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CHAPTER ONE

INTRODUCTION

I intend in this dissertation to enquire into the ideas held by the Pre-Socratics and Plato about the nature and properties of the substances that we now call 'gases' - a word invented by van Helmont (1577 - 1644), a pioneer of modern chemistry, who was the first man to recognise the nature of gases other than air. Before his time, and indeed for some time after, man had no idea of what gases really are, and what gives them their properties. Yet the Greeks did realise that there are certain things that, although they are invisible and intangible, and therefore fail to pass two of the typical tests for reality used by the early 'scientists', are, nevertheless, real substances. What led to this discovery, how did they interpret it, and how far was that interpretation in accord with modern theory? These are the questions that I hope to answer.

The answer will involve a general survey of the history of early Greek science; for there were, of course, many schools of thought, and several stages in the development of the various schools. It will, in particular, be necessary to study Greek theories of the nature of matter, and of the primary 'element' or 'elements' out of which they imagined the universe to be made.

Before attempting, however, to interpret and criticize the theories of the ancients, it is necessary to have a clear idea of the answers given by modern science to the questions asked by the Greeks, in order to be able to understand both the problems with which they were faced and the degree of success or failure achieved by their answers.

I propose to begin, therefore, with a brief outline of what is now known about gases and about matter in general, in order to explain, or in some cases define, the words that will form the technical vocabulary of the main body of the thesis, and to avoid repetitive statements of modern theory in the latter.

The theory of matter held at present is the 'atomic theory'. The first step towards this was taken by Robert Boyle (1627 - 1691). He first cast eyes on the ancient atomic theory with the idea of modifying it to form a satisfactory hypothesis for the explanation of the nature and composition of matter. He objected to the 'three element' theory of Paracelsus (sulphur, salt and mercury), and to the 'four element' theory that had survived until his own day from its origin in Classical Greece: he showed the advantages of the atomic hypothesis in explaining chemical changes, and was the first to distinguish properly elements, compounds and mixtures. The survival of the 'four element' theory for two millennia was probably due to the fact that it was sufficiently vague to suit almost any phenomena, and exceedingly hard to disprove.

After Boyle's suggestion had had some time to sink in, true modern chemistry commenced when Dalton gave the atomic theory its first clear enunciation and practical demonstration in 1807. * A quantitative basis was soon established for the theory by Avogadro's Hypothesis, in 1811; and great strides had been made by the time that

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* He made the following assumptions (quoted from "Inorganic and Theoretical Chemistry", 7th. Ed., by F. Sherwood-Taylor, p. 39):

1. Atoms are real separate material particles which cannot be subdivided by any known chemical process.
2. Atoms of the same element are similar to one another in all respects, and equal in weight.
3. Atoms of different elements have different properties - weight, affinity, etc..
4. Compounds are formed by the union of atoms of different elements in simple numerical proportions, such as 1:1, 1:2, 1:3, etc..

Mendeleef gave chemistry practically its modern form by drawing up, in 1869, the Periodic Table of the Elements. Since then the main line of progress has been physical rather than chemical.

Spectrographic research and X-ray analysis interpreted by mathematics led to the Quantum Theory, the Bohr Billiard Ball Atom, and the Rutherford Atom. From this relativity, wave-mechanics, and probability theory, have given us our present theoretical conception of the atom, which is shown to be at least fairly near to the truth by the successful invention of the Atom Bomb and its successors. As we see it now, the atom is a complicated structure bearing no resemblance to the man-in-the-street's notion of matter, but rather resembling a mystical entity in which electricity and probability pursue, as it were, a wavy course through a four-dimensional nothingness.

Since there is nothing in Greek theory comparable to wave-mechanics, I do not propose to deal here with the nuclear structure of the atom, nor even with the outer 'rings' of electrons whose interrelations govern the Periodic Table of the Elements. For my purpose the terms, not of atomic physics, but of ordinary chemistry, suffice.

Chemistry is concerned with 'pure' substances that appear to consist of a single kind of material that has properties sufficiently constant and well marked to distinguish them from other kinds of material. These substances are considered to be composed of one or more pure substances known as 'elements', of which at the time of writing ninety eight have been named (at least six more than the usually cited ninety two having been isolated during atom bomb research and allied studies).

"A chemical element is a distinct species of matter which cannot be converted by the action of heat, chemical reaction with other substances, or small electrical potentials into two or more electrically neutral different kinds of matter". * "Every portion of matter consists either of a single pure substance or a mixture of two or more pure substances, each of which is either an element or a chemical compound". ** A 'compound' is a homogeneous substance with a fixed proportion of certain elements in its composition that can only be split

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* Sherwood-Taylor, op. cit., p. 22, note 1.

** Op. cit., p. 23.

into its constituent elements by the application of fairly intense chemical energy, heat energy, radiation, or electric potential: a 'mixture' is a substance that may be homogeneous or heterogeneous, that has no constant proportional elementary composition, and that may be divided into its constituent substances by comparatively feeble forces such as friction of some kind, or magnetism; or may even divide spontaneously by e.g. diffusion, or evaporation.

All material substances are composed of atoms; but only one type of atom (ignoring isotopes) is contained in portions of each different element: there are, consequently, only about 98 types of atom known to us. It is impossible to divide an element into two or more simpler substances without splitting the atoms of which it is composed. The properties of the element are a function of the arrangement within its atoms of sub-atomic particles (protons, electrons, neutrons) of an electrical nature in a probability distribution, with which we shall not be concerned. We may, then, define an atom as "the smallest particle of an element that can take part in a chemical change". Of more immediate importance for the physical speculator who has no laboratory is the molecule, defined as "the smallest particle of a specific form of an element or compound that can exist in the free state" (i.e. in other than man-made conditions).

Of the utmost importance for the understanding of the nature of a gas is the 'kinetic theory of matter'. Matter of every kind in all known conditions is discontinuous, being made up of molecules, which are in rapid motion, and a void, which contains them and in which they move. The velocity of the motion, other things being equal, is inversely proportional to their mass. The velocity is also dependent on the temperature of the substance concerned. The science of thermodynamics, in fact, informs us that temperature is nothing more nor less than the physical manifestation to our senses of that molecular motion, just as matter is the manifestation to them of quantised sub-atomic energy. (Heracleitus was right when he said: "Eyes and ears are bad witnesses to men if they have souls that understand not their language".) An increase of molecular velocity is manifested as an increase of temperature, and vice versa.

Within a substance the molecules have only a limited amount of room in which to move, a certain 'mean free path'. It is the magnitude of the mean free path that determines whether a substance is in the gaseous, liquid, or solid state. In a gas the mean free path is of the order of a hundred times the diameter of the molecule. Thus the molecules can have a practically independent and unhampered rapid and random motion. A gas is consequently diffuse, and has no well-defined boundary; nor, unless compressed until the molecules are close enough to interfere with each other's motion, does it offer any great resistance to a body moving through it.

The large extent of the free path means, in effect, that the molecules are relatively far apart from each other, which explains both the tenuous nature of a gas and the fact that things can pass through it: the latter include the photons of light (which, like matter itself, partakes of the nature both of waves and of particles), so that gases are usually transparent and invisible.

In a liquid the mean free path is not much greater than the molecular diameter, so that the molecules are close enough together to be bound by a mutual attraction of an electro-magnetic character, though still far enough apart to admit of transparency. As a result of the binding, liquids are fluid, but continuous to the senses, and possessed of a definite shape, variable though this be.

In a solid the mean free path is very small. The molecules are so close together that they cannot wander freely throughout the substance, as can those of gases and liquids, but are rigidly confined to definite places where they merely undergo a restricted vibratory motion. As a result, solids are rigid, permanent in shape, and hardly, if at all, compressible. In some solids the fixed places form a lattice, so that the substance is crystalline, in others they are random, so that the substance is 'amorphous'. Some solids have a structure through which light can pass; but most are opaque.

Because the temperature of a gas is proportional to the velocity of motion of its molecules, an increase in temperature entails an increase in volume; for the molecules travel further in a given time: this statement assumes that the pressure remains constant. * On the other hand, when the temperature is constant, the volume is inversely proportional to the pressure. ** When either the increase in pressure or the decrease in temperature as conditions change is so great that the mean free

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* Charles' Law, also called Gay-Lussac's Law.

** Boyle's Law.

path becomes of the same order as the molecular diameter, the gas 'liquefies'; and if the increase or decrease respectively continues (or occurs in a liquid) to the point when the molecules become so close that they are confined to oscillation about fixed centres as mutual attraction binds them tightly together, the liquefied gas (or liquid) 'solidifies' (in the case of water, 'freezes'). Change of pressure or temperature in the reverse sense, of course, causes a solid to become liquid ('melt' or 'fuse') or a liquid to become gaseous ('boil' or 'vaporise'). Such manifestations as those quoted in parentheses, as we shall see, attracted the attention of the early Greek thinkers, in whose theories changes of physical state play an important role: we shall have to compare their explanations with this modern kinetic theory.

Amongst the others, the Greeks were faced with the phenomenon of 'evaporation'. This is actually due to 'vapour pressure'. Those molecules near to the surface of a liquid will, in the course of their random motions, often be moving towards the boundary between the liquid and the surrounding substance, and at any given instant there will be a number doing so: these will exert pressure upon the boundary. If the surrounding substance offers a sufficiently small resistance to this pressure, the molecules concerned will escape from the liquid. If the surrounding substance is a gas, its resistance will be low enough; and the molecules as they escape will be said to 'evaporate'. The rate of evaporation naturally depends on the temperature: the higher the temperature, the faster the molecular motion, and the greater the 'vapour pressure'. Boiling, too, involves vapour pressure. The boiling point of a liquid is the temperature at which its vapour pressure becomes equal to the vapour pressure of the atmosphere.

Turning now from processes to substances, we realise that the gaseous substance that would be most familiar to the Greeks would be atmospheric air. The atmosphere of the earth is a stratified envelope of gas. The main strata are two: the troposphere, which extends about 7 miles upwards from the earth's surface, and the stratosphere, subdivided into the stratosphere proper, up to 50 - 60 miles, and the ionosphere, whose boundary with interplanetary space is ill-defined owing to its tenuosity but may be set at 300 miles, though there is still some gas at 600 miles. This produces the outer streamers of the aurora, but its density the laboratory worker would call a very high vacuum, absolutely unattainable by him.

The temperature of the troposphere varies with altitude, and within it occur, through differences in temperature and humidity, pressure and electric charge, all the winds and clouds, almost all the phenomena that we, like Aristotle, call 'meteorological' - the weather. The air in this stratum is an extremely complex mixture, not a simple substance such as the early Greeks imagined it to be. Dry tropospheric air consists of approximately 78% Nitrogen, 21% Oxygen, and 1% Argon by volume, together with minute traces of Hydrogen and other gases. But there is also up to 4% water vapour, according to climatic conditions, and, in the presence of living creatures, a small proportion of Carbon dioxide. In marshy country like the Lake Copais area there will also generally be some Methane (marsh gas). Near towns there is some free carbon in the form of dust or smoke particles, near volcanoes sulphurous compounds, and in coastal areas there are salt particles.

By contrast, the stratosphere is of fairly uniform (very low) temperature, cloudless, and extremely rarefied. It is nearly windless. Within it occur the aurora borealis (an electrical phenomenon), twilight (the reflection of sunlight), and shooting stars (meteors and meteorites).

The gases of which it is a mixture are perhaps stratified by gravity with hydrogen, the lightest, forming the highest layer. *

The distinction between the two main strata recalls the early Greek distinction between the murky ἀήρ that we mortals inhabit and the pure, rare, αἰθήρ in which the gods live; while the stratification by gravity, if it exists, has analogues in the theories of several Greek philosophers, as we shall see. We shall also see, however, that the Greeks often guessed the right answers for the wrong reasons.

Of the gases that I mentioned on p. 12, the most important is oxygen. It was ignorance of the nature of this that vitiated all the ancient and mediaeval attempts to explain the facts of nature and of life. ** It was Lavoisier (1743 - 1794) who in 1772, making use of the experimental results of his contemporaries Scheele (1742 - 1780) and Priestley (1733 - 1804), first demonstrated

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* This used to be definitely stated; but the latest information available to me indicates that it may not be so.

** E.g. those of Boyle, Hooke (1635 - 1703) and their contemporary Mayow, all of whom experimented with combustion.

that combustion, calcination, and respiration, are processes of combination of other elements with oxygen. There could be no true physics or chemistry until combustion was thus explained, and the 'phlogiston' theory developed by Stahl (1660-1734) was abandoned, nor medicine until respiration was thus understood. *

In fact, combustion oxidizes an organic fuel with the liberation of carbon and other substances, most of which are carbon compounds. The latter may be solid particles - e.g. smoke or ashes - or the vapours of liquids or 'true gases' (v. inf.). Boiling is the conversion of a liquid not into air, as early speculators thought, but into its own vapour (e.g. water into steam), which is generally invisible: the converse process, 'condensation', may in suitable conditions produce, not a continuous liquid, but a mass of discrete droplets in the form of a 'cloud' or 'mist': if these droplets have condensed around smoke or dust particles the result is a 'fog', and if the latter is contaminated with oil it becomes, in American parlance, a 'smog'.

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* Phlogiston was thought to be present in all combustible bodies, and combustion to be a release of this phlogiston.

Respiration involves a transfer of oxygen from the inhaled air to the tissues of the body by means of the oxidation of certain compounds in red blood corpuscles, and an expulsion into the exhaled air of waste carbon di-oxide, itself a product of a combustion-like process in the body.

In conclusion, gases are tenuous and discontinuous, and for the most part invisible and tasteless, though many have a distinctive odour. They can pass, reflect, or refract light, and also act as a medium for the transmission of sound, which itself consists of longitudinal compression waves in a suitable medium. They are extremely compressible and elastic, but offer little resistance to a moving body unless compressed considerably. 'True gases' are gaseous at everyday pressure and temperature, while vapours are the gaseous form assumed by substances normally solid or liquid when exposed to abnormal conditions of pressure or temperature. The uneducated eye often takes mists fogs and smokes to be gases, though they are actually discrete liquids or solids.

This concludes our rapid survey of the essential facts and theories that must be borne in mind when discussing the subject of gases.

