ARISTOTLE

We will only be directly interested here in Aristotle's ideas on 'physics', and his related views on metaphysics and logic. These appear very confusing to the modern reader- even to professional philosophers. However the historical importance of Aristotle's views cannot be overemphasized. The most obvious impact on physics came from highly distorted versions of Aristotle's ideas, which led much later to a protracted battle between a reactionary Catholic church and the nascent Renaissance science.

LIFE of ARISTOTLE

Aristotle was born in 384 B.C. at Stagirus, a Greek colony and seaport on the coast of Thrace. His father Nicomachus was one of the court physicians to King Amyntas of Macedonia, the father of Philip of Macedon- and hence grandfather of Alexander of Macedon, later Alexander the Great. Aristotle's long association with the Macedonian Court played an important role in his life. His father died when he was still young. In 367 BC., at the age of 17, his guardian Proxenus sent him to Plato's Academy in Athens to complete his education- he studied there for 20 years. On Plato's death in 347 BC, Plato's nephew Speusippus became director of the Academy, and Aristotle thereupon left along with Xenocrates for the court of Hermeas. Hermeas was a former slave, who had become a pupil at the Academy and then eventually ruler of Atarneus and Assos in Mysia (Asia Minor). Aristotle stayed for 3 yrs, marrying Pythias, the King's niece (who later died giving birth to their daughter); at the end of this time Hermeas was assassinated by the Persians, and Aristotle and Pythias fled to Mytilene in Lesbos- many of his biological investigations belong to his time in Lesbos. In later life he was married a second time to Herpyllis, who bore him a son, also called Nicomachus. In 343 BC, at the invitation of Philip of Macedon he became the tutor of his 13 year old son Alexander; he continued with this for the next 3-4 years. In 340 Philip asked him to direct the restoration of Stagirus, which had been laid waste by the Olynthians, and to draw up a code of laws for it.

Upon the assassination of Philip in 336 BC by Pausanius (one of his officers), his son Alexander gained control of the kingdom of Macedonia, and prepared for his epic conquests. Aristotle then returned to Athens, which he had not visited since the death of Plato. He found the Platonic school flourishing in the Academy under Xenocrates, peopled mostly by the sons of aristocrats, and the school of Isocrates frequented more by colonial Greeks. He thus set up his own school at a place called the Lyceum (named after the god Apollo Lyceus). When teaching at the Lyceum, Aristotle had a habit of walking under covered walks called '*peripatoi*' as he lectured- his followers thence became known as the "peripatetics". For the next 13 years he devoted his energies to his teaching and research, and to the writing of his many works. He apparently gave detailed discussions in the morning for advanced students, and popular discourses in the evening. His research involved the gathering and classification of 'knowledge' in a large variety of fields, ranging from the politics and customs of different parts of the world (particularly Greek city states), the chronology of victors in the Pythian games, to an enormous corpus of data on animals, plants, and history.

At the sudden death of Alexander in 323 BC., the pro-Macedonian government in Athens was overthrown, and a general reaction occurred against anything Macedonian. A charge of impiety was trumped up against him. To escape prosecution he fled to Chalcis in Euboea so that (Aristotle says) "The Athenians might not have a chance to sin against philosophy a 2nd time" (as they had done first by executing Socrates). In his first year of his residence at Chalcis he complained of a stomach illness and died (322 BC).

1. WORKS of ARISTOTLE

Most of Aristotle's works are apparently lost to us- his output seems to have been enormous. It included (i) popular writings and dialogues- the 'exoteric' works (ii) Memoranda, and collections of facts and material from his more scientific work; and (3) systematic scientific and philosophical treatises. These works were apparently held in their entirety by Aristotle's student Theophrastus, who succeeded him as leader of the Peripatetic School. Theophrastus's library then passed to his pupil Neleus- to protect the works of Aristotle from theft, Neleus's heirs then hid them in a vault, where they remained for some 400 yrs and were damaged by damp, bacteria, moths and worms. They were discovered about 100 BC by Apellicon, a wealthy bibliophile, and brought back to Athens. After the capture of Athens by Sulla in 86 BC, what was left was taken to Rome, and finally published in an organised form around 30 BC by Andronicus of Rhodes- one of a new generation of Roman scholars responsible for a resurgence of interest in both Aristotle and philosophy in general. This collection forms the basis of the works of Aristotle that we have today- we owe these to what later reached the hands of Islamic scholars after the fall of Rome. The organisation of these

remaining works of Aristotle dates from Roman times- it is likely that in their original form they were unpublished notes, perhaps organised in quite a different way, and perhaps not intended for publishing at all. In total, of the roughly 200 written works of Aristotle, we only have 31, and it is not clear how much of these were written by him. Such are the vagaries of history.

