in about 24 hours. In some sense it is dragged along with the general motion of the sphere of the fixed stars. But the sun also seems to have a slow motion west to east, about one degree a day, so that at the end of 365 days the sun will have travelled back to the same position against the background of the fixed stars that it had one year earlier. The moon also does this--has this slow backwards motion (west to east)--about 12 degrees backwards a day, so that after about a month it returns to the same position against the background of the fixed stars. Each of the planets has its own backward period. This is a good theory for explaining eclipses of sun and moon, the seasons, the general pattern of the motions of the planets and stars.

What, finally, is out beyond the sphere of the fixed stars? For Aristotle and other pagan Greeks there is outside the spherical cosmos literally no-thing; that is, nothing physical is out there, since all of nature (the cosmos), is inside the great sphere; and since, moreover, nothing supernatural (or beyond the natural) exists, there simply is nothing there. In the Middle ages with the Christianisation of Aristotle's Natural Philosophy and its adoption as the official, learned vision of the world, the story was modified by saying that just as Hell resided at the centre of the earth (centre of the cosmos), so heaven, the abode of God and the various heavenly hosts and angels etc, was out beyond the limits of the physical cosmos.

Now let's follow through and examine Aristotle's answers to some of the other key questions of Natural Philosophy. In order to do this and make it more palatable, we shall play a game: Aristotle, as I observed, was one of the inventors of the Western story of 'the scientific method'. He claimed that his Natural Philosophy was based on careful observation of objective facts and generalisation of those observations -- generalisations of 'the Facts'. What he did not realise, of course, is the theory-loading, indeed the 'culture-loading' of observation and of facts, so that when we generalise about observed facts we are often simply making explicit the theories that have shaped our observations or facts in the first place. I intend to play 'Aristotle-the-methodologist' here. We will observe and generalise about some 'facts', and build more facts and generalisations upon our initial facts. In this way I, as Aristotle, shall derive the main lines of 'my' Natural Philosophy, by means of the scientific method, by observation and generalisation of facts!!

Of course, what will really be happening is that I shall be reporting and playing with theory-loaded facts and will be building larger and larger conceptual schemes based on originally theory-loaded facts. This will teach you some of the detail of Aristotle's Natural Philosophy, and it will also teach you how we can discern the theories and assumptions that lurk behind and shape facts, in this case Aristotle's facts. This is also a little exercise in the futility of scientific method. It will look as though all we are doing is observing Nature and generalising; but, really all the work takes place behind the scenes in the complex 'loading' of basic facts and their being built into even more theory-loaded big facts or generalisations.

First, let us look at the contrast between the heavens and the earth. Aristotle observed quite plausibly that nothing in the heavens ever changes -- Greek (and Babylonian) observations had never revealed any birth, death or change of a heavenly body (meteors are in the atmosphere and are terrestrial phenomena--so are comets!). We can therefore conclude that the matter making up the heavens--sun, moon, planets and stars is perfect and eternal. Admittedly everything in the heavens does appear to move in large circles around the earth--that has always been observed -- so this perfect, symmetrical circular motion must be the sort of behaviour most fitted to the perfect, noble heavenly matter. There is, furthermore, a great contrast between the perfect heavens and the seething cauldron of the earth where everything is in flux: the seasons change; the tides ebb and flow; the weather is variable; animals and plants are born, mature, reproduce and die. All this and its contrast to the eternal, perfect circular motion of the heavens is patently obvious to objective observers. We can therefore rationally conclude that the terrestrial area is different from the celestial. (Having a certain 'fact' becomes the basis of making other judgements that are supposedly factual but which are heavily theory-loaded by your original assumptions).

Now let's go further and examine what follows from the fact of the earth/heavens distinction. We know that in that each realm there is a kind of motion that appears to be natural to or symptomatic of that realm. In the heavens there is only ever circular motion, uniform circular motion. In the terrestrial area--on earth--we have 'heavy' things and they fall straight 'down' when we release them. Clearly heavenly bodies move in circles because it is part of their nature, this relates to the kind of matter they are made of; and earthly bodies fall straight down because of their nature, the kind of matter they are made of. This entails there are two kinds of matter at least! The heavens are made out of one kind of stuff and the earth another. We already suggested that maybe the heavens are made out of some perfect, eternal unchangeable stuff, and so the earth and earthy things must be made out of a different heavy kind of matter. However, on earth we also have things that seem to have a natural motion 'up' such as air bubbles

in a bath of water, or flames from a fire when there is no wind, and so clearly there are three types of matter and things -- 'heavenly' ones, 'heavy' ones and 'light' ones. The terms 'Up' and 'Down' here have clear meanings -- from simple observation: 'down' means toward the centre of the earth which is the centre of the universe; and 'up' means away from the centre of the universe; so the universe has directions built into it. This, let us note, is not Newton's universe; in fact Newton must be wrong, because observation and generalisation 'prove' there is an 'up' and a 'down'.

(After this Aristotle's theory of matter becomes much more complex than we need to go into here. He breaks up the heavy matter into two kinds of 'elements' called earth and water and he breaks up the light matter into two 'elements' called air and fire.The circularly moving, perfect heavenly matter is the fifth element, 'quintessence' to the Medievals. We are more interested here in Aristotle's distinctions between heaven and earth and the light and the heavy. We leave the rest for more detailed study).