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CHAPTER TWO

THE NATURE OF GREEK SCIENCE.

We find in Greek science certain theories that appear to be similar to some of those believed in today: these have been enthusiastically claimed by some to have been brilliant anticipations of modern science. Much has been written on this subject, from the 'lost notebook' idea of writers like Burnet, the idea that Greek science was fully based on experimental, or at any rate on observational, evidence, to the diametrically opposed view that it was a mere mass of childish speculation, or at best a body of _a priori_ thought that just occasionally, by accident, happened to come somewhere near to the truth.

The extremists of either viewpoint, however, fail to observe that not only the methods, but also the aims, of Greek and modern science differ. Our aims are utility and progress. While knowledge for its own sake is far from spurned, our science is most often directed towards either a greater understanding of nature in order that we may the better harness it for our own ends or a greater facility and efficiency in mechanical invention. We work therefore towards an increasing knowledge of 'cause and effect' and of sequences of behaviour. Induction from observation provides a tentative hypothesis: deduction suggests experiments to check it and make it a 'law of nature': the knowledge thus obtained is then put to use.

The Greek aim was entirely different; for their machines were not mechanical like ours, but human - the slaves. We measure capacity for work in units of a fictitious mechanical 'horse-power', the Greeks in units of a very real living 'man-power'.

Curiosity, not efficiency, was their driving force. Their aim was εὐδαιμονία arrived at through acquiring ἐπιστήμη from θεωρία. They wished to discover what things really are and how they became so - in a word, their φύσις. This word, as Cherniss shows, implies an interest in processes at least as intense as in primary substances; and since knowledge of what things are involves knowledge of what they grew from or how they were made, the typical Greek theory is expressed and narrated in the form of a cosmogony. * It describes the formation of a universe out of primaeval chaos by means of a process of either evolution or creation.

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* Cherniss, Aristotle's Criticism of Presocratic Philosophy, p. 359.

The Milesians described how one primitive substance gave rise to the many substances that we see, and how life emerged from slime warmed by the heat of the sun. Plato and Aristotle described the creation of a universe containing intelligent design, the work of divine reason. The former type of cosmogony deals with the origin of matter, the latter with that of form. Both deal with unobservables and both give a narrative of imagined past events. Even if observation shows that what they state to be the present result of the past processes described is in agreement with the phenomena, it cannot be claimed that the cosmogony has been 'checked by observation'; for some other sequence of past events could conceivably also have led to the same observed result.

For example, observation alone could not decide between the astronomy of Ptolemy, whose central earth had the support of both Greek and Christian cosmogony, and that of Copernicus, whose planetary earth would have had the support of certain Pythagoreans and of Aristarchus in the past, but deeply shocked contemporary Christianity. The geocentric hypothesis was destroyed neither by the first telescopic observations of Galileo (in 1609 - 1610 a.d.) nor by the contemporary announcement of Kepler's laws of planetary motion (depending on elliptic orbits with the sun at one focus), which were based on the measurements of accurate observers like Tycho Brahe. It was rather the combination of these with the explanation for them given half a century later by Newton's theory of gravitation that carried conviction. Then further observation necessitated a further alteration of theory, which Einstein's relativity provided; and that in turn was checked by yet more observations.

For the solidly based description of the present state of the solar system (the cosmology) successive attempts have been made to provide an equally solidly based cosmogony (the 'Nebular Hypothesis', the 'Tidal Theory', and, most recent, Littleton's 'Double Sun Theory'). The process has been one of first checking that a hypothetical cosmogony <u>could</u> give the present observed result (the check of internal consistency that alone is applicable to Greek cosmogony, and the only one demanded by the Greeks), and then checking each process postulated against the known behaviour of matter as discovered by laboratory experiments specially designed to imitate as ably as possible the hypothetical external conditions, in an attempt to prove that the cosmogony concerned is the <u>only</u> one that can have led to the present result. Each new hypothesis is the outcome of fresh knowledge obtained by observation, experiment, or mathematical calculation based on these.

I chose astronomy as my example because it is the science towards which our attitude most resembles the Greek curiosity and least our normal utilitarianism. However even in this science, as elsewhere, Greek theories tended to state what things ultimately are and their mode of existence, while ours tend to state why things are and their laws of behaviour.

The only branch of science to which at least some of its Greek innovators had the same approach as ourselves is medicine: the reason is that here the aim is practical, so that what we ourselves call 'scientific method' must apply. The contrast between the two types of approach is, in fact, pointed out in the Hippocratic treatise 'Ancient Medicine':

> Wherefore I have deemed that it has no need of an empty postulate, as do insoluble mysteries about which any exponent must use a postulate, for example things in the sky or below the earth. If a man were to learn and declare the state of these, neither to the speaker himself nor to his audience would it be clear whether

his statements were true or not. For there is no test the application of which would give certainty. But medicine has long had all its means to hand, and has discovered both a principle and a method, through which the discoveries made through a long period are many and excellent, while full discovery will be made, if the inquirer be competent, conduct his researches with knowledge of the discoveries already made, and make them his starting point. *

The view of ancient astronomy expressed in this passage is shared by Kepler: **

I will triumph over mankind by the honest confession that I have stolen the golden vases of the Egyptians to build up a tabernacle for my God far away from the confines of Egypt. If you forgive me I rejoice; if you are angry, I can bear it; the die is cast, the book is written to be read either now or by posterity, I care not which; it may well wait a century for a

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* Anc. Med. I, 20, transl. W.H.S. Jones: cf. his remarks in Loeb, Hippocrates, Vol. I, p. 8; and also B. Farrington, Science in Antiquity, p. 94.

** Quoted in Skilling and Richardson, Astronomy, p. 99: my underlining on p. 22.

reader, as God has waited six thousand years for an observer.

The Greeks were thus not interested in science for the same reasons as we are, and so their methods were different. Consistency was for them more important than point by point observational checking: consequently I do not agree with writers who claim that all Greek science was based on observation (even though the records of the observations have not survived), nor yet with those who call it childish because it was not checked by observation. The best a Greek asked his theory to do was to 'save the phenomena', and in some cases not even that was demanded. To those who are loud in admiration of Greek 'anticipations of modern science' I quote in reply Farrington's words:

> The true history of science, however, should be rather a history of method than of results, for the latter are often accidental and only seem impressive to later generations when they have been rediscovered by improved methods. [x]

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[x] Op. cit., p. 58.

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CHAPTER THREE

THE MILESIANS

Greek philosophy originated in the Ionian part of Asia Minor, in particular in Miletus. Here commercial prosperity provided the possibility of leisure that is conducive to thought.

We can see from the works of the Greek mythological writers that speculation had already been taking place by the start of the sixth century B.C. about the nature of the physical universe; and Greek philosophy proper grew out of this mythology by a process of rationalisation. It retained the cosmogonical mould of mythology, and cast its results in that mould. The sequence of events in the earliest Milesian cosmogonies bears a considerable resemblance to that of the theogonies, especially to those of Hesiod and the Orphics.

Air plays a part in both theogony and cosmogony. Its importance for the mythologers is illustrated by the reference of Aristotle to the 'Orphic Poems' in de Anima 410 b 28:

> φησὶ γὰρ τὴν ψυχὴν ἐκ τοῦ ὅλου εἰσιέναι ἀναπνεόντων, φερομένην ὑπὸ τῶν ἀνέμων.

We see here a connexion between the soul and breathing and the winds; and the conception of soul as breath or air is one that we shall often meet again. Air is connected with life (cf. our phrase 'the last gasp' that occurs as we 'give up the ghost'), and to the primitive observer it is indeed the breath of life.

Let us now find the place of air in the primitive speculations. Hesiod's cosmogony (given in Theog. 116 - 132) contains the following sequence of events. First of all a Χάος was generated, which revealed Γαῖα (the earth) and Ἔρως. Out of this chaos darkness was born in the form of Ἔρεβος and Νύξ, and the latter gave birth to light in the form of Αἰθήρ and Ἡμέρα. The chaos represents the yawning gap between heaven and earth, which were originally united. * This gap revealed Eros, who surely represents here the rain that falls from heaven and fertilises the earth: the gap is filled with darkness, which we shall shortly find to be a form of air in early Greek

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* Cf. the possibly Orphic reference in Apollonius Rhod., I 496 (which Schol. ad loc. says to be from Empedocles and not, as Apollonius claims, from Orpheus):

.... γαῖα καὶ οὐρανὸς ἠδὲ θάλασσα
τὸ πρὶν ἐπ' ἀλλήλοισι μιῇ συναρηρότα μορφῇ
νείκεος ἐξ ὀλοοῖο διέκριθεν ἀμφὶς ἕκαστα.

speculation, and from this arises light - also a form of air, as one of its names, Aether, shows.

Hesiod's next event surprises us: we already have a heaven and yet we are told that earth now gave birth to the heaven for the first time. Cornford * has given a reason for this double separation of heaven from earth: the reason is connected with the ritual side of religion, rather than with physics, and need not concern us here. The next physical event is the production from the earth of the mountains and the sea; and Hesiod emphasises that this occurs now 'without delightful love': in other words the coming to be of heaven, the earth's features, and the sea, is the result of physical, asexual, separation alone.

The Orphic cosmogony is similar, although details vary in different accounts of it. In the place of Eros, the fertilising rain, however, the Orphics put an Egg in the gap. This is split into two halves, the upper half forming the heaven and the lower half the earth (so that again we have a double separation of heaven from earth).

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* Essay: "A Ritual Basis for Hesiod's Theogony", in: The Unwritten Philosophy. He compares Hebrew, Babylonian, and even Maori, myths in which a similar double sequence occurs.

From this egg springs Φάνης, the son of Νύξ: he is the generative principle of this cosmogony. He brings about the generation of the divine and human inhabitants of the world. In effect he holds the same place as Eros in Hesiod, but the Orphic story, after the stage where the splitting of the egg corresponds to Hesiod's second separation of heaven, includes biological generation in the next stage too, where Hesiod specifically denies it.

The Orphic Rhapsodies give, in the first of the two passages quoted below, three alternative sources for Phanes: the Egg, the Bright Robe, or, more probably, the Bright Membrane, and the Cloud. The splitting eggshell gives a more vivid picture for the mind to grasp than does Hesiod's mechanical separation. The Cloud is the source of the fertilising rain, and therefore recalls both the Darkness and the Eros of Hesiod. The second alternative, obscure if taken as a 'Robe' becomes more intelligible as a 'Membrane'; for then it can be interpreted along with the eggshell in the manner of the second of the passages that I now quote:

> ἀντὶ δὲ τοῦ ὄντος ἁπλῶς τὸ *ᾠ ὸ ν* ἀπολογιζόμενοι, καὶ τριάδα ταύτην πρώτην ποιοῦντες· εἰς δὲ τὴν δευτέραν τελεῖν ἤτοι τὸ κυούμενον καὶ τὸ κύον *ᾠ ὸ ν* τὸν θεὸν ἢ τὸν *ἀ ρ γ ῆ τ α χ ι τ ῶ ν α* ἢ τὴν *ν ε φ έ λ η ν*, ὅτι

ἐκ τούτων ἐκθρώσκει ὁ Φάνης ... τὴν δὲ τρίτην τὸν Μ ῆ τ ι ν ὡς νοῦν, τὸν Ἠ ρ ι κ ε π α ῖ ο ν ὡς δύναμιν, τὸν Φ ά ν η τ α αὐτὸν ὡς πατέρα ...... τοιαύτη μὲν ἡ συνήθης Ὀρφικὴ θεολογία. *

τὴν δὲ τάξιν, ἣν δεδώκαμεν τῷ σφαιρώματι, οἱ Ὀρφικοὶ λέγουσι παραπλησίαν εἶναι τῇ ἐν τοῖς ᾠοῖς· ὃν γὰρ ἔχει λόγον τὸ λέπυρον ἐν τῷ ᾠῷ, τοῦτον ἐν τῷ παντὶ ὁ οὐρανός, καὶ ὡς ἐξήρτηται τοῦ οὐρανοῦ κυκλοτερῶς ὁ αἰθήρ, οὕτως τοῦ λεπύρου ὁ ὑμήν. **

The gap between heaven and earth that has arisen from an original unity, if we may thus rationalise the mythological language, is filled with darkness, light, and air, under various divine names, not only in the Hesiodic and Orphic, but also in a number of other similar cosmogonies, however different their details. *** These systems are, although mythical, not mere childish stories:

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* Damasc. de Princ. 123, Diels 1 B 12.

** Achill. Isag. 4, p. 33, 17, Diels 1 B 12.

*** Cf. Epimenides and Acusilaus in Damasc. ibid. 124, in D. 3 B 5 and 9 B 1 respectively:

τὸν δὲ Ἐπιμενίδην δύο πρώτας ἀρχὰς ὑποθέσθαι Ἀέρα καὶ Νύκτα.

Ἀκουσίλαος δὲ Χάος μὲν ὑποτίθεσθαί μοι δοκεῖ τὴν πρώτην ἀρχὴν ὡς πάντῃ ἄγνωστον, τὰς δὲ δύο μετὰ τὴν μίαν· Ἔρεβος μὲν τὴν ἄρρενα, τὴν δὲ θήλειαν Νύκτα. ... ἐκ δὲ τούτων φησὶ μιχθέντων Αἰθέρα γενέσθαι καὶ Ἔρωτα καὶ Μῆτιν.

they reflect a definitely speculative thought that has not yet been divorced from religious colouring, but that has arrived at a well-defined idea of the process of world creation. The details and genealogical relationships may be due to the myths' bearing an aetiological connexion with certain obscure, even forgotten, rituals, as Cornford pointed out (op. cit.), but the outline is clearly based on the same type of speculation as that employed by the Milesians.

Thales of Miletus, flor. 585 b.c., first set aside the mythopoeic method of exposition, and Greek science was born. We now find men convinced that there is an entirely rational explanation of the universe, which needs no gods for its creation.

The Milesians made a conscious effort to be materialistic, but it was natural for environment and upbringing to cause them to adopt a sequence of events similar to that of the myths. We may therefore expect to find in their theories creation brought about by a process of separation from an original unity. Earth and heaven will come apart (once only!): the gap will be filled with air or cloud, and the sea will separate out from the dry land. The stars will also be the result of a separation.