Basic Classification

(1) *Popular*: Among Aristotle's 'exoteric' writings of a popular nature there are fragments of several letters, which may be forgeries, and of 3 poems. The most important of his popular writings were apparently the *Eudemus, Proprepticus*, and *On the Good, On the Ideas*, and *On Philosophy*, none of which survive, although we have extracts from these by later writers, and some hundred quotations or references from them. It seems likely that some of these writings were quite remarkable- Aristotle's prose was described as a 'golden river of language' by writers of antiquity.

Memoranda, Collections: Almost nothing survives of this. The works in the second group include over 200 titles, most in fragments, collected by Aristotle's school and used for research. Some may have been done under the aegis of Aristotle's successor Theophrastus. Included in this group are constitutions of 158 Greek states, of which only one survives- entitled 'On the Polity of the Athenians', rediscovered in a papyrus in 1890. There was also a record of dramatic festivals, called the *Didascaliae*, and what was in all likelihood an enormous corpus of data collected by Aristotle and his pupils- and this research-gathering continued under Theophrastus.

Treatises: The systematic treatises of the third group are not distinguished by their literary style. This may be because these works were not, in most cases, published by Aristotle himself or during his lifetime, but were edited after his death from unfinished manuscripts and notes. Werner Jaeger argued in 1912 for an early, middle and late period (genetic approach), where the early period follows Plato's theory of forms and soul, the middle rejects Plato, and the later period (which includes most of his treatises) is more empirically oriented. Argument has raged over this ever since- another school argues that late in life his approach became more Platonic.

Aristotle's systematic treatises may be grouped in several division:

(1) **Works on Logic/Arumentation**: (the **Organon**)

Categoria (Categories): 10 classifications of terms
De Interpretatione (On Interpretation): propositions, truth, modality
Prior & Posterior Analytics: syllogistic logic, scientific method and syllogism
Topica(Topics): rules for effective arguments and debate
De Sophisticis Elenchis (On Sophistical Refutations): informal fallacies

(2) **Works on Physics**

Physica (Physics): explains change, motion, void, time
De Caelo (On the Heavens): structure of heaven, earth, elements
De Generatione et Corruptione (On Generation and Passing away): via combination and dispersal of material constituents
Meteorologica: origin of comets, weather, disasters

(3) **Psychological works** (the **Parva Naturalia**)

De Anima (On the Soul): explains faculties, senses, mind, imagination
De Memoria et Remeniscentia (On Memory & Reminiscence)
De Somniis (On Dreams)
De Diviniatione per Somnum (on Prophecy by Dreams)

(4) **Works on natural history**

Historia Animalum (History of Animals): physical/mental qualities, habits
De Partibus Animalium (On the parts of Animals)
De Motu Animalium (On the Movement of Animals)
De Incessu Animalium (On the Progression of Animals)
De Generatione Animalium (On the Generation of Animals)
Minor treatises
Problems

(5) **Philosophical works**

Metaphysica (Metaphysics): substance, cause, form, potentiality
Ethica Nicomachea (Nicomachean Ethics): soul, happiness, virtue, friendship
Ethica Eudemaia (Eudemain Ethics)
Magna Moralia: probably a later contribution
Politica (Politics): best states, utopias, constitutions, revolutions
Rhetorica (Rhetoric): elements of forensic and political debate
Poetica (Poetics): art of tragedy, epic poetry

We can group the works of Aristotle, as he apparently did, into 3 groups. The first group, of most interest to us, comprises the 'theoretical sciences' (where 'science' here simply means 'knowledge/understanding'). This includes what we now call metaphysics, but which Aristotle called 'first philosophy', as well as his works on logic and argumentation, and then the whole corpus of what we now think of as Science, including mathematics, physics, biology, and even psychology (NB: whether or not Aristotle considered psychology to be a theoretical science was a question much debated in the Renaissance).

From this point of view the works in the Organon are essentially theoretical, but of a different character from the rest. They are concerned with the basic methods and tools to be used in thinking and argument (NB: *organon* means "tool"). In addition to Aristotle's ground-breaking ideas about logic and argumentation (appearing mainly in the "*Prior Analytics*" and "*Topics*"), the Organon also dealt with his classification of different terms to be used in argument (in the "*categoria*"), his theory of propositions, and how one was to decide whether they were true or not (in the "*Interpretatione*"), and in a more limited way, the basic underlying principles of scientific theory, and the principles of epistemology (in the "*Posterior Analytics*". Related work is of course to be found in the "*Metaphysics*", where he discusses the basic principles governing causes, forms, and 'substance, along with his curious ideas about '*potentia*", which were to be incorporated into his ideas about the natural world.