The next thing we can say about Aristotle's universe is that it is very tidy and harmonious because everything has its **natural place:** earth, air, water, fire and the celestial matter everything is where it should be. The earthy matter is going to be compacted in as close as possible to the centre of the universe, allowing for a few mountains and oceans. And on top of the earth element is going to sit whatever water there is and then air will sit above that and then fire will be further up, but below the level of the moon, the nearest celestial body. The celestial region would surround all this.

In addition now we can see why things move 'naturally'. It is because they move to restore themselves to their natural places if they have been removed from them: 'natural motion' restores the **order of nature**! Hence, why does this heavy thing, this piece of chalk, say, fall? Well its natural place is towards the centre of the universe, therefore that is why a heavy thing like this moves downwards if we lift it up and release it. Air bubbles water move up because their natural place is above the region of earth and water. But, natural motion does not occur is when something or somebody interferes with the natural motion of the object. Lifting a piece of chalk up, I am constraining it, I am making it do what it is not intended to do, and as soon as I let it go, it is 'programmed' to fall. So we can conclude with Aristotle that, 'Natural motion' restores natural place and 'violent motion' is something that you do to bodies--to coerce them, remove them from their natural places, or generally force them to move in ways not natural two them (given the elements they are made of).

Given all these 'observtions' and true 'genralisations', we can reveal some important value judgement and orientations of Aristotelian natural philosophy: The distinction between 'natural motion' and 'violent motion' suggests to Aristotle an important point: Aristotelian Natural Philosophy has nothing to do with human technology or human crafts; that is, anything that humans do artificially to accomplish tasks or bring about results, because technology and crafts are based on making bodies do what is not natural to them. Metal ores do not turn into metals by themselves; trees do not turn into houses by themselves; wood does not burn by itself; pottery does not take shape by itself; ships do not move across the surface of the sea by themselves, so all of these technical wonders that humans do are actually irrelevant to the study and cultivation of Natural Philosophy, or at least Aristotle's version of it because everything that happens in technology is a result of violent constraints upon nature, a forcing of bodies not to follow their natures, their natural motions. Natural Philosophy, or at least Aristotle's version of it, on the other hand, is the study of natural things when they are left to themselves to carry out their natural motions and behaviours. This means that

technology and experiment, which place bodies in unnatural conditions and constraints cannot instruct us about nature. Careful observation, not experiment or technological experience is the basis of natural philosophy for Aristotle and for his followers down through the period of the Scientific Revolution.

This attitude is perfectly reasonable, given all the background assumptions: Aristotle is not saying that all technology is of no use, he is saying it is of no import in (his version of) Natural Philosophy. It is fine for there to be craftsmen, miners, shipwrights, people who make weapons, fortifications or whatever, because they produce an economic surplus that allows me, Aristotle and my friends, to sit around the Lyceum and discuss why their work is not part of science. But the really important thing to do is Natural Philosophy (in my, Aristotle's, manner!).

All this also indicates a certain social location and context for Aristotelian Natural Philosophy. Obviously it is not going to be at home in a military camp, in a boat yard, in a mill or in a printer's shop in the Renaissance. No, Aristotelianism is going to be at home in a place where people-- leisured men--are going to be able to analyse Aristotle's books, argue and write some more, and not where they are going to get their hands dirty actually dealing with human crafts or technology, because that is not relevant. That does not mean that Aristotelian Natural Philosophy was irrelevant to the societies--Greek, Roman, Medieval and Renaissance European--in which it later existed. It was relevant to people who were members of the elite and who were able to organise their lives and their pursuits in certain ways -- it was highly relevant to them. It just looks silly to us, perhaps, but let's not be Whiggish. In Greece and Rome the elite was educated for ruling society on a diet of moral and Natural Philosophy; in the Middle Ages and Renaissance a Christianised Aristotelian Natural Philosophy gave the educated elite its world-view, its values, and provided a basis for the study of theology.

As we shall see later (Chapters 19 and 20), in the seventeenth century there were groups of people who want to replace Aristotle's Natural Philosophy. They not only argue that his cosmology is wrong; they also argue that the whole attitude towards technology is wrong; that human craft and technology is the exact thing that you should be studying in order to improve science; and that this would in turn enrich human practice. Despite their own differences over what is the correct system of natural philosophy, figures such as Francis Bacon, Rene Descartes, Robert Boyle and others argued that you do not distort nature by using technology; rather, you actually reveal what is really going on, that is hidden by the superficial patterns of nature studied by Aristotelianism.

But remember...do not be whiggish! This is not a difference between one group that was right and another group that was wrong. Rather the difference is between two sets of social attitudes and values, because in the seventeenth century neither group could prove that one or the other's viewpoint was the right answer to questions about Natural Philosophy. The question of why some intellectuals in the sixteenth and seventeenth century asked different questions about Natural Philosophy and set new aims for it inconsistent with Aristotle's version of Natural Philosohy, was not because they had seen some new truth or discovered scientific method. No, it is an historical, social and political question of why they had different values and aims. We are going to examine some of the factors shaping new aims, values and goals for Natural Philosophy in the Scientific Revolution -- we will be asking these historical questions about Copernicus and his followers in Chapters 7 and 8; and later in Chapters 19 and 20 when we talk about challengers to Aristotle's monopoly of Natural Philosophical truth: 'magical' Natural Philosophies and 'mechanistic' Natural Philosophies in the early 17th century.

Figure 1 Two Sphere Cosmos