The purpose of the Milesians was to try to find the φύσις that underlay all the many changing things in the universe around us; and their merit was that not only did they appear as the first rationalisers but also as the first men in history to adopt the method of generalising from particulars that is one of the foundations of scientific method.

Since my subject is air, I shall pass over Thales himself; for little is known about his theories except that he claimed that the fundamental stuff of the universe is water, or rather moisture. * Aristotle's guesses about his reasons for this choice (given in Met. 983 b 6sq.) are not evidence - as Cherniss says (op. cit. p. 375): "The only honest course is to make the history of Greek philosophy proper begin with Anaximander". I propose to discuss that philosopher in considerable detail; for his theory was both typical of the early Greek thinkers and one that had a great influence upon the thought of the whole period under review.

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* Cf. Homer, Il. xiv, 201:

'Ωκεανόν τε θεῶν γένεσιν καὶ μητέρα Τηθύν.

This is of course merely a parallel from mythology, and not the source of Thales' theory. The line is referred to by Plato in Theaet. 180 D 2 and Crat. 402 b 4, and by Aristotle, loc. cit. line 27.

Anaximander's dates are c.610 - 545 b.c. according to Diogenes Laertius, Hippolytus and other sources. He was dissatisfied with Thales' moisture theory, and substituted one that for the first time spoke of 'opposites'. The most remarkable thing about nature to early Greek eyes was that its processes seem to show the working of 'opposites': night follows day, summer follows winter, death follows life; things are either light or dark, hot or cold, wet or dry. Physically the last two pairs seemed especially significant, and became the 'opposites' par excellence.

Much of Greek thought concerns itself with these as opposite substances or qualities. Until the time of Plato there was no clear realisation of the distinction between substance and quality, and our sources speak of an opposite as if it were now the one, now the other, and now a confused mixture of both. But it must be remembered that it was not until the fifth century that the idea of the real existence of anything incorporeal was first conceived; so that the Milesians at least must have thought of the opposites as corporeal substances, even though that thought may have been contaminated by vague notions of qualitativeness.

Such, then, are the 'opposites' of which Anaximander speaks. I shall now start my discussion of his theory by quoting the most important source material.

1. Ἀναξίμανδρος ... ἀρχήν τε καὶ στοιχεῖον εἴρηκε τῶν ὄντων τὸ ἄπειρον, πρῶτος τοῦτο τοὔνομα κομίσας τῆς ἀρχῆς. λέγει δ' αὐτὴν μήτε ὕδωρ μήτε ἄλλο τι τῶν καλουμένων στοιχείων, ἀλλ' ἑτέραν τινὰ φύσιν ἄπειρον, ἐξ ἧς ἅπαντας γίνεσθαι τοὺς οὐρανοὺς καὶ τοὺς ἐν αὐτοῖς κόσμους· "ἐξ ὧν δὲ ἡ γένεσίς ἐστι τοῖς οὖσι, καὶ τὴν φθορὰν εἰς ταῦτα γίνεσθαι κατὰ τὸ χρεών· διδόναι γὰρ αὐτὰ δίκην καὶ τίσιν ἀλλήλοις τῆς ἀδικίας κατὰ τὴν τοῦ χρόνου τάξιν". ... οὗτος δὲ οὐκ ἀλλοιουμένου τοῦ στοιχείου τὴν γένεσιν ποιεῖ, ἀλλ' ἀποκρινομένων τῶν ἐναντίων διὰ τῆς ἀιδίου κινήσεως.

Simpl. Phys. 24, 13 (from Theophr. Phys. Op. fr. 2), Diels 12 A 9; cf. Hipp. Ref. I 6, 1-2, D. 12 A 11:

οὗτος ἀρχὴν ἔφη τῶν ὄντων φύσιν τινὰ τοῦ ἀπείρου, ἐξ ἧς γίνεσθαι τοὺς οὐρανοὺς καὶ τὸν ἐν αὐτοῖς κόσμον. ταύτην δ' ἀίδιον εἶναι καὶ ἀγήρω, ἣν καὶ πάντας περιέχειν τοὺς κόσμους. ... οὗτος μὲν ἀρχὴν καὶ στοιχεῖον εἴρηκε τῶν ὄντων τὸ ἄπειρον, πρῶτος τοὔνομα καλέσας τῆς ἀρχῆς. πρὸς δὲ τούτῳ κίνησιν ἀίδιον εἶναι, ἐν ᾗ συμβαίνει γίνεσθαι τοὺς οὐρανούς.

See Burnet p. 54 n. 2 for taking no. 1 line 2 as: "he being the first to introduce this name of the material cause". There is dispute whether An. believed in many worlds or in one, which contained the heavens (τοὺς οὐρανούς) and regions (κόσμους). I accept the latter interpretation (I do not see how there could be simultaneous plurality of worlds if the stars are not worlds). The words ἀρχή (probably) and στοιχεῖον ("element") are from the post-Socratic technical vocabulary.

2. ἐναντιότητες δὲ εἰσὶ θερμόν, ψυχρόν, ξηρόν, ὑγρόν, καὶ τὰ ἄλλα.

Simpl. Phys. 150, 24, Diels 12 A 9.

3. οἱ μὲν γὰρ ἓν ποιήσαντες τὸ ὂν σῶμα τὸ ὑποκείμενον ἢ τῶν τριῶν τι ἢ ἄλλο ὅ ἐστι πυρὸς μὲν πυκνότερον ἀέρος δὲ λεπτότερον, τἆλλα γεννῶσι πυκνότητι καὶ μανότητι πολλὰ ποιοῦντες. ... οἱ δὲ ἐκ τοῦ ἑνὸς ἐνούσας τὰς ἐναντιότητας ἐκκρίνεσθαι, ὥσπερ Ἀναξίμανδρός φησι καὶ ὅσοι δ' ἓν καὶ πολλά φασιν εἶναι, ὥσπερ Ἐμπεδοκλῆς καὶ Ἀναξαγόρας· ἐκ τοῦ μείγματος γὰρ καὶ οὗτοι ἐκκρίνουσι τἆλλα.

Arist. Phys. 187 a 12sq., D. 12 A 16 & 9.

4. ἀλλα μὴν οὐδὲ ἓν καὶ ἁπλοῦν εἶναι ἐνδέχεται τὸ ἄπειρον σῶμα, οὔτε ὡς λέγουσί τινες (τ. ἑ. Ἀναξίμανδρος) τὸ παρὰ τὰ στοιχεῖα, ἐξ οὗ ταῦτα γεννῶσιν, οὔθ' ἁπλῶς. εἰσὶ γάρ τινες οἳ τοῦτο ποιοῦσι τὸ ἄπειρον, ἀλλ' οὐκ ἀέρα ἢ ὕδωρ, ὡς μὴ τἆλλα φθείρηται ὑπὸ τοῦ * ἀπείρου αὐτῶν· ἔχουσι γὰρ πρὸς ἄλληλα ἐναντίωσιν, οἷον ὁ μὲν ἀὴρ ψυχρός, τὸ δ' ὕδωρ ὑγρόν, τὸ δὲ πῦρ θερμόν· ὧν εἰ ἦν ἓν ἄπειρον, ἔφθαρτο ἂν ἤδη τἆλλα· νῦν δ' ἕτερον εἶναί φασι, ἐξ οὗ ταῦτα.

Arist. Phys. 204 b 22, D. 12 A 16. Cf. a. Aët. I 3, 3, D. 12 A 14; b. Arist. Phys. 208 a 8, D. 12 A 14.

a. Ἀναξίμανδρος δὲ ... φησι τῶν ὄντων ἀρχὴν εἶναι τὸ ἄπειρον· ἐκ γὰρ τούτου πάντα γίγνεσθαι καὶ εἰς τοῦτο πάντα φθείρεσθαι. διὸ καὶ γεννᾶσθαι ἀπείρους κόσμους καὶ πάλιν φθείρεσθαι εἰς τὸ ἐξ οὗ γίγνεσθαι. λέγει γοῦν διότι ἀπέραντόν ἐστιν, ἵνα μηδὲν ἐλλείπῃ ἡ γένεσις ἡ ὑφισταμένη.

b. οὔτε γὰρ ἵνα ἡ γένεσις μὴ ἐπιλείπῃ, ἀναγκαῖον ἐνεργείᾳ ἄπειρον εἶναι σῶμα αἰσθητόν.

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* Cf. Meteor. 340 a 1 and b 1, where he argues that the heavens cannot contain fire alone for the same reason.

5. φησὶ δὲ τὸ ἐκ τοῦ ἀιδίου γόνιμον θερμοῦ τε καὶ ψυχροῦ κατὰ τὴν γένεσιν τοῦδε τοῦ κόσμου ἀποκριθῆναι καί τινα ἐκ τούτου φλογὸς σφαῖραν περιφυῆναι τῷ περὶ τὴν γῆν ἀέρι ὡς τῷ δένδρῳ φ λ ο ι ό ν · ἧστινος ἀποῤῥαγείσης καὶ εἴς τινας ἀποκλεισθείσης κύκλους ὑποστῆναι τὸν ἥλιον καὶ τὴν σελήνην καὶ τοὺς ἀστέρας.

Ps. Plut. Strom. 2 (D. 579), D. 12 A 10.

6. τὰ δὲ ἄστρα γίνεσθαι κύκλον πυρός, ἀποκριθέντα τοῦ κατὰ τὸν κόσμον πυρός, περιληφθέντα δ' ὑπὸ ἀέρος. ἐκπνοὰς δ' ὑπάρξαι πόρους τινὰς αὐλώδεις, καθ' οὓς φαίνεται τὰ ἄστρα· διὸ καὶ ἐπιφρασσομένων τῶν ἐκπνοῶν τὰς ἐκλείψεις γίνεσθαι. τὴν δὲ σελήνην ποτὲ μὲν πληρουμένην φαίνεσθαι, ποτὲ δὲ μειουμένην παρὰ τὴν τῶν πόρων ἐπίφραξιν ἢ ἄνοιξιν.

Hipp. loc. cit. 4-5, D. 12 A 11.

7. ... (τὰ ἄστρα εἶναι) πιλήματα ἀέρος τροχοειδῆ, πυρὸς ἔμπλεα, κατά τι μέρος ἀπὸ στομίων ἐκπνέοντα φλόγας.

Aët. II 13, 7, D. 12 A 18. Cf. other passages of similar purport in D. 12 A 21 & 22.

8. περὶ βροντῶν ἀστραπῶν κεραυνῶν πρηστήρων τε καὶ τυφώνων. 'Α. ἐκ τοῦ πνεύματος ταυτὶ πάντα συμβαίνειν· ὅταν γὰρ περιληφθὲν νέφει παχεῖ βιασάμενον ἐκπέσῃ τῇ λεπτομερείᾳ καὶ κουφότητι, τόθ' ἡ μὲν ῥῆξις τὸν ψόφον, ἡ δὲ διαστολὴ παρὰ τὴν μελανίαν τοῦ νέφους τὸν διαυγασμὸν ἀποτελεῖ.

Aët. III 3, 1, D. 12 A 23.

9. ἀνέμους δὲ γίνεσθαι τῶν λεπτοτάτων ἀτμῶν τοῦ ἀέρος ἀποκρινομένων καὶ ὅταν ἀθροισθῶσι κινουμένων, ὑετοὺς δὲ ἐκ τῆς ἀτμίδος τῆς ἐκ γῆς ὑφ' ἥλιον ἀναδιδομένης· ἀστραπὰς δέ, ὅταν ἄνεμος ἐμπίπτων διϊστᾷ τὰς νεφέλας.

Hipp. loc. cit. 7, D. 12 A 11; cf. Aët. III 7, 1, D. 12 A 24.

a. Ἀ. ἄνεμον εἶναι ῥύσιν ἀέρος τῶν λεπτοτάτων ἐν αὐτῷ καὶ ὑγροτάτων ὑπὸ τοῦ ἡλίου κινουμένων ἢ τηκομένων.

10. εἶναι γὰρ τὸ πρῶτον ὑγρὸν ἅπαντα τὸν περὶ τὴν γῆν τόπον, ὑπὸ δὲ τοῦ ἡλίου ξηραινόμενον τὸ μὲν διατμίσαν πνεύματα καὶ τροπὰς ἡλίου καὶ σελήνης φασὶ ποιεῖν, τὸ δὲ λειφθὲν θάλατταν εἶναι· διὸ καὶ ἐλάττω γίνεσθαι ξηραινομένην οἴονται καὶ τέλος ἔσεσθαί ποτε πᾶσαν ξηράν.

Arist. Meteor. 353 b 6, D. 12 A 27; cf. Alex. 67, 3, D. ibid.

a. οἱ μὲν γὰρ αὐτῶν ὑπόλειμμα λέγουσιν εἶναι τὴν θάλασσαν τῆς πρώτης ὑγρότητος· ὑγροῦ γὰρ ὄντος τοῦ περὶ τὴν γῆν τόπου κἄπειτα τὸ μέν τι τῆς ὑγρότητος ὑπὸ τοῦ ἡλίου ἐξατμίζεσθαι καὶ γίνεσθαι πνεύματά τε ἐξ αὐτοῦ καὶ τροπὰς ἡλίου τε καὶ σελήνης ὡς διὰ τὰς ἀτμίδας ταύτας καὶ τὰς ἀναθυμιάσεις κἀκείνων τὰς τροπὰς ποιουμένων, ἔνθα ἡ ταύτης αὐτοῖς χορηγία γίνεται, περὶ ταῦτα τρεπομένων· τὸ δέ τι αὐτῆς ὑπολειφθὲν ἐν τοῖς κοίλοις τῆς γῆς τόποις θάλασσαν εἶναι. ... ταύτης τῆς δόξης ἐγένετο, ὡς ἱστορεῖ Θεόφραστος, Ἀναξίμανδρός τε καὶ Διογένης.