From then, lowering the level of abstraction somewhat, one proceeds to mathematics and physics. Physics for Aristotle is a study of the universe as a whole, focussing on the key theoretical and conceptual questions underlying the study of Nature, as opposed to detailed empirical work. Part of this work also includes what we now think of as purely epistemological or even metaphysical questions; eg., his theory of causal explanation and his arguments for an unmoved mover thought to be both the first and the final cause of all motion (*cf.* his "*Efficient*" and "*Final*" Causes). This work appears both in the "*Metaphysics*" and in the "*Physica*". Other topics are what we would now think of as mathematical problems related to central aspects of physics, such as his discussion of Zeno's paradoxes of motion and time, the nature of the infinite, the nature of geometry and geometrical objects, what it means to be at a point in space, etc., etc. (primarily in the "*Physica*"). And then there are his detailed ideas about meteorology, the heavens, and his cosmological theory, which are now of little but historic interest.

Finally comes the great mass of work on biology, which is fascinating its mixture of detailed observation, of remarkable quality in some cases, along with a theoretical framework for understanding this empirical work which to us seems extraordinarily strange. For Aristotle the key to living things was that they all possessed a "*soul*"; this explained their unique ability to move around, and to reproduce. He viewed the soul as (i) the cause of motion for living things (ie., the efficient cause), (ii) that which gave purpose to this motion (ie., the final cause), and (iii) the "*substance*" of living organisms. Thus for Aristotle, the soul was both the cause and the source of life. These ideas also led him into what we now think of psychology, discussed in his "*Parva Naturalia*"). A detailed discussion of all of this is too far off our topic here.

The other works of Aristotle were grouped into the 'practical' sciences - this included social and individual conduct, and all of what we would now consider as ethical questions - and the 'practical' sciences, which dealt with what we now thing of as engineering, agriculture, medicine, and the whole range of artistic and cultural activities of his time (including the art of rhetoric). Again, most of this is quite irrelevant to our present topic.

2. SUMMARY of IMPORTANT IDEAS

To capture the enormous scope of Aristotle's work, even given the restriction to what has come down to us, is too difficult here. It is sobering to realise that Plato was writing in the absence of any real idea of either logic or grammar- even elementary ideas about Western language such as the subject and predicate in a phrase, or logical implication, were not understood in any systematic way, if at all. In the same way the present categorisation of things in the world around us- the classification of different kinds of knowledge, ideas about matter, the classification of different kinds of physical object into animate and inanimate, the idea of knowledge itself, of causation, etc., were either very different from what we have now or non-existent. Certainly nobody before or since Aristotle has made a greater contribution

to the organization and elaboration of human thought in all of these spheres. Here we simply address in a cursory way a few things relevant to our present topic, the development of physical science.

2.1: Logical Questions

One of the many essential tasks that Aristotle set himself was to give a proper understanding of the structure of rational thought, as an essential preparation to more rigorous and systematic thinking, and to the understanding of philosophical issues. Aristotle used the term "logic" (his term was "analytic") in a sense equivalent to verbal reasoning- the *Organon* (meaning "instrument") was a prerequisite for all rational inquiry. The *Categories* are simply classifications of different kinds of individual words (as opposed to propositions), and there are 10 of these: substance, quantity, quality, relation, place, time, situation, condition, action, passion. There is a hierarchy here which becomes clear in his metaphysical ideas. For Aristotle the structure depended on the way in which one would go about investigating the nature of something. We ask first what a thing is, then how large or plentiful it is, what its basic qualities are, etc; thus the categories attempt to tame philosophical inquiry by a methodology. Substance is always regarded as the most basic of the categories- it is a kind of primitive, which has no opposite. Substances are further divided into first and second: first substances are individual objects, whereas second substances are the species and genera in which first substances or individuals inhere- ie., what individual objects *are*. Thus Socrates is a 1st substance- he is also a Man (species) and an animal (genus).

Logic and logical notions such as truth and falsehood for Aristotle only applied to demonstrative propositions. Propositions were collections of words representing basic notions, giving rise to rational speech and thought. They may take many forms, but logic considers only demonstrative forms- their truth or falsehood is determined by their agreement with facts. Thus propositions are either affirmative or negative.

A definition, for Aristotle is a statement of the essential character of a subject. To get at a true definition we must determine those qualities within the genus, whose intersection is precisely equal to it- one should think in terms of Venn diagrams here. For example, "French", and "prime minister" taken together do not specify a particular object- but if we add "female", we get the unique object "Edith Cresson" (who was for a short 6-month period a rather disastrous Prime Minister of France). Analogous specifications lead to Kim Campbell in Canada, Indira Gandhi in India, etc. Obscurity in definitions, according to Aristotle, may arise from the use of ambiguous terms, of metaphorical phrases, or of eccentric words. A central part of Aristotle's logic is the syllogistic form, the classic example of which is as follows:

All men are mortal; Socrates is a man; therefore, Socrates is mortal.

However this is not all- other logical principles, such as the laws of 'excluded middle' and 'contradiction', etc., are also involved.

Perhaps the most remarkable thing about Aristotle's logical studies is the recognition in the first place of the existence of laws of logic, and the attempt to discover them. It is a testament to the achievement of Aristotle (and to the vice-like grip that established tradition can exercise on human thought and culture) that his views on logic, and the syllogistic form, dominated logic and rational discourse in Western civilisation for over 2,000 years, in many different language groups having quite different grammatical structures. The indirect effect of this domination, on the evolution of language and culture, was colossal. In the 21st century we now have a rather different view of logic- to which I return much later in these notes- but the basic pattern was set by Aristotle and by the Greek mathematicians.

Notice the important connection between logical and linguistic structures. Interestingly, in Chinese civilisation logic was almost entirely neglected, as was systematic grammatical study- and Chinese philosophy was consequently largely unconcerned with mathematics and science. In Indian civilisation logical studies were important (as was mathematics), but much of this development is still poorly known. The full story on alternative logic systems to the Western one (which is now used all over the world) will be of enormous philosophical significance- both in understanding how universal are different logical principles, and in understanding the relation between logical structure and grammar. It is hard to believe that the present structure will survive unscathed.

2.2: Metaphysics, and the Attack on Platonic Forms

Aristotle's metaphysics (and his physics) derive from a quite different conception of the fundamental stuff of the universe. He was dissatisfied with the immutable Forms of Plato for at least the following reasons:

(i) The problem of change- Forms are powerless to explain changes of things, or the genesis and extinction of some thing. Plato contended that Forms are not causes of movement or change in the physical objects of our world of experience; and Forms themselves are immutable. It is indeed hard to see how immutable objects, even in a transcendental world, could explain change in our world.

(ii) The problem of knowledge- Forms cannot explain how we arrive at knowledge of particular things. The Forms place knowledge outside of particular things- real knowledge is of Forms. Yet it is hard to see why knowledge of, say,

the existence of a physical object like the Sun, or of our own body, is less sure than that of Forms- or to see how knowledge of Forms makes our knowledge about the Sun any more secure. Aristotle was also dissatisfied with what Platonists had to say about objects of art, which seem just as knowable as anything else (but which for Plato did not exist in a fundamental way);

(ii) The problem of existence of physical objects- Plato argued that Forms do not exist in the objects of the physical world. Instead, these objects were supposed to 'partake', more or less, in the Forms. The nature of this intermediate link between the form and the particular object is not clear- moreover, it raises the problem of the 3rd Man (see Plato notes); there must always be a "third man" between the individual man and the Form of man, if they are somehow both to relate to whatever qualities have to do with Man (and so on ad infinitum).

The answer of Aristotle to this came in several parts. His discussion of the physical world is given below. His metaphysics is very hard to understand in parts- one suspects that one reason why it exercised such a strong hold on later religious thinkers is precisely *because* of its obscurity, which lent it an air of deep mystery. My own personal opinion is that much of the obscurity derives from the fragmentation of what were originally no more than notes. The term 'metaphysics', which is nowadays usually taken to mean the understanding of 'being' or 'existence' in the most general sense (as opposed to physics which studies the particular objects which do exist). It can also mean the inquiry into, or search for, first principles in the understanding of the world. Both of these fell under the umbrella of Aristotle's writings on the subject.

Some of Aristotle's ideas in metaphysics are not so different from what is sometimes nowadays described as the idea of 'logical constructs' (see Supplementary notes on Socratic Dialogue). Aristotle asserts that the primary entities in the world are not Plato's Forms, which are super-sensible and unchanging, but instead what he calls "*Ousia*". This term is usually translated nowadays as "substance", which is very confusing. It is useful to note a number of the key terms in Aristotle:

aether: the 'ether', or eternal fire- the 5th element.
aition: usually translated as 'cause', but much more general.
dunamis: 'Potentiality', sometimes translated as 'faculty'. The potential to be something
eidos: 'species'; this is also used to mean 'form' (not a 'Form').
idea: this is 'Form', in the Platonic sense.
kath' houlou: 'universal', as opposed to 'particular'; sometimes the same as 'Form'.
kinesis: best translated as 'process', sometimes to mean 'change'.
ousia: usually translated as 'substance', or as 'essential reality'.
physis: Nature- which is rather different from what we now mean by this (see below)

Roughly speaking, the substance of a particular thing is that which is unique to it, and not to anything else- it is what it makes it what it is. In some sense it is what is 'real' about the thing. This is where we enter into linguistic confusion because often this is expressed by saying that the substance *is* the thing.