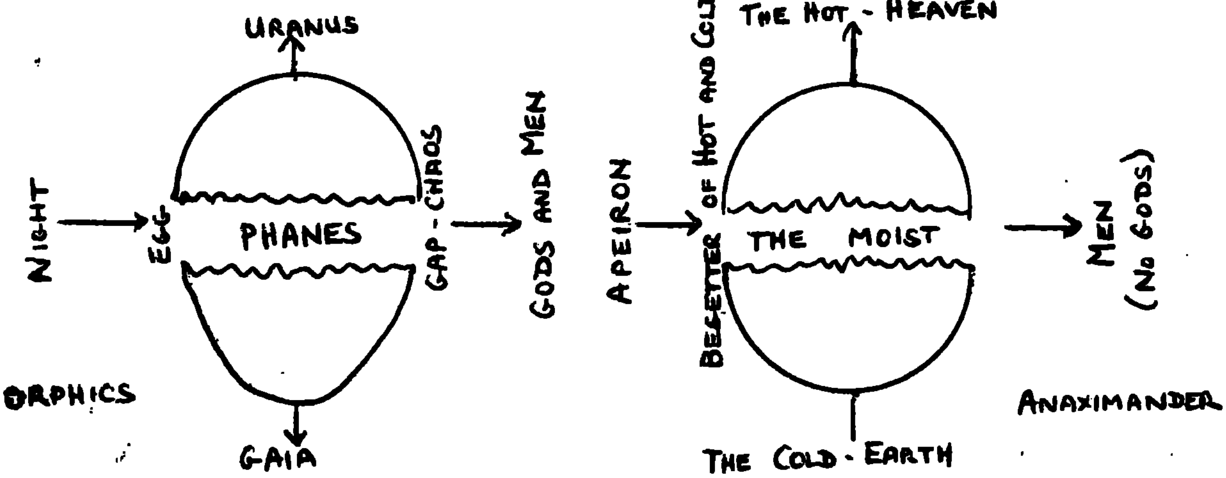
11. Ἀναξιμένης δὲ καὶ Ἀναξίμανδρος καὶ Ἀναξαγόρας καὶ Ἀρχέλαος ἀερώδη τῆς ψυχῆς τὴν φύσιν εἰρήκασιν.

Aët. IV 3, 2, D. 12 A 29.

In interpreting the sources that we have for the Pre-Socratics, most of whose own works have perished, one must be wary of the anachronistic terminology used by our authorities, who were accustomed to write in terms of the four element theory, and in the vocabulary of Plato and Aristotle. Cherniss (Op. cit.) performed a great service by his criticism of Aristotle's veracity and methods in reporting the theories of his predecessors. Cherniss has indeed torn holes in a great deal of the traditional interpretation of the Pre-Socratics. He is an excellent destructive critic; his attack on the credibility of Aristotle and the doxographical tradition carries conviction: but in his constructive efforts to replace the tradition by a new interpretation he fails to persuade. Perhaps of most value to a study of Anaximander are his insistance that φύσις does not solely denote a material substrate and his attack on Aristotle's conception of what is connoted by the word 'opposites'.

From the Milesian point of view, though not from Aristotle's, two pairs of opposites separated out from the apeiron: the hot and the cold, and the wet and the dry. Sometimes our authorities identify them with the elements fire air water and earth in that order, and sometimes fire is called hot and dry in opposition to the other three. This is not Anaximander: it is a consequence of Aristotle's own conception of identity (Cherniss, p. 370). The distinction between substance and quality had not yet been drawn, as I said above, nor 'elements' yet postulated.

Examining the sources with the above in mind, we can see in this cosmogony of Anaximander an attempt at complete rationalisation of the process of creation that the theogonies had allegorised. Night is replaced by the original condition of the apeiron before separation occurred. To the Orphic Egg corresponds that which is capable of begetting Hot and Cold: to the splitting of the Egg and to Hesiod's separation, Anaximander's separation. Phanes or Eros is replaced by the layer of air and moisture between earth and fire, which plays its part in the generation of the heavenly bodies, and is also the source of living creatures. The parallel can best be demonstrated by this diagram:



In this system of Anaximander the apeiron denoted some blend of ideas that do not appear to have been completely separated in his mind. In Phys. 203 b 13 sq. Aristotle gives five reasons for belief in the infinite:

1. The infinity of time.

2. The divisibility of magnitudes.

3. The fact that the perpetuity of generation and destruction can be maintained only if there is an infinite source to draw upon.

4. The fact that the limited is always limited by something else.

5. The fact that there is no limit to our power of thinking of the infinity of number, of magnitudes, and of what is outside the heavens.

The second reason is not relevant here. It applies more to the time of Zeno and Anaxagoras: similarly the fifth smacks of Aristotle himself. The other three reasons, however, may well have been in Anaximander's mind. His apeiron was 'unbounded', probably, in all these ways:

1. In time - for it is ἀίδιον καὶ ἀγήρω (passage in note to passage no. 1, p. 31 sup.).

2. In extent.

3. In quantity - ἵνα μηδὲν ἐλλείπῃ ἡ γένεσις (passages nos. 4a & 4b; cf. reason 3 sup.).

4. In the sense that it does not adjoin other things of the same order as itself, against which it would have to strive as the opposites strive against each other (cf. reason 4 sup.).

5. Possibly also in the sense that there are within it no boundaries between the opposites that will eventually be separated out from it.

I agree with Bailey and Cherniss * that the doxographers and the school of thought to which Tannery belonged ** are wrong in taking the apeiron to mean 'indeterminate matter'; but I cannot still agree with Cherniss when he proceeds to argue against Burnet (with whom on this point Bailey is in agreement) about the reason for adopting the apeiron: 'that becoming may not fail' - he uses passages nos. 1 & 4b sup. together with the assumption that he attributes to Anaximander of innumerable worlds to support an attempt to prove that the given reason was unnecessary, and that, if any reason was necessary, it may have been to provide the matter for the innumerable worlds.

Cherniss rightly points out that neither Tannery, Diels, nor Burnet, translated literally the plurals of Frag. 9 (quoted by Simplicius in passage no. 1 sup.); but from these plurals and certain parallels of language in

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* C.Bailey: The Greek Atomists and Epicurus, p. 15; Cherniss: Op. cit., p. 375 et al.

** Ueberweg-Prächter, Zeller, Teichmüller, Rey, Baccou and others.

Anaxagoras and Plato he builds up for Anaximander a pluralistic scheme that recalls that of Anaxagoras, and in fact makes of the latter's theory a mere 'refinement' of Anaximander's. With this tour de force I cannot agree. Nor do I agree with some commentators, ancient and modern, who say that the apeiron is 'denser than fire and rarer than air' (cf. passage no. 3 sup.), i.e. that it is the μεταξύ about which so much has been written, and with which I shall be dealing in Chapter 9 inf.

What, then, is the apeiron? Zeller first, and lately, among others, F.M.Cleve following A.Rey [x] objected to the view of Ritter that the apeiron is to be considered as a mechanical mixture of four opposites conceived of as substances - a view at first sight supported by passage no. 3 sup. and by Arist. Met. 1069 b 20 sq.:

> καὶ τοῦτ' ἔστι τὸ Ἀναξαγόρου ἕν· βέλτιον γὰρ ἢ "ὁμοῦ πάντα" - καὶ Ἐμπεδοκλέους τὸ μῖγμα καὶ Ἀναξιμάνδρου, καὶ ὥς Δημόκριτός φησιν - "ἦν ὁμοῦ πάντα δυνάμει, ἐνεργείᾳ δ' οὔ".

The apeiron may have been a quasi-migma, or even, as Aristotle would have it, a potential mixture; but in its own

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[x] F.M.Cleve: The Philosophy of Anaxagoras; Abel Rey: La Jeunesse de la Science Grecque.

original state it was homogeneous. Ross in his note to this passage of the Metaphysics says: "But the fact is that in Aristotle's terminology the word μῖγμα (a complete fusion) is more appropriate to Anaximander's apeiron in which the elements were only potentially present than to the original matter of Empedocles and Anaxagoras in which they were actually present. The latter is a mechanical σύνθετον rather than a genuine μῖγμα".

Cherniss on the other hand thinks that a satisfactory description of the apeiron is: "A congeries of elements infinite in number and dissimilarity". He quotes Augustine (de Civ. Dei, viii, 2):

> non enim ex una re, sicut Thales ex umore, sed ex suis propriis principiis quasque res nasci putavit. quae rerum principia singularum esse credidit infinita....

Cherniss also says that Aristotle's account, which of course he does not accept, must mean that that original state of the apeiron was a mechanical mixture.

I see more truth in the words of Ross than of Ritter or of Cherniss himself here. Ross' wording is indeed Aristotelian - naturally, as he is commenting on Aristotle: but I do agree with the distinction that he draws between Anaximander and the other two. The originally homogeneous apeiron was one thing different from all the things that we see now, as is quite clearly stated in passages nos. 1, 3 & 4; but it was something out of which the four opposites could separate (passage no. 5), and into which they could return (nos. 1 & 4a); for, unlike the ephemeral things of everyday experience, it was eternal. As the φύσις of the universe it was a mechanically active material substance - active spontaneously so that it could give rise to τὸ ἐκ τοῦ ἀϊδίου γόνιμον θερμοῦ τε καὶ ψυχροῦ, and so bring about the process of creation and change that as Cherniss says was the great interest of the Milesians, and material necessarily, for the non-material had not yet been conceived of by the Greeks.

Because of the confusion between substance and quality, Anaximander was not successful in explaining how one thing changes into another. He attempted to explain qualitative change by the interchange of the opposites. These are at war, and first one side and then the other wins the day. Hot evaporates wet (cf. passages nos. 9 & 9a) and cold condenses wet: a thing is now warm, now cold. There is give and take between the opposites (Fr. 9, in passage no. 1), so that they are not completely and irrevocably separated apart. It was left to Aristotle (in the de Generatione et Corruptione, passim) to give a rational explanation of how change might be caused by the interaction of opposites - but his opposites were qualities characterizing a substrate. Heracleitus made a fair attempt; but in Anaximander's case, in spite of his effort to be completely rationalistic, there is an intrusion of the non-rational; for in the description of the give and take: "They make reparation and satisfaction to one another for their injustice according to the ordering of time" we see the age-old idea of the dispensation of Moira, a moral dispensation with penalties against transgression (a factor that enters into the scheme of Heracleitus too).

It has been difficult to pin down the apeiron: it is possible with more ease to gain a clear idea of what Anaximander considered to be the properties of ἀήρ. It is from passages nos. 5 to 11 that we gain our information. Ἀήρ is corporeal, obviously; but the Greeks did not, until the time of Empedocles and Anaxagoras, know that the invisible, tasteless, and odourless substance known to us as air is corporeal. In modern terms, his aer * is, as I shall show, that substance known to us as a mixture of

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* From now on I shall spell 'air' when I mean air as it is conceived of today, and 'aer' when I mean something different from that, to which the Greeks in general or a given Greek thinker gave the name ἀήρ.

air (N. O. A, H, CO_2, etc.) and water (H_2O) that found itself between the earth and the sphere of flame that surrounded it like the bark of a tree during the cosmogonical process described in passage no. 5. Burnet [x] concludes "that after the first separation of the hot and the cold by the δίνη, the heat of the flame turned part of the moist, cold interior of the world into air or vapour - it is all one at this date - and that the expansion of this mist broke up the flame itself into rings". The heavenly bodies are rings of fire shut off into tubes of this aer that have pipe-like holes in them (the shape of the tubes being like that of the inner tube of a bicycle tyre), see passages nos. 5, 6, & 7. Aëtius, in passage no. 7, describes them as πιλήματα ἀέρος τροχοειδῆ, πυρὸς ἔμπλεα: πίλησις (the felting process) is a favourite word of the Milesians, living as they did in an industrial city, for 'compression' and processes akin to it.

Late though our authorities are for the details of this astronomical picture, nobody doubts that it does represent the theory of Anaximander; but, anyway, we do not need statements by our sources to help us to ascertain

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[x] Burnet, E.G.P.[4], p. 64.

the properties of this aer: we may deduce them ourselves from this accepted picture.

We can infer that aer is, firstly, compressible (for the word 'felting' must be genuinely Milesian); secondly, non-inflammable (so as to be able to contain the fire within its tubes without itself igniting); and, thirdly, opaque (for we can only see the fire inside the tubes through the holes - when they are closed we have eclipses, see passage no. 6). This last property in turn implies visibility, in the form of the black darkness between the stars. It was not yet known that darkness is due to the absence of light and that black is not, therefore, a true colour. This property, visibility, alone is enough to indicate the existence of a considerable difference between the Greek aer and the modern air.

From the meteorological passages, nos. 8, 9, 9a, 10, & 10a, we can see that aer is connected with clouds and vapours. Winds come from the lightest vapours of the aer that have evaporated from the 'moist' around the earth through the heat of the sun, and have been set in motion. Rain is derived from vapour that originated in a similar manner. Aer, then, must have been a dense, opaque, mist or vapour, light in weight, and not fully homogeneous. Some parts are described as being lighter and finer, or moister, than others; and variations in fineness or moistness caused it to appear in various phenomenal forms, from the winds that can be felt and can tear through a cloud to produce thunder and lightning, but that are not in themselves visible and can only be seen in the sense that we see things moved by them, through the rather more easily visible vapours mists and clouds, to the extremely visible darkness of the night sky.

The tearing of the thunder-cloud presents us with resistance as a further property of aer; and if, as is doubtful, the 'turnings of the sun and the moon' really were specifically ascribed by Anaximander to the cause given in passages nos. 10 & 10a, this would be another instance of that property.

The original mass of aer at the world's creation was derived in a way described as 'separation' from the apeiron; but we can now see that it is replenished not only from the apeiron, but also by evaporation; unless Burnet's conclusion quoted above is correct in that all aer is secondary and derived from evaporation - only the flame and the earth with its mantle of water having separated out. However this may be (Ps.Plutarch's words could just as well support the conclusion that the aer came to be around the earth as a result of the original separation), Anaximander has in fact, in spite of his ignorance of the true nature of air and water, correctly interpreted the cycle: evaporation - rain - evaporation.

Since true vapours are mostly invisible, and the Milesians were working in terms of the everyday visible things, it is reasonable to infer that Anaximander's aer is to be thought of as being like a dense mist (which we now describe as a mass of discrete droplets of water suspended in air) rather than like a continuous water vapour. True water vapour is invisible, being in fact steam - but that which the Greeks (and modern laymen too) call by the name 'steam' (when, for example, they watch a pot boil) is really the mist formed when true steam condenses into droplets on contact with the cool atmosphere.

This conception of aer as a substance of the nature of mist or cloud, or even of darkness, had a long history behind it, and it persisted a long time after Anaximander. By the time that the Greek language had its first extant literary expression in Homer, a distinction had grown up between ἀήρ and αἰθήρ (cf. Introd. p. 13). ἀήρ was that part of the atmosphere nearest to the ground, the part that we breathe (and thus that from which the Orphics believed that we breathe in soul), the part in which we see mist, fog, and clouds, and even the part that can be identified with the immediately surrounding darkness of night. Αἰθήρ was the clear upper atmosphere, the bright sky, the origin of the Indo-European Dyaus-Zeus-Jupiter himself, the home of the Gods, and, to Hesiod and others, a God itself. Homer, speaking of the cloud in which the heroes can be wrapped in order to attain invisibility, refers to it now as ἀήρ and now as νεφέλη. Burnet cites passages from classical and post-classical authors in which the word ἀήρ retains its old meaning of mist or darkness. * On the other hand Hesiod links together Αἰθήρ and Ἡμέρα, the light of the upper atmosphere and the light of day.

One can observe on a hot day a heat mist rising from the sea or a river and gradually obscuring the landscape. This mist is the Milesian aer; and it involved no great stretch of the imagination to carry the process one stage further and to think that as the mist became

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* E.G.P.[4], p. 74, n. 2. The passages are: Hipp. Airs Waters Places, 15; Plato, Tim. 58D; Plut., de Prim. Frig. 948E.

increasingly thick it turned into darkness and night. In a country of mountainous valleys leading down to the sea and situated in a hot zone twilight is very often accompanied by this mist, and one of the first signs of the approach of darkness is the purple colour of the hills, which looks very much like mist. These phenomena would be much more widely observed in Greece and Asia Minor than in England where even today many inhabitants have never seen the sea.

There is one last property of Anaximander's aer that modern science would by no means attribute to air. Aët. IV 3, 2 (Diels 12 A 29) includes the name of Anaximander alongside those of Anaximenes, Anaxagoras, and Archelaus (all members of the Ionian School), in a list of those who say ἀερώδη τῆς ψυχῆς τὴν φύσιν. There was a tendency in Greek thought to draw parallels between the universe and the sentient being, the macrocosm and the microcosm. There was a world soul as well as a human soul (cf. Plato, Timaeus), and the universe, like the man, breathes (cf. the Orphics and Pythagoreans). The substance breathed, πνεῦμα, is in this theory the life-giving substance, or the soul. That which is breathed is obviously aer, for we breathe out mist on a cold day. Similar ideas can be seen in the meanings of the Latin words 'animus' and 'anima' (cf. ἄνεμος), and in the belief in reproduction by wind-impregnation. Air breath and wind are to the primitive observer, as I said on p. 24 sup., the 'breath of life'; because the instant of death is only recognisable when a man 'breathes his last', and it is necessary to slap newborn infants to induce them to breathe, their first extra-uterine activity of life. The whole conception of air as soul or as a sort of 'life-force', however, is alien to modern physics; and I propose to postpone discussion of this aspect of Greek thought to an appendix, and to proceed now to the next step in the development of physical speculation of the Milesian type, with reference to aer.

.oOo.

Section ii

The next philosopher of Miletus was Anaximenes, of uncertain date, whose floruit is given by Apollodorus as 546/5 B.C.. He modified and simplified the theories of his predecessor, and proceeded even farther along the path of rationalisation. He abandoned Anaximander's apeiron in favour of a more recognisable substance, aer, when choosing his first principle, giving as a reason for this choice the analogy between the microcosm and the macrocosm that I mentioned on p. 48 sup.: Passage 12 inf. contains this analogy, and the following passages contain the basic theory of Anaximenes.

12. Ἀναξιμένης Εὐρυστράτου Μιλήσιος ἀρχὴν τῶν ὄντων ἀέρα ἀπεφήνατο· ἐκ γὰρ τούτου πάντα γίγνεσθαι καὶ εἰς αὐτὸν πάλιν ἀναλύεσθαι. "οἷον ἡ ψυχή", φησίν, "ἡ ἡμετέρα ἀὴρ οὖσα συγκρατεῖ ἡμᾶς, καὶ ὅλον τὸν κόσμον πνεῦμα καὶ ἀὴρ περιέχει" (λέγεται δὲ συνωνύμως ἀὴρ καὶ πνεῦμα).

Aët. I 3, 4, Diels. 13 B 2.

13. Ἀναξιμένης δὲ ... μίαν μὲν καὶ αὐτὸς τὴν ὑποκειμένην φύσιν καὶ ἄπειρόν φησιν ὥσπερ ἐκεῖνος (τ.ε. Ἀναξίμανδρος), οὐκ ἀόριστον δὲ ὥσπερ ἐκεῖνος, ἀλλὰ ὡρισμένην, ἀέρα λέγων αὐτήν· διαφέρειν δὲ μ α ν ό τ η τ ι καὶ π υ κ ν ό τ η τ ι κατὰ τὰς οὐσίας. καὶ ἀραιούμενον μὲν πῦρ γίνεσθαι, πυκνούμενον δὲ ἄνεμον, εἶτα νέφος,

ἔτι δὲ μᾶλλον ὕδωρ, εἶτα γῆν, εἶτα λίθους, τὰ δὲ ἄλλα ἐκ τούτων. κίνησιν δὲ καὶ οὗτος ἀίδιον ποιεῖ, δι' ἣν καὶ τὴν μεταβολὴν γίγνεσθαι. *

Simpl. Phys. 24, 26 (Theophr. Phys. Op. Frag 2), D. 13 A 5.

14. Ἀναξιμένην δέ φασι τὴν τῶν ὅλων ἀρχὴν τὸν ἀέρα εἰπεῖν καὶ τοῦτον εἶναι τῷ μὲν μεγέθει ἄπειρον, ταῖς δὲ περὶ αὐτὸν ποιότησιν ὡρισμένον· γεννᾶσθαί τε πάντα κατά τινα πύκνωσιν τούτου καὶ πάλιν ἀραίωσιν. τήν γε μὴν κίνησιν ἐξ αἰῶνος ὑπάρχειν.

Ps. Plut. Strom 3, D. 13 A 6.

15. Ἀναξιμένης ... ἀέρα ἄπειρον ἔφη τὴν ἀρχὴν εἶναι, ἐξ οὗ τὰ γινόμενα καὶ τὰ γεγονότα καὶ τὰ ἐσόμενα καὶ θεοὺς καὶ θεῖα γίνεσθαι... (2) τὸ δὲ εἶδος τοῦ ἀέρος τοιοῦτον· ὅταν μὲν ὁμαλώτατος ᾖ, ὄψει ἄδηλον, δηλοῦσθαι δὲ τῷ ψυχρῷ καὶ τῷ θερμῷ καὶ τῷ νοτερῷ καὶ τῷ κινουμένῳ. κινεῖσθαι δὲ ἀεί· οὐ γὰρ μεταβάλλειν ὅσα μεταβάλλει, εἰ μὴ κινοῖτο. (3) πυκνούμενον γὰρ καὶ ἀραιούμενον διάφορον φαίνεσθαι· ὅταν γὰρ εἰς τὸ ἀραιότερον διαχυθῇ, πῦρ γίνεσθαι, ἀνέμους δὲ πάλιν εἶναι ἀέρα πυκνούμενον, ἐξ ἀέρος <δὲ> νέφος ἀποτελεῖσθαι κατὰ τὴν πίλησιν, ἔτι δὲ μᾶλλον ὕδωρ, ἐπὶ πλεῖον πυκνωθέντα γῆν καὶ εἰς τὸ μάλιστα πυκνότατον λίθους. ὥστε τὰ κυριώτατα τῆς γενέσεως ἐναντία εἶναι, θερμόν τε καὶ ψυχρόν.

Hipp. Ref. I 7, 1-3, D. 13 A 7. Cf. 13 A 8.

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* Technical terms underlined mean, in order: substrate (Aristotelian term), infinite (in extent), indeterminate (v. p. 38 sup.), rarefaction, and condensation. For the last two v. p. 52sq.

In these passages we may see several refinements of the theory of Anaximander. In the latter's system the four opposites are treated as οὐσίαι, independent entities that separated from an original mass of apeiron. How they could have sprung from that precosmical unity, and how their interplay could have brought about qualitative changes, are two serious difficulties in his theory. Anaximenes, however, treats the four opposites as merely πάθη of one primary substance, ἀήρ. They are states of aer, functions of its density. The postulation of the process of rarefaction and condensation made possible for the first time a self-consistent theory in which change is plausibly explained. * Since apparently different types of matter are simply the same basic substance under different degrees of compression, there is no difficulty in seeing how one type can change into another.

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* We are accustomed to use the word 'condensation' for the process also called 'felting' by the Milesians, but it must be understood that this does not mean condensation in the popular sense of e.g. steam condensing in a retort or breath condensing on a windowpane, but in the more literal sense of becoming denser - having more matter in a given volume. Retort condensation does result in greater density, but that use of the word now implies the modern kinetic theory of matter. Anaximenes had no such atomic theory; he was presumably thinking in terms of continuous matter, not of the degree of packing together of discrete particles. But Parmenides saw that he was in error over this, v. p. 185 inf.

It is only fair in this connexion to quote the words of Cherniss (Op. cit. p. 379): "Anaximenes' chief interest was also in this process ... it is the definite unity of this mechanism of rarefaction-condensation, rather than the fact that the great mass of material that surrounds all the world and is infinite in extent has been given the definite name of "air", which lends an air of "monism" to his system. ... One body <u>becomes</u> another by reason of the process ... water changes into earth and earth into water. Air gets the role of honour simply because it is the most extensive of all bodies and "the most evenly distributed" ... and also because of the identification of the air in our bodies with the soul ... nor does the definite designation of it as "air" imply here an identity which includes homogeneity, for the other characteristics of the air as of all bodies depend upon the mechanical distribution of its parts".

According to Cherniss this system of Anaximenes implies a physical relativism of the Heracleitan type, and as in the case of Anaximander I cannot go all the way with Cherniss. I agree that the keystone of the theory is the process, and that aer is not an Aristotelian indeterminate substrate with various qualities imposed upon it. But

I cannot agree that aer is one of many bodies, and, as it were, just happens to have "the role of honour" for the reasons given; especially since I feel that Cherniss has with the phrase "the most evenly distributed" mistranslated and misapplied the ὁμαλώτατος of passage no. 15 sup., which I take to refer to a particular state of aer - when it is most 'even', vid. inf. - and not to the distribution of aer as a whole with respect to the universe. I do not agree that Anaximenes was so close in thought to Heracleitus any more than I agree that Anaximander was to Anaxagoras. The process was vital, yes: but aer was nevertheless the one basic substance, which, as a result of the operation of the process, was able to appear in various phenomenal forms.

Not only is the process of Anaximenes better able to explain change in the present world; a mechanical process of cosmogony through the agency of increasing density is a simpler idea than the process of separation described by Anaximander. Like the latter, however, Anaximenes explained the first cause of the creation of the universe as an eternal motion. The early thinkers as a whole saw no necessity to assign a cause to the latter: it was accepted as 'given' until men like Parmenides questioned it.

Before the Eleatics demonstrated the logical difficulties of change the problem of motion was no problem at all as Cherniss says (op. cit. p. 372): causation was mechanical and did not need an Aristotelian efficient cause.

It is noteworthy, but certainly not to be hailed as a Milesian anticipation of modern science, that our position is similar. We assume that the original state of the universe was that of an undifferentiated mass of hydrogen of roughly uniform density (or rather, tenuosity, for the number of particles in a given volume will have been extremely low), and that then, by reason of random motions whose cause we do not explain, certain parts of the gas became more dense than others, so that gravity began to operate. This caused a more regular motion which led to the formation in turn of spiral nebulae, stars, and planets. We even have now, in the theory expounded by F. Hoyle, the idea of continuous creation, analogous to the Milesians' infinite store of matter "so that becoming may not fail".

There is this great difference: whereas to us the factor that causes the increasing condensation, once the unexplained motion has started it, is gravity (or rather whatever corresponds in a particular mathematical or astrophysical theory to this lay concept), to Anaximenes there were two other possible causes apart from motion: change of moisture content or of temperature (v. passage no. 15).

We know that temperature and motion are interconnected: heat can cause motion, and motion heat, though not without some wastage of heat (2nd. Law of Thermodynamics), for they are two aspects of the same thing (cf. p. 7 - they are different forms of energy). But to Anaximenes it is temperature and density that are thus interconnected. The statement of Hippolytus (passage no. 15) that cold and heat can make aer visible means, as we shall see, that they increase or decrease respectively its density. We shall later be examining also a passage from Plutarch that shows that Anaximenes thought that conversely density changes bring about corresponding changes in temperature.

Let us first consider the relation inferred from Hippolytus. While it is true that heat causes expansion and cold contraction in a gas at constant pressure, the true connexion is not between temperature and density, but between temperature and molecular velocity: since the pressure (a function of both density and molecular velocity) is constant, it is the change in velocity associated with temperature change that causes change in density.

If, however, pressure varies, as it does in the atmosphere, for example, temperature change need not necessarily, as it does in Anaximenes' theory, cause a corresponding density change.

One case in which Anaximenes' theory breaks down is this: he held that aer, as it became increasingly felted by cold, became first liquid, then solid; so that the difference between water and ice was that in ice the aer was denser: this implies that the same quantity of aer occupied a smaller volume. But in fact the most elementary type of experiment shows that water's volume increases on freezing. We know this because our plumbing bursts after freezing, and he could have learned it by leaving a jar of water out in the open in frosty weather and observing that the level of the ice formed is higher than that of the original liquid. He could have done this, and to our minds he should have; but we saw in Chap. II that Greek philosophy did not demand any such experimental or observational checks.

At any rate, Anaximenes did in his theory of creation, purely by coincidence, have very roughly the right idea: that motion caused a progressive increase in density which brought into being the heavenly bodies and the earth.

His theory more resembles our own than do most of the more mature Greek theories, even though his method of arriving at it differed radically from our own.