The secondary categories can be thought of as properties or qualities of the primary substance. There is an irresistible tendency here to say that the relation between substances (or 'particulars') and these secondary qualities is nothing but the linguistic relation between a subject and its predicates. In this sense the subject can exist without the predicates, but not vice-versa. For example grass and leaves can exist without being green, but 'green' (or 'greenness') cannot exist without subjects like grass and leaves. This is of course completely opposite to the Platonic idea of Forms (in which 'Green' would be an eternal Form, and grass merely part of the impermanent and imperfect physical world of our experience).

The question then is how one can specify a particular substance. This is already discussed above, where the idea of an overlap of qualities is required to specify the essential nature of an object (see the discussion on 'definitions'). However Aristotle goes a lot farther than this. This is necessary because he wishes to solve the problem left over by the theory of Forms, the problem of change. Thus it is necessary to say how it is that substances can change, even though they are in some way supposed to be the most fundamental things there are (what we might now call 'elements of reality'). The way he does this is to to assume that substances are composite. This should be understood in a rather peculiar way. To specify how substances change, we need to talk about 4 'Causes'. This name is confusing because only one of the causes corresponds to the modern use of the word. The Causes are

(i) The *Formal Cause*: This is the form of the object- such as the shape of an object like the human body. One should think of form in a more general sense than just shape- in the case of the body, it includes presumably all the detailed physical structure, internal and external.

(ii) The *Material Cause*: This is the matter out of which the substance is 'made'. What matter is made from will be explained below- it has to be composite as well otherwise we could not explain the different kinds of matter.

(iii) The *Efficient Cause*: This is what we conventionally think of as cause, in the sense of being what is driving the change. One should strongly refrain from thinking in terms of 'forces' here- the concept was quite absent from

the whole Greek system.

(iv) The *Final Cause*: This the end point of the thing in question, what it is finally destined to become. This notion is somewhat teleological- it is easily confused with the idea that all things have some purpose. For Aristotle all things had a 'natural' place or state- more on this when we discuss his physics.

Aristotle gave a few examples of what he meant. Consider, eg., a marble sculpture. In this case the material cause is the marble, the formal cause is the shape of the sculpture, the efficient cause is the set of actions of the sculptor's tools on the marble; and the final cause is more obscure, but is in some sense the artistic/aesthetic goal of the sculpture.

The idea of change is now supposed to be explained by invoking the idea of 'potentiality'. Things (substances) change in order to fulfil their potentiality- according to Aristotle this typically means acquiring more form (as in the example of the sculpture). If this seems a little mysterious then it is important to realise just how much Aristotle was influenced by his observations and understanding of living things, and the way they change. They were a blueprint for his metaphysics- again, more on this when we get to Aristotle's physics. In any case, for Aristotle, 'bare matter' was 'potentiality of form' (it is not quite clear what he meant by matter without form- perhaps an unbounded gas), and change meant an evolution towards more form, making the substance 'more actual'. In this connection note that Aristotle thought the 'Soul" was the form of the body (which presumably departs from the body upon death and disintegration of the body after death- Aristotle did not follow Plato in his arguments for immortality of the soul).

2.3: Aristotle's Physics

The key to understanding a lot of the Aristotelian philosophy is the connection with what we now call biology. It is important to realise that our modern mechanistic conceptions did not exist then. What was however glaringly obvious to the Greeks was that most things that moved around, did so because they were alive. It was then just a small step to argue that all motion was associated with life in some way. The word '*physis*', from which 'physics' derives, is usually translated as 'Nature', but for Aristotle this means more than just the living world- it means the end point to wards which something (indeed all things) are evolving, thereby fulfilling their 'potentiality'. One can think of many examples- the way a seed becomes a plant, but also the way things degrade after death- or the way a sculpture evolves to have more 'form'. Thus 'Nature' is a source of change (or what we could also call 'dynamics'); it involves motion, change of size and shape, physical development and growth, or degeneration.

If one starts from this point of view, then what we consider to be inanimate objects, which nevertheless move, are going to have to be explained by the same sort of theory. It is clear that a mountain (which may have started as a volcano, and will be finished eventually by erosion) or the sea, or the planets, moon and sun moving in the sky, are not alive in the usual sense- but the Greeks had little of our current understanding of what life was, and indeed it was not hard for them to imagine that some kind of living entity was associated with such objects. These were the Greek Gods- and recall that the whole ancient Greek culture had emerged from a pagan society. Thus the God Hephaestus (called by the Romans Vulcan) lived under the best known volcano of the Mediterranean, the sea was controlled by Poseidon (the Roman Neptune), etc..and the celestial objects were also divine.