In dealing with the converse relation mentioned on p. 56 he was definitely less successful. The microcosm was as usual the starting point:

> τὸ γὰρ συστελλόμενον αὐτῆς (τ.ε. ὕλης) καὶ πυκνούμενον ψυχρὸν εἶναί φησι, τὸ δ' ἀραιὸν καὶ τὸ χ α λ α ρ ὸ ν (οὕτω πως ὀνομάσας καὶ τῷ ῥήματι) θερμόν. ὅθεν οὐκ ἀπεικότως λέγεσθαι τὸ καὶ θερμὰ τὸν ἄνθρωπον ἐκ τοῦ στόματος καὶ ψυχρὰ μεθιέναι· ψύχεται γὰρ ἡ πνοὴ πιεσθεῖσα καὶ πυκνωθεῖσα τοῖς χείλεσιν, ἀνειμένου δὲ τοῦ στόματος ἐκπίπτουσα γίγνεται θερμὸν ὑπὸ μανότητος. τοῦτο μὲν οὖν ἀγνόημα ποιεῖται τοῦ ἀνδρὸς ὁ Ἀριστοτέλης· ἀνειμένου γὰρ τοῦ στόματος ἐκπνεῖσθαι τὸ θερμὸν ἐξ ἡμῶν αὐτῶν, ὅταν δὲ συστρέψαντες τὰ χείλη φυσήσωμεν, οὐ τὸν ἐξ ἡμῶν, ἀλλὰ τὸν ἀέρα τὸν πρὸ τοῦ στόματος ὠθεῖσθαι ψυχρὸν ὄντα καὶ προσεμπίπτειν.

Plut. de prim. frig. 7, 947 f; Diels 13 B 1.

Not only was Anaximenes wrong in thinking that the temperature effect is due to density differences dependent upon the labial pressure, but the explanation of Aristotle referred to by Plutarch (Arist. Probl. 964 a 10) also fails to state the whole truth. It is true that when the mouth is wide open we breathe out air that has been warmed inside the body (and not by Anaximenes' reason, the rarefaction); but it is not true that in the other case it is the air in front of the mouth, which is cold, that is impelled forward. The air behind the pursed lips is under pressure as the lung muscles force it through the narrow orifice, and upon emerging it enters, in the atmosphere, a region where the pressure is lower, which permits it to expand. The expansion is adiabatic (adiabatic change may be defined as 'a change in the volume and pressure of the contents of an enclosure without exchange of heat between the enclosure and its surroundings). Adiabatic expansion causes a drop in the heat energy, and thus in the temperature, of the substance concerned, the energy released being capable of being transformed into work, in this case the work of pressing against the skin of a hand held in front of the mouth. Consequently we feel a cooler stream of air press against our skin than in the case of the open mouth. A contributory factor may be that the stronger current of air blowing over the skin when the lips are pursed assists in the evaporation of sweat by carrying away the vapour thus formed more rapidly, and evaporation itself, a fact unknown to the Milesians, also causes a drop in temperature.

From the quite correct observation, therefore, Anaximenes drew the incorrect conclusion that condensation cools and rarefaction heats. He has again, as in the converse case (p. 57 sup.) fallen into a trap through ignorance of the effect of non-constant pressure. In fact if gas is compressed its temperature rises and vice versa (adiabatic expansion and compression), unless some special laboratory precautions are taken to maintain a constant temperature (isothermal expansion and compression). In the observation described he was dealing with adiabatic expansion and perhaps also evaporation, contrasted with normal conditions, and not with condensation contrasted with rarefaction, in his sense of the words, at all; and the increased pressure at the lips is irrelevant to what happens when the breath stream has met the atmosphere. In fact, upon repeating his observation, I find that if I place my hand very close to my pursed lips I feel the air emerging at body temperature (which at once vitiates both the observation of Anaximenes and the explanation of Aristotle), and I do not perceive the coolness until I have moved my hand a half an inch or more from my mouth, and thus given the expansion both time and room to effect itself.

Consequently, however close an analogy there may be between Anaximenes' theory and ours on the plane of cosmic creation, he was very far from anticipating our modern micro-cosmic gas laws (Boyle's Law and Charles' Law, p. 9 sup. and the laws of thermodynamics). He built up his theory, in fact, by forming risky conclusions from his observations and then generalising these conclusions beyond the limits of observation. This is so not only in the case of the observation just dealt with, but also in the addition of the stage of rarefaction of aer into fire that follows on the correctly given stages of rarefaction of solids (e.g. stones and earth) into liquids (e.g. water) and liquids into gases (e.g.aer). Flame is, of course, neither a separate real substance, 'fire', nor a separate kinetic state of matter, but merely gas rendered incandescent by heat energy (more accurately, the atoms of the gas are in a state of excitation wherein they emit electromagnetic radiation in the form of photons that are visible as light rays or invisible as infra-red heat rays). The gas molecules are indeed further apart owing to the increased kinetic energy, so that the gas is rarer than when it is cool; but the <u>substance</u> is the same, and Anaximenes was not dealing with (sub-)atomic phenomena.

We must now examine the properties of Anaximenes' aer. Of the utmost importance is the theory mentioned by Hippolytus (passage no. 15) that aer in its natural state, viz. when 'most even' (ὁμαλώτατος, a word which in this context must surely refer to one possible physical state of aer, contrasted with another state when it has undergone some type of excitation, and not to its distribution as Cherniss has taken it, cf. pp. 53-4 sup.), is invisible, but that 'it becomes visible under the action of cold and heat and moisture and motion'. Anaximenes was the first man to see the possibility of the real corporeal existence of an invisible substance. In this invisible state the aer is the πνεῦμα that we breathe. * It is still precisely the same substance as the visible aer, that described by Anaximander, but in a rarer, more tenuous state. Man had still not recognised that invisible air is a different substance from opaque mist, and that in fact the air that we inhale is different in composition from that which we exhale (oxygen replaced by carbon dioxide).

Whereas Anaximander thought that the natural state of aer was mist, Anaximenes thought that it was the form

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* On a cold day, however, we breathe out a visible mist which we, like Anaximenes, attribute to condensation, but in a different sense of the word. The observation of this misty breath must have played an important role in the formation of the early Greek notions about aer.

that is invisible - the form in fact that constitutes the normal atmosphere. This new idea of invisible air was not immediately adopted, and we shall soon meet thinkers who confused invisible air with empty space: acceptance had to wait until the experimental proof cited by Empedocles, v. inf.. *

It is now time to examine the part played by aer in the cosmology of Anaximenes. His astronomy is backward compared with that of his predecessor, whereas his meteorology is similar. The whole universe is of course made of aer; but instead of the separative process postulated by Anaximander we have the process of rarefaction and condensation, and of evaporation. The relevant passages follow:

16. (4) τὴν δὲ γῆν πλατεῖαν εἶναι ἐπ' ἀέρος ὀχουμένην, ὁμοίως δὲ καὶ ἥλιον καὶ σελήνην καὶ τὰ ἄλλα ἄστρα πάντα

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* From now until I reach the chapter on Empedocles I shall use the spelling 'aer' to mean a substance that consists of some sort of water vapour, like the aer of Anaximander, but that may be visible or invisible. The passages, however, that Burnet quoted (v. p. 47 sup.), together with the fact that Empedocles used 'aether' for elementary invisible air, show that in normal language 'aer' continued to mean 'mist' or even 'darkness'. I shall be using 'aer' in the stated sense for convenience rather than with accuracy, to distinguish between aer conceived as water vapour and air as oxygen, nitrogen, etc..

πύρινα ὄντα ἐ π ο χ ε ῖ σ θ α ι τῷ ἀέρι διὰ πλάτος. (5) γεγονέναι δὲ τὰ ἄστρα ἐκ γῆς διὰ τὸ τὴν ἰκμάδα ἐκ ταύτης ἀνίστασθαι, ἧς ἀραιουμένης τὸ πῦρ γίνεσθαι, ἐκ δὲ τοῦ πυρὸς μετεωριζομένου τοὺς ἀστέρας συνίστασθαι. εἶναι δὲ καὶ γεώδεις φύσεις ἐν τῷ τόπῳ τῶν ἀστέρων συμπεριφερομένας ἐκείνοις.

Hipp. Ref. I 7, 4-5, D. 13 A 7; cf. (a) Aët. II 13, 10, D. 13 A 14, (b) Id. II 20, 2, D. 13 A 15.

(a) Ἀναξιμένης πυρίνην μὲν τὴν φύσιν τῶν ἄστρων, περιέχειν δέ τινα καὶ γεώδη σώματα συμπεριφερόμενα τούτοις ἀόρατα.

(b) Ἀναξιμένης πύρινον ὑπάρχειν τὸν ἥλιον ἀπεφήνατο.

17. Ἀναξιμένης δὲ καὶ Ἀναξαγόρας καὶ Δημόκριτος τὸ πλάτος αἴτιον εἶναί φασι τοῦ μένειν αὐτήν· (τ.ε. γῆν) οὐ γὰρ τέμνειν, ἀλλ' ἐπιπωματίζειν τὸν ἀέρα τὸν κάτωθεν, ὅπερ φαίνεται τὰ πλάτος ἔχοντα τῶν σωμάτων ποιεῖν· ταῦτα γὰρ καὶ πρὸς τοὺς ἀνέμους ἔχει δυσκινήτως διὰ τὴν ἀντέρεισιν. ταὐτὸ δὴ τοῦτο ποιεῖν τῷ πλάτει φασὶ τὴν γῆν πρὸς τὸν ὑποκείμενον ἀέρα. τὸν δ' οὐκ ἔχοντα τοῦ μεταστῆναι τόπον ἱκανὸν ἀθρόον τῷ κάτωθεν ἠρεμεῖν, ὥσπερ τὸ ἐν ταῖς κλεψύδραις ὕδωρ.

Arist. de Cael. 294 b 13, D. 13 A 20; cf. (a) Ps. Plut. Strom. 3, D. 13 A 6, (b) Aët. II 22, 1, D. 13 B 2a, and (c) Id. III 15, 8, D. 13 A 20.

(a) πιλουμένου δὲ τοῦ ἀέρος πρώτην γεγενῆσθαι λέγει τὴν γῆν πλατεῖαν μάλα· διὸ καὶ κατὰ λόγον αὐτὴν ἐ π ο χ ε ῖ σ θ α ι τῷ ἀέρι· καὶ τὸν ἥλιον καὶ τὴν σελήνην καὶ τὰ λοιπὰ ἄστρα τὴν ἀρχὴν τῆς γενέσεως ἔχειν ἐκ γῆς. ἀποφαίνεται γοῦν τὸν ἥλιον γῆν, διὰ δὲ τὴν ὀξεῖαν κίνησιν καὶ μάλ' ἱκανῶς θερμὴν ταύτην καῦσιν λαβεῖν.

(b) πλατὺν ὡς π έ τ α λ ο ν τὸν ἥλιον.

(c) Ἀναξιμένης διὰ τὸ πλάτος ἐ π ο χ ε ῖ σ θ α ι τῷ ἀέρι.

18. Ἀναξιμένης ὑπὸ πεπυκνωμένου ἀέρος καὶ ἀντιτύπου ἐξωθούμενα τὰ ἄστρα τὰς τροπὰς ποιεῖσθαι.

Aët. II 23, 1, D. 13 A 15.

19. (7) ἀνέμους δὲ γεννᾶσθαι, ὅταν ᾖ πεπυκνωμένος ὁ ἀὴρ καὶ ὠσθεὶς φέρηται (†)· συνελθόντα δὲ καὶ ἐπὶ πλεῖον παχυνθέντα νέφη γεννᾶσθαι καὶ οὕτως εἰς ὕδωρ μεταβάλλειν, χάλαζαν δὲ γίνεσθαι, ὅταν ἀπὸ τῶν νεφῶν τὸ ὕδωρ καταφερόμενον παγῇ· χιόνα δέ, ὅταν αὐτὰ ταῦτα ἐνυγρότερα ὄντα πῆξιν λάβῃ. (8) ἀστραπὴν δ' ὅταν τὰ νέφη διϊστῆται βίᾳ πνευμάτων· τούτων γὰρ διϊσταμένων λαμπρὰν καὶ πυρώδη γίνεσθαι τὴν αὐγήν. ἶριν δὲ γεννᾶσθαι τῶν ἡλιακῶν αὐγῶν εἰς ἀέρα συνεστῶτα πιπτουσῶν.

Hipp. Ref. I 7, 7-8, D. 13 A 7; cf. (a) Aët. III 4, 1, D. 13 A 17, (b) Id. III 5, 10, and Schol. Arat. p. 515, 27 (from Posidonius), both in D. 13 A 18.

(a) Ἀναξιμένης νέφη μὲν γίνεσθαι παχυνθέντος ἐπὶ πλεῖον τοῦ ἀέρος, μᾶλλον δ' ἐπισυναχθέντος ἐκθλίβεσθαι τοὺς ὄμβρους, χάλαζαν δέ, ἐπειδὰν τὸ καταφερόμενον ὕδωρ παγῇ, χιόνα δ' ὅταν συμπεριληφθῇ τι τῷ ὑγρῷ πνευματικόν.

(b) Ἀναξιμένης ἶριν γίνεσθαι κατ' αὐγασμὸν ἡλίου πρὸς νέφει πυκνῷ καὶ παχεῖ καὶ μέλανι παρὰ τὸ μὴ δύνασθαι τὰς ἀκτῖνας εἰς τὸ πέραν διακόπτειν ἐπισυνισταμένας αὐτῷ.

τὴν ἶριν Ἀναξιμένης φησὶ γίνεσθαι, ἡνίκα ἂν ἐπιπέσωσιν αἱ τοῦ ἡλίου αὐγαὶ εἰς παχὺν καὶ πυκνὸν τὸν ἀέρα. ὅθεν τὸ μὲν πρότερον αὐτοῦ τοῦ ἡλίου φοινικοῦν φαίνεται, διακαιόμενον ὑπὸ τῶν ἀκτίνων, τὸ δὲ μέλαν, κατακρατούμενον ὑπὸ τῆς ὑγρότητος. καὶ νυκτὸς δέ φησι γίνεσθαι τὴν ἶριν ἀπὸ τῆς σελήνης.

Note: it is, of course, true that rainbows are caused by the falling of the rays of the sun or, by night, the moon on precisely what Anaximenes meant by condensed aer, viz. a heavy mist or raindrops; but the Greeks always remained ignorant of the fact that the colours of the rainbow are caused by the variations in the angles of refraction of light waves of different frequencies (or wave-lengths), as demonstrated by Isaac Newton with the prism.

In these passages we see the workings of rarefaction and condensation upon aer on the cosmic scale. The heavenly bodies arose from earth (very condensed aer) by rarefaction through the stages of moisture and normal aer to the rarest state, fire. Passage no. 16 describes this process, but this passage and no. 16a also refer to certain invisible earthy bodies in the heavens. These occur also in some later systems, where they are postulated to explain eclipses, as is the case with Anaxagoras, whose astronomy is much indebted to Anaximenes.

Passage no. 17a states what we should have had to infer from no. 16, namely that the earth was the first to be created; but after stating that the origin of the heavenly bodies was the earth, Ps. Plut. goes on to say that the sun was earth, apparently contradicting nos. 16, 16a and 16b. It is, however, no real contradiction: since the earth is the source of the matter of the sun, and since all matter, including earth, is only aer in different forms, the phrase is true in a manner of speaking.

Ps. Plutarch next gives the cause of the fiery nature of the sun, namely rapid motion (one of the possible causes of change of state given by Hippolytus in passage no. 15). We know that Anaximenes' universe revolved;

for in a number of passages (Diels 13 A 12-14) we are told that it did, and in such a way that the stars go around rather than under the earth - the mode of revolution is like that of a millstone or of a cap round the head (Hipp. Op. Cit. 1 7, 6, D. 13 A 7). So the rapid motion referred to will have been that of the δίνη that acts as motive cause throughout Ionian speculation.

The property of aer called resistance that we inferred from passage no. 8 of Anaximander is for the first time explicitly dealt with by Anaximenes: it is the reason why the heavenly bodies and the earth remain in position; they are flat, and borne up by the aer, v. passages nos. 16, 17, 17a & 17b, of which no. 17 gives the explanation.

It appears from the first two sections of Book II of Aristotle's Meteorologica, especially passage no. 10 sup., if we can trust the (somewhat doubtful) identifications given by Alexander on the authority of Theophrastus in no. 10a (p. 34 sup.) of the people vaguely referred to, that whereas Anaximander (and Diogenes) explained solstices and the movements in declination of the moon by failure of the moisture by which the sun and moon were nourished, Anaximenes (and Anaxagoras) explained them by means of the resistance of compressed aer, cf. passage no. 18, in which Aëtius generalises this explanation to cover the τροπαί of the stars as a whole. Aristotle rightly rejects both explanations. In any case, the identifications that I referred to are not certain, the whole passage of Aristotle is fraught with difficulty, and the meaning 'solstice' for τροπή rather than 'revolution' is disputed. Too much importance should not, therefore, be attached to this subject with reference to either Anaximander or Anaximenes.

If we add this property of resistance and the possibility of invisibility to the list of properties of aer inferred for Anaximander, and take away non-inflammability (for aer, rarefied, turns into fire), we obtain a complete description of the aer of Anaximenes, with the proviso that the former's was derived from the apeiron while the latter's is a real substance in its own right.

Finally it is worth noticing, though the point is not scientific, that since Water, Apeiron, or Aer, the principle of the Milesians, is eternal and deathless, it tends to have been spoken of by commentators as having been considered to be divine, or a god. This is an ancient misinterpretation. The word 'divine' itself meant to the

Milesian rationalisers simply 'eternal and deathless' and nothing more. It was to be taken metaphorically and not literally, and is an example of the way in which a pioneer in any subject is hampered by the lack of a pre-existing technical vocabulary (cf. the well-known complaint of Lucretius). The Milesians were rationalising mythology into science and not substituting one type of religion for another. It is not even certain that Thales ever did say: "All things are full of Gods", and if he did he was not advancing a pantheistic dogma. Cicero committed this misinterpretation in the case of Anaximenes:

> post Anaximenes aëra deum statuit eumque gigni esseque immensum et infinitum et semper in motu, quasi aut aer sine ulla forma deus esse possit ... aut non omne quod ortum sit mortalitas consequatur.
>
> Cic. de Nat. D., I 10, 26, D. 13 A 10.

Aer was definitely not created. On this point Hippolytus (passage no. 15 sup., sec. 1) and Augustine preserve a more correct interpretation:

> omnes rerum causas aëri infinito dedit, nec deos negavit aut tacuit; non tamen ab ipsis aërem factum, sed ipsos ex aëre ortos credidit.
>
> Aug. C.D. VIII 2, D. 13 A 10.

Even here, however, we must be wary of the assertion that gods were created from aer. If Anaximenes did indeed say that gods (and not just things that were 'divine', i.e. eternal) were created from air, he may not have been making a scientific assertion that gods exist, but rather meaning that if the Homeric gods, or indeed any gods, existed, they would not be made of something supernatural, but of aer, just as our soul is, and our body come to that. (Cf. Galen, D. 13 A 22: οὔτε γὰρ πάμπαν ἀέρα λέγω τὸν ἄνθρωπον ὥσπερ Ἀναξιμένης.) With regard to the first principle itself being called a god, in addition to the point I have made about the meaning 'eternal', there may also be some truth in the comment of Aëtius:

> Ἀναξιμένης τὸν ἀέρα (τ.ε. θεὸν εἶναι)· δεῖ δ' ὑπακούειν ἐπὶ τῶν οὕτως λεγομένων τὰς ἐνδιηκούσας τοῖς στοιχείοις ἢ τοῖς σώμασι δυνάμεις.

Aët. I 7, 13, D. 13 A 10.

We shall find that Anaximenes' theory had a very great influence upon his successors. The Pythagoreans were much indebted to it. Anaxagoras and the Atomists adopted many views typical of him, while Diogenes tried to reconcile his theory with the refinements of Anaxagoras. An Ionian School persisted with many minor thinkers following in Anaximenes' footsteps in addition to those just mentioned. In fact his speculations and conclusions became as it were a basic starting point from which later thinkers deviated along their respective paths, and a storehouse of material from which they drew ideas about aspects of science in which they were not themselves primarily interested but about which they felt that they ought to say something for the sake of completeness.

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CHAPTER FOUR

EARLY WESTERN THOUGHT

The work of Anaximenes marked the culminating point of Milesian science. There were certain difficulties inherent in any monistic system; but other schools of thought that approached the subject differently escaped some of these. * The idea of an infinite store of the primary substance outside of, or 'encompassing', the particular universe in which we live is logically unsatisfactory (but it is unsafe to say 'scientifically unsatisfactory' as one would have a few years ago until the continuous creation theory of F. Hoyle is definitely accepted or rejected). It places the matter of the world that one has explained in the midst of a far greater amount of matter that one has not explained, which is both irrational and uneconomical.

The infinite store is there 'that becoming may not fail'. Aristotle points out in Phys. 208 a 8:

> οὔτε γὰρ ἵνα ἡ γένεσις μὴ ἐπιλείπῃ, ἀναγκαῖον ἐνεργείᾳ ἄπειρον εἶναι σῶμα αἰσθητόν· ἐνδέχεται γὰρ τὴν θατέρου φθορὰν θατέρου εἶναι γένεσιν, πεπερασμένου ὄντος τοῦ παντός.

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* C. Bailey in The Greek Atomists and Epicurus, p. 18, discussed these difficulties and I am indebted to him here.

The latter is of course Aristotle's own view, and was that of Heracleitus, v. inf. - logically at least it disposes of the infinite store.

Moreover the Milesians had not solved the problem of the relation of the One and the Many. If opposites, which are things, separated out of an apeiron, the apeiron should not have been conceived of as homogeneous; but it was so ex hypothesi. If on the other hand all things are merely different aspects of aer, why do they seem to be so different from aer? Are the liquid nature of water and the solidity of earth merely illusions?

The next philosopher in the main line of Ionian thought, Heracleitus, made an attempt to deal with these difficulties; but before examining his answers it will be as well to abandon Ionia temporarily, for he may have been indebted for some of his ideas to two philosophers who, though Ionian by birth, spent their maturity in the West: Pythagoras and Xenophanes.

South Italy and Sicily became the home of a religious brand of philosophy that contrasted sharply with Ionian rationalism. The religion was the mysticism associated with the Delian Apollo, the religion of ecstasy and catharsis for which the purpose of philosophy was not to satisfy curiosity but to purify the soul. Living in organized communities, such philosophers at times adopted an almost prophetic tone. Great advances in science and slavish adherence to taboos occurred in one and the same school. A man might even expound quite irreconcilable views on the same subject according as he was speaking as a scientist or as a man of religion.

Pythagoras of Samos, whose floruit is given as 532 b.c. migrated to Croton and there founded the most famous of these communities. He became a legendary figure, and it is never easy to decide which of the Pythagorean theories are due to him and which to his disciples. In this chapter I propose to deal with what I believe to have formed an early type of Pythagorean science, some of it perhaps due to Pythagoras himself and some to his earliest followers. This type of Pythagoreanism I believe to have been developed before the critique of Parmenides, and some at least of its theories I believe to have been available for study in the time of Heracleitus. I propose to postpone to its proper place in the chronological order the discussion of the later types that arose during the later fifth century as a result of the Eleatic criticism and the general advances in knowledge that had by then spread throughout the Greek world.

There are several reasons why it is difficult to obtain a precise idea of the Pythagorean theories current at any particular date. Firstly there was the Pythagoreans' own habit of ascribing innovations not to the innovator but to the master himself: secondly there is the lack of contemporary documents, which is made more serious by the spurious nature of the fragments ascribed to Philolaus, who lived in the second half of the fifth century: thirdly there is the reluctance of Plato and Aristotle to attribute views to individual members of the school by name, and also there are Aristotle's misrepresentations and confusions with Platonism (cf. Cherniss): finally there is the modern confusion introduced by those who, like Taylor and Burnet, see the hand of the Pythagoreans in much of Plato, especially in the Timaeus.

Consequently it is a question of quot homines tot sententiae. I have above all consulted the works of Cornford, Ross (who mostly agrees with him), Raven, Cherniss, and, with caution, Burnet, and A. Rey (who relies much on Burnet). Before examining the Pythagorean speculation in detail in so far as it concerns aer, I shall briefly summarise the opinions of Raven, Cornford, and Cherniss, and then indicate where I agree or disagree with one or other of them. * In doing so I shall have to anticipate by a bare statement some of the points that I shall later be discussing in detail.

Firstly, all scholars agree that the Pythagoreans were concerned with numbers, and something must be said about this. Stobaeus (Ecl. I 1, 6, D. 58 B 2) quotes Aristoxenus as saying:

> Pythagoras appears to have honoured the study of arithmetic most of all men, and to have advanced it beyond the needs of commerce for the first time, likening all things to numbers.

The reason for his numerical interest is said to have been that he discovered the relation between number and music. Whether or not Pythagoras himself observed the musical consonances in a smithy as legend has it **

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* I shall not quote the authorities in full, for many passages would be too long to quote in Greek when they are not devoted to aer. They are all either quoted by Raven or collected in Diels 58 B, and many are translated by Cornford. To save space I shall merely refer to them, except for quoting in translation passages of particular note or doubtful interpretation. The books concerned are: Raven, Pythagoreans and Eleatics: Cornford, Plato and Parmenides: Cherniss, Op. Cit..

** As Burnet points out (E.G.P. p. 106), this story will not bear examination, but Pythagoras could have reached the result by the use of the monochord.

it is clear that the early Pythagoreans were aware that, other things being equal, the pitch of a note depends on the length of the vibrating body, and that the lengths that give consonant notes are in simple integral ratios. This observation both prompted and appeared to confirm the notion that all things are numbers and the World is a harmony. * For if so different a thing, apparently, as music is based on number, Pythagoras or some early disciple must have asked, may not other things too be based on number? Things, for example, like fire earth and water, or justice soul mind and opportunity? Compare Aristotle, Met. 985 b 23, D. 58 B 4:

> Among these (the Atomists) and before these the so-called Pythagoreans, bred in the study of mathematics, which they were the first to advance, thought that the principles (ἀρχαί) of mathematics are the principles of all things. Of these principles numbers are by nature the first; and in these, rather than in fire and earth and water, they seemed to observe many likenesses to things that exist and come into being: e.g. such and such a property (πάθος) of numbers is justice, and such and such is soul and mind, and another is opportunity, and so on. Further they saw that the properties and ratios of musical scales (ἁρμονίαι) were expressible in numbers. Since, then, all other things seemed in their whole nature to be fashioned like numbers, and numbers seemed to be the first things in the whole of nature, they supposed that the elements (στοιχεῖα) of numbers are the elements of all things, and that the whole Heaven is a scale or number.

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* 'Harmony' means a scale with simple numerical relations, not anything to do with chords or progressions.

At times, as in the above passage and in Met. 990 a 22, 1078 b 21, and 1090 a 20, Aristotle talks of numbers or of the elements of numbers as being the elements of things; at times he talks of things resembling numbers, as in the above passage and in Met. 987 b 11, D. 58 B 12. However these alternative ways of describing the relation between numbers and things are, as will be seen below, errors or guesses of Aristotle; and it is clear that to at least the majority of Pythagoreans things actually were composed of numbers, compare Met. 986 a 15, 58 B 5:

> Evidently these philosophers also consider number to be a principle, both as the matter for things and as their modifications and states.

Compare also Met. 987 a 13, B 8: *

> In the same way the Pythagoreans say that the principles are two, but they added further the following, which is peculiar to themselves: they thought that the Limited and the Unlimited were not characteristics of something else such as fire or earth or anything else of that sort, but that the Unlimited itself and the One itself were the substance of the things of which they are predicated; and therefore number was the substance of all things.

Given, then, that things are numbers, there arise the questions: how are numbers generated, and how are

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* Other passages that assert that things are numbers include: Met. 987 b 22, 58 B 13; 989 b 29, B 22; 1036 b 8, B 25; 1080 b 6; b 14, B 9; 1083 b 8, B 10; 1090 a 20.

things generated? This is where the arguments start. Clearly these questions were not answered identically by all Pythagoreans at all dates. Raven and Cornford (among others) both postulate successive stages in the development of their cosmogony, but disagree about the content of these stages.