It remains to fill in the details. These were interesting. Not only was 'substance' composite, in the form of the 4 causes, but also matter, which is one of the 4 causes, is also composite according to Aristotle. He simply adopted the earlier idea of Empedocles here- the 4 fundamental 'elements' or basic constituents of matter were Earth, Fire, Air, and Water. However Aristotle added his own twist- each of these had a 'natural tendency' to find its own place in the world. Earth, being the heaviest (NB: actually, most dense) naturally wanted to find the lowest place, whereas Fire was exactly the opposite, and tended to rise. If this was al there was, one then would see a rapid separation of the elements; but Aristotle contended that the elements also converted between each other (again, there is a basic obscurity here- how did this happen, and what 'caused' it?). One should perhaps imagine something like the convection that takes pace in a heated room, and which is so important for weather- we have all seen how a hot fluid rises, subsequently giving up its heat to then sink again (setting up a flow pattern which the Greeks were surely aware of).

Notice that the modern ideas of 'dynamics' and dynamical laws, which included physical forces, were utterly foreign to the Greeks- they only came 2000 yrs later with Newton. Thus 'gravity' or gravitational force would have been meaningless ideas to them. The explanation of dynamics in everyday life was to be found in 'natural tendencies' which drove all change, and which were part of 'Nature'. As a corollary to this Aristotle had no need for the vacuum, or empty space- he explicitly rejected this idea, under the powerful influence of the older arguments of Parmenides- this neglect of the ideas of Democritus was a huge loss to the historical development of science.

Incidentally, these ideas about dynamics do not mean that there was no room for a discussion of time in Aristotelian physics. In fact, heavily influenced by mathematical thinkers like Zeno, Pythagoras, and perhaps even Democritus, Aristotle saw time in terms of countable intervals. Moreover, he argues that there could be no time without motion- in a certain sense this is quite a modern idea, which we will return to in the discussion of Newton and Einstein.

Finally, Aristotle argued that the series of actions leading one object to cause motion in another had to be initiated by a 'Prime mover', or 'unmoved mover'. Thus for Aristotle, we see that the motion and/or physical disposition of an object relied on having both a 'First efficient cause' (the Prime mover), and also a Final Cause, which governed how it ended up. Both of these ideas influenced his his cosmology, to which we now turn.

2.4: Aristotle's Cosmology

In fact Aristotle invoked not a single prime mover, but a large number- either 47 or 55 (numbers arrived at by arguments which are irrelevant here). Aristotle's picture of the universe was rather interesting (if a trifle bizarre)- we are speaking here of his final picture of it, since his ideas evolved in the different books. At the centre of the universe was the Earth, surrounded by a large number of celestial spheres (47 or 55). The 'lunar sphere', marking the orbit of the moon, also demarcated the border between the eternal realm, outside the lunar orbit, and the terrestrial realm, inside the lunar orbit. In the eternal realm the heavenly bodies reside; these are composed of the 'fifth element', which is called *aether* (and later called *quintessence*), which is a kind of 'eternal fire', from which the stars, planets, and sun are made. The 'natural' motion in the eternal realm is in circular paths- the celestial bodies move around one of the various celestial spheres, which themselves do not move. Thus each of the celestial spheres represents a separate unmoved mover. This celestial world is unchanging and indestructible- and no evolution or change occurs in it.

Inside the lunar sphere one has the steadily changing world made form the 4 other elements, whose essential composition and characteristics were described above. Inside the lunar sphere natural motion is no longer circular but rather is rectilinear.

The theory of Aristotle here is a strange mixture of ideas absorbed from Greek astronomers and mathematicians like Eudoxus, and his own philosophical speculations. It is clear that these ideas were a kind of compromise between, or an attempt to fuse, an empirical or taxonomic approach, akin to modern sciences like biology, with the more philosophical approach of the Athenian school. It is likely that for Aristotle, much of this work was in the same speculative vein as that of Plato. However what survived the vicissitudes of history- his notes- was framed in quite a different way. Instead of appearing in the form of dialogues, wherein it would be have been obvious that any conclusions were open-ended, Aristotle's ideas were handed down in the more dogmatic and systematic form of a set of treatises. This was have to have huge consequences for European history, as we shall see later on. It seems likely that Aristotle would have been horrified at what was done with his ideas- but he would be neither the first nor the last to whom this has happened.

3. LOOKING BACK at ARISTOTLE

Probably no other writer in history has so influenced the course of human thought as Aristotle, and for so long. One may discern two important questions here. First, in what ways have our ideas about the world been the product of Aristotle's work, and how has this thinking evolved over the centuries, in the various cultures (European, Islamic, etc.) that fell under his spell for so long). This is primarily a question about the history of ideas, and their practical effect on human history.