Raven thinks that before Parmenides the theory began with two principles, Limit (equated with Unity, the One) and the Unlimited. (Limit may have been regarded as light and hot, the Unlimited as dark and cold). Unity/Limit injects the 'first unit having magnitude' like a seed into the womb of the Unlimited. The precise method of constitution of this first unit is left unclear. The simile given is a guess of Aristotle in Met. 1091 a 12sq., 58 B 26, (cf. 1092 a 32). The first unit now 'breathes in' the surrounding Unlimited, which is breath or void, so as to give a line and the number 2 (for the line is two points having magnitude separated by an interval of void).

The remainder of the number series is now generated by the breathing-in process. Numbers are thus a discrete congeries of points having magnitude (ἄτομα μεγέθη), separated by void. Geometrical solids are next generated by this process, for the number 1 is the point, 2 the line, 3 the triangle (minimum plane), and 4 the tetrahedron (minimum solid). Thus solids too are discrete congeries of points. From them come sensible (concrete) bodies. Qualitative differences in these depend upon the varying proportions of Limit and the Unlimited in them, the proportions forming the λόγος μίξεως. *

Cornford's interpretation had minor differences from Raven's. He claimed that the starting point was a divine monad (it was a religious theory too), different from the first unit of number, but sometimes synonymous with Limit. Limit and the Unlimited were secondary, derivative, principles, acting as the 'elements of numbers'; for the first numerical unit was a compound of both. Its constitution may have combined two of Aristotle's guesses (loc. cit.): four points in pyramid (tetrahedron) formation may have formed a seed from which the universe grew - by the breathing-in process. This seed may have been fiery in nature, contrasting with aer and void, which were equated or at least confused, and were dark. Solids and

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* At this early time, according to Raven, the Greeks did not recognise the existence of abstracts, and so Justice etc. were concrete and consisted of number just like everything else. References to 'imitation' are errors of Aristotle, who was misled by Platonism.

sensible bodies were generated as above. Qualitative differences were, perhaps, caused by condensation and rarefaction. *

Raven holds that there was no radically new theory between Parmenides and Zeno, only an emendation: the identity of Unity and Limit was abandoned for, if Limit were the One (Parmenides' only real existent), the Unlimited would be non-existent. There was now a dualism with the unit considered as a compound of both principles (as Cornford claimed it always had been). The rest of the theory remained unaltered, but destructive arguments were raised against Parmenides, including the following: if the One of Parmenides is limited (viz. spherical), void can exist beyond that limit, and the existence of extra-cosmic void permits the breathing-in theory to stand unaltered.

Cornford's view was very different. The Pythagoreans, because of Parmenides' objections to the void and to the old accounts of generation, abandoned the generation of number from the first unit and of the Universe from the fiery pyramidal seed, gave up also the confusion of

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* Abstracts, in Cornford's view, have resemblances with the properties of numbers so that Aristotle's references to imitation referred to abstracts not concretes.

void with aer, and consequently renounced the breathing-in theory, and probably the void itself.

The system, says Cornford, was completely recast into a type of 'number-atomism' that failed as yet to take into account the distinction between the infinite divisibility of geometrical magnitudes and the indivisibility of the ultimate units of which solids consist. Each concrete body consisted of a plurality of unit-points (ἄτομα μεγέθη), which themselves composed an ultimate plurality of entities having all the reality claimed for Parmenides' One. Any body could so consist of unit-points since lines were rows of discrete points, planes of juxtaposed point-containing lines, and solids of juxtaposed planes.

For Raven the radical alteration in theory came after Zeno. His arguments about continuity and divisibility had showed that matter must be considered either continuous and infinitely divisible, like geometrical magnitude, so that the unit could no longer be thought to have magnitude or extension, or discrete and ultimately indivisible, so that it could not be equated with geometrical magnitude. The unit is still derived from the two principles, and its method of generation is still not clearly stated. The generation of number is still by breathing-in, but it is now interval that is inhaled, no longer aer because of Empedocles, so that the line is length without breadth between two limiting points without magnitude. Its matter is empty space and its essential nature comes from the number of points that bound it. *

Sensible bodies differ from geometrical solids only in being less regular: they therefore also have continuous infinitely divisible space for matter, with the number of points that bound their lines and surfaces determining their essence. These points (ὅροι, termini) mark out the external form of an object, so that their number determines the 'number of the thing' in the manner ascribed to Eurytus in D. 45, 2 and 3.

Qualitative differences are now (after Philolaus?) explained by equating the four Empedoclean elements, fire air water and earth, with the tetrahedron octahedron eicosahedron and cube respectively, and making the λόγος μίξεως describe the interrelations between numbers associated with these regular figures.

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* In the fourth century the line-triangle-pyramid method of generation gave way to the fluxion method, viz. line-square-cube, for it was more consistent with continuity since it still derived numbers from the unit, but no longer implied that a line is an aggregate of discrete units, and so escaped Zeno's criticism.

Again Cornford's view was very different. This was an age of clarification rather than innovation. Arithmetic (dealing with the discrete) and geometry (with the continuous) were separated because of Zeno. The unit was still an ungenerated ἄτομον μέγεθος - that is why Aristotle can find no clear exposition of its generation in mature Pythagoreanism. There was an ultimate plurality of these basic units. The generation of mathematical objects was eventually realised to be a logical not a temporal process, and geometrical solids to differ radically from sensible concretes: the former were continuous and infinitely divisible, but the latter probably consisted of ἄτομα μεγέθη composing the four regular figures, equated with the four 'elements' as above. The use of ὅροι by Eurytus was different from what Raven says: they were not 'termini' but 'terms' in the sense in which alphas were set out as the terms of patterned numbers (v. p. 91), so that the 'number of the thing' was the total number of 'point-atoms' in the thing. The λόγος μίξεως, the interrelation between the regular solid figures, was as described in Chap. 10 inf..

Cherniss differs from both Raven and Cornford. They both base a considerable amount of their interpretations on the words of Aristotle; but Cherniss, as usual, rejects much of his testimony as either confused, or special pleading. He speaks of an attempt by Aristotle to belittle Plato by making much of Platonism merely plagiarized Pythagoreanism, an attempt that involves his reading Platonic ideas into Pythagorean theory.

Cherniss believes (Op. cit. pp. 387sqq.) that though there may have been individual differences in detail among the members of the school or at different times the basic system remained in much the same form at least until the late 5th. Century. This system can be summed up in the theses: 'things are numbers' or 'bodies consist of points'. Aristotle's account, which brings in the ideas of 'elements of numbers' and of 'imitation', is self-contradictory.

'Things are numbers' is incompatible with the last two ideas. If numbers, which are things, consist of a group of units, i.e. points having position, neither numbers nor things can be derived from higher principles, and the thesis 'the elements of numbers are the elements of things' is meaningless. Aristotle's attempt to reconcile these two theses depends upon his finding a theory of the derivation of the numerical unit, and in one place he admits that he cannot. His guesses in Met. 1091 a 12 are just that, guesses; and the 'seed' that Raven and Cornford accept Cherniss believes Aristotle to have borrowed from Speusippus. *

Cherniss believes the breathing-in theory to apply to concretes but not to numbers, so that Aristotle will have confused the cosmogony with the number theory. The numerical unit is not a generative principle; it is the 'principle' of number simply because all numbers are groups of units. The thesis that all apparent continuity is an aggregate of points was the butt of Zeno's attack, which proves that his opponents made sensible bodies consist of aggregates of material points (as Cornford also argued). This thesis was held at least as late as Eurytus, whereas in the fourth century the fluxion theory replaced it.

Cherniss is not certain that number is identified with fire and limit as opposed to darkness and the unlimited, and denies that numbers are derived from higher elements. His own conclusion is that the thesis about the 'elements of numbers' is Aristotle's own recasting

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* Raven admits the derivation of the unit throughout, though its constitution was left unclear. Cornford admitted it for the early period, but would have agreed with Cherniss for the 'mature' period.

of the original thesis, caused by his inability to understand how anyone could have seriously maintained the notion of material number, and by his tendency to Platonize Pythagoreanism. *

Cherniss, then, differs greatly from Raven, and also from Cornford about the early period, postulating for the entire period a kind of number-atomism like that of Cornford's later periods; he also differs from both in rejecting the parallelism between number generation and cosmogony that they accept. I accept it also, but am for my purposes most interested in the cosmogony. But before I

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* Cherniss says that Aristotle was taught by Speusippus, who was familiar with the work of Philolaus, and that he may have been influenced by Speusippus in the recasting, which shows some similarity with the system of the latter.

With reference to 'imitation', Cherniss believes it to be an attempt to belittle Plato by showing that he used a Pythagorean tenet: Aristotle may here have been influenced by his pupil Aristoxenus, who was antagonistic to Plato, and claimed first-hand knowledge of the Pythagoreans; but it is also possible that Aristoxenus' Pythagorean teacher Xenophilus may have introduced 'imitation' into contemporary Pythagoreanism under Plato's influence.

Cherniss claims elsewhere in his book that all the opinions following are either guesses, deductions, Platonizings, or recastings by Aristotle: the substantial nature of the Unlimited and of Unity, the equation of the Unlimited with void and of Limit with Unity, and the idea that the Pythagoreans had conceptual numbers as well as physical numbers (materialised points).

proceed to this I must indicate my position with respect to the system as a whole.

I agree with Raven and Cherniss in rejecting Cornford's divine Monad prior to the two principles, and the idea that the latter are the 'elements of numbers'. As Raven admits, the rest of what Cornford says about the early stage is hard to disagree with, and I accept the common ground of Raven and Cornford. While I agree with Cherniss that theories about the constitution of the first unit are based on guesses of Aristotle, I am prepared to accept that the 'seed' is a good guess; but I am as wary as Raven of Cornford's further guess that the seed was a fiery pyramid (v. inf., p. 93). *

I cannot agree with Raven that all that was needed after Parmenides was to abandon the equation of Unity and Limit. ** Raven may be right that something can exist

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* Cornford's attempt to divide the universe into concretes and abstracts and to say that the former 'are' numbers and the latter 'resemble' the properties of numbers has a specious plausibility; but I believe Raven to be closer to the truth, whether or not Cherniss' suggestion about the influence of Aristoxenus be sound.

** Especially in view of Cherniss' opinion that this equation was Aristotle's invention, and Cornford's opinion that the One was only 'sometimes' synonymous with Limit.

outside a spherical universe, viz. his extra-cosmic void, but I must agree with Cornford that Parmenides had dealt a death blow to the equation of void and aer and to the literal interpretation of the breathing-in theory in cosmogony. Consequently I must align my conception of the second stage with Cornford's ultimate plurality of units and Cherniss' materialised points rather than with the almost unchanged system of Raven.

Moreover Raven's third stage seems to err in the direction of Platonism (cf. the 'Receptacle' of the Timaeus and Raven's use of interval) and even to be tainted with Aristotle's 'informed matter'. I believe that Raven has fallen into the trap sprung by Cherniss of failing to spot some of Aristotle's axe-grinding. Discussion of this must, however, be postponed to Chap. 10.

In this chapter I now wish to review only the purely physical side of Pythagoreanism before Parmenides (q.v. in Chap. 6). Here one would expect to find ideas not greatly dissimilar to, or less primitive than, those current in contemporary Ionia, ideas about as far advanced from those of the Milesians as are those of Heracleitus.

By concentrating on number as the clue to the world the Pythagoreans tended to deal with the formal rather than the material; so much so that, as Cherniss rightly says, Aristotle is misled into importing his own formal cause into their theory so as to vitiate some of his interpretation. There is, however, at least in the case of the mature theory, some truth in Met. 1028 b 16:

> It seems to some that the limits of body, e.g. surface and line and point and monad, are substances, and more so than body and the solid.

Some scholars believe that Aristotle is correct when he says (in Met. 1078 b 21) that at first they only reduced the definitions of a few things, like opportunity, justice, and marriage, to numbers. I shall proceed, however, on the premiss that the thesis 'all things are numbers', if not due to the master himself, is at any rate very early; Xenophanes specifically states his disagreement with certain parts of the physical theory connected with it (v. inf.).

The Pythagoreans will have been aided in working out this thesis by the existence of a primitive way of expressing numbers, not by the Classical use of letters of the alphabet as numerical symbols, but by the use of a more pictorial method, akin to the abacus that is still used in China, namely that of setting out the relevant number of alphas side by side or of placing pebbles on the ground in similar fashion. * From this developed the idea of patterned numbers: 1 is represented by one alpha, pebble, dot, or imaginary point in the mind's eye, 2 by two in a line, 3 by three in a triangle, 4 by either four in a square or four (imaginary points) in a pyramid (tetrahedron); higher numbers could similarly be represented by triangles, squares, oblongs, or cubes.

The method may be summed up as the use of dots (ὅροι: lit. 'boundary-stones') marking out a field (χώρα). This procedure led to the method discussed on p. 84 by which Eurytus determined the 'number of a thing'.

It will be easily seen how familiarity with this pictorial representation of figured numbers could suggest the theory of generation of number described on pp. 79sq., a generation that is, pace Cherniss, parallel to and part of the generation of the physical universe.

It was a great step forward in the history of science when to the study of matter there was added the study of structure and a connexion with number that could lead to the idea of quantitative analysis. Modern science

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* Cf. Nicomachus, Arithm. 82sq., and Iamblichus, in Nicom. 57. From the Latin for 'pebble', of course, we derive the English word 'calculation'.

with its non-material subatomic entities, its quantum theory and wave-mechanics, and its probability theory, may be said now to concentrate rather on these aspects than on the grossly material, and we have to thank the Pythagoreans for being, after Thales, second 'Fathers of Science' in that they took the first steps along this path.

The Pythagoreans, however, confused number, which is really an aspect of form or structure, with body itself so that in their cosmogony number is that out of which things are made, that of which they actually consist. The Universe, like number itself, starts from the 'first unit having magnitude'. Aristotle discusses this at Met. 1091 a 12, D. 58 B 26:

> It is strange to postulate a generation of eternal entities - nay more, it is impossible. However there can be no dispute whether or not the Pythagoreans do postulate one; for they openly say that when the Unit had been constructed - whether out of planes or surface or seed or out of something that they are at a loss to