Second, instead of asking about the history of the ideas, we can ask about the ideas themselves, and attempt to form a critical judgement of them. Obviously in many ways the context in which we view the ideas has changed, but what is just as interesting is to look at Aristotle's arguments for them. Since many of the key questions are just as relevant today as they were in his time, this exercise can be very useful.

3.1: HISTORICAL SURVEY

¡¡ This is to be done at a later date ¿¿

3.2: A CRITICAL LOOK at the ARGUMENTS

In what follows we will look at some of Aristotle's key arguments, and the role they play in this theoretical framework. We are interested here primarily in the arguments themselves and the conclusions they lead to. Where the arguments are relevant to other topics, modern or otherwise, we also look at this. Again, we will be most interested in arguments that are relevant to modern science, particularly the physical sciences.

3.2.1: Exhaustive Description/Explanation: The 4 Causes

¡¡ This is to be done at a later date ¿¿

3.2.2: The Teleological Argument and Final Causes

The argument that part of the explanation/description of any object must involve a Final Cause has been the most controversial part of Aristotle's theory of knowledge. As noted above, it was used in the middle ages by Thomas Aquinas to produce one of his 5 arguments for the existence of God, in the form of the '*Argument from Design*'; Aquinas was consciously using part of the Aristotelian theoretical framework in support of his arguments. Since Aquinas this argument has resurfaced many times, notably in historically important discussions about the origin of the universe, of the earth, of life, and about the theory of biological evolution. It underlies current discussions over subjects as diverse as the 'anthropic principle' (which purports to explain certain features of physical law in terms of the existence of intelligent beings) and the argument for 'intelligent design' (which tries to demonstrate that the existence of order and law in the universe must be the result of a designer). The argument has of course acquired, from time to time, strong religious connotations, but we will not be concerned with these - instead we simply wish to understand the argument and its strengths and weaknesses.

Let us first examine more carefully what Aristotle did and did not say, before proceeding to an analysis of it. The least controversial part of Aristotle's doctrine has to do with the idea that objects such as a sculpture, or a house, are obviously designed and built for a purpose, and that a complete description and understanding of these objects must necessarily include a discussion of this purpose. Moreover, if we are to characterize the history of the object (which is part of what is described by the Efficient Cause), then it is not enough to enumerate the physical influences that have led to its formation and present state, but one much also explain the goal to which all of these actions were directed. Thus, a house does not spontaneously assemble itself out of sand, stone, trees, metallic ores, etc., but is assembled by purposeful agents which cut up the trees, manufacture concrete from sand and stone, and electrical cables from metals that have been refined from the products of mines, and then designs and builds the house using these materials. None of this could happen without the efficient causative actions of these purposeful agents, but equally, none of it would have happened unless there had been a very specific *intention* guiding the actions of these agents. One could make the same remarks over, for example, the prehistoric artifacts that we have found, dating back in some cases millions of years, which form a key part of our knowledge and understanding of human history. It is precisely the obvious design features of these artifacts that distinguishes them from the rocks and bones amongst with they are buried.

However, Aristotle's Final Cause applies much more generally than this, and embraces not just objects that have obviously been designed by humans or animals, but many other things in the world which obviously have a structure or pattern which is not accidental. Thus, in considering an object like a seashore, one has to ask why it possesses a certain structure, which is hardly accidental, even though it was might not have been created by any intentional agent. Nowadays we might talk of the forces acting on the rocks and sand from gravity, the sea, wind, and sun, as well as including a discussion of the crystal structure of the rocks, to explain why the seashore adopts the form it has, and why the sand and rocks form certain shapes - in other words, we would discuss everything in terms of causative agents and forces, which fall under the heading of Efficient Causes for Aristotle. For Aristotle, it was necessary understand and explain the existence of order and regularity in Nature, and this could not be done purely in terms of efficient causes, since there was no reason why these would produce order or regularity.

To pick an example: in the *Physics*, Aristotle, in a discussion of the different parts of the body, remarks that:

" *For these and all other natural things come about as they do either always or for the most part, whereas nothing which comes about due to chance or spontaneity comes about always or for the most part. Then these are either the result of coincidence or for the sake of something, and if they cannot be the result of coincidence or spontaneity, it follows that they must be for the sake of something.... "*

The basic idea here is that unless something is either accidental or 'spontaneous' (ie., created in an accidental way), then it is there 'for the sake of something'; ie., that it is not there accidentally but in conformity with some pattern or order. One must then seek a teleological or Final Cause for this. Thus, eg., one finds teeth aligned in a regular way in many organisms - the pattern here is there 'for the sake of something', ie., it requires an explanation in terms of some teleological cause. As regards living things, Aristotle remarks:

" *This is most obvious in the case of animals other than man: they make things using neither craft nor on the basis of inquiry nor by deliberation. This is in fact a source of puzzlement for those who wonder whether it is by reason or by some other faculty that these creatures workspiders, ants and the like. Advancing bit by bit in this same direction it becomes apparent that even in plants features conducive to an end occurleaves, for example, grow in order to provide shade for the fruit. If then it is both by nature and for an end that the swallow makes its nest and the spider its web, and plants grow leaves for the sake of the fruit and send their roots down rather than up for the sake of nourishment,*

it is plain that this kind of cause is operative in things which come to be and are by nature. And since nature is twofold, as matter and as form, the form is the end, and since all other things are for sake of the end, the form must be the cause in the sense of that for the sake of which."

This is a typical example of Aristotle's fine art of observation in the realm of the natural world. We note that his idea that all living things have souls does not have the modern religious connotation, and does not imply that birds, spiders, or plants are able to reflect on what they do, or that there is any conscious or rational intent on the part of animals or plants. But there is clearly a purpose to the things that they are doing - this is his point. And once he has discerned purpose in the actions of organisms like plant, it is for him a small step to look for purpose inherent in all of the regular organized forms of Nature, in which things are apparently not happening randomly but rather according to some pattern.

It is of course very easy to slip from the idea that Nature and natural events are regulated by pattern and form, to the idea that there is some *plan* inherent in Nature. This is how one very easily crosses over to the 'argument from design', according to which the regularity and structure in Nature has to be the result of a design - that because it could not have happened by chance, it must have been designed. So it is important to emphasize that this is *not* what Aristotle thought. Indeed, he explicitly denied that the various causes which operate in the world require an active agent for their explanation or existence. In other words, organisms or seashores have final causes, but they do not have them because of the designing activities or intent of some active agent. To put it more bluntly - Aristotle explicitly rejects the 'argument from design', according to which a Final Cause or purpose requires a designer. In this context it should be recalled that Aristotle himself was rather hostile to the idea of supernatural explanations of phenomena in Nature - he rejected the religion of his day as primitive, and felt that a proper explanation of the world should not rely on unexplained or inexplicable deities, which for him, provided no explanation at all.

¡¡ Analysis of these arguments: to be done at a later date ¿¿

From the point of view of modern science, one may immediately remark that physics makes a crucial distinction between (i) physical structures and processes in which pattern or apparent design is manifested, and (ii) completely disordered or random phenomena. Thus in this sense Aristotle anticipated a point of view that is actually quite modern. However we are now in a position that was way beyond what Aristotle could have imagined: we now have a very precise way to mathematically characterize order and pattern, in terms of concepts like entropy and information that were developed in the last 100 years or so. We also have at least a partial explanation for the way in which order and structure seem to increase in certain regions of the universe as time goes on (eg., on planets like our own), even though the universe as a whole is becoming more and more random. As we shall see later on, the two key reasons for this are (i) that the universe began, in the Big Bang, in a state of very low entropy (ie., it was highly ordered, at least compared to what could have been); and (ii) that the existence of gravitational fields has caused an initially homogeneous (and very dense) universe to become extremely inhomogeneous, wherein the average density is almost zero (ie., with huge regions of almost empty space) but where there are, here and there, massive concentrations of matter and energy (stars, planets, galaxies, black holes, etc.).

Nevertheless big questions and mysteries do remain in our understanding. For example, the question of why complex structures can survive, grow, and reproduce on earth is easy to answer in terms of the high-energy radiation coming in from the sun; this radiation keeps the world warm and far from thermal equilibrium, and is able to drive and support most of the interesting processes on earth that we are accustomed to - from thunderstorms to life. The sun itself is the result of the condensation, under gravitational forces, of clouds of gas and dust, and is itself an organized structure. But there is as yet no *detailed* explanation for the initial creation and growth of extremely complex structures in Nature, and the tendency for some of them to become more and more sophisticated over time - most notably in the form of living structures. We have essential clues to this, in our understanding of catalytic processes, and of evolution and competition even at the molecular level, amongst molecules or groups of interacting molecules that are still very far from being part of any living system. But while these clues are very suggestive, they do not yet constitute a detailed theory for the continuing evolution of ever more complex structures in 'non-equilibrium' systems (ie., physical systems that are not in thermal equilibrium because they are being driven by energy fed in from outside).

From this point of view one can remark that Aristotle's views, even though they seem quite far removed from our own, at least succeeded in pinpointing a rather important aspect of the natural world, and in avoiding a lot of intellectual traps in trying to explain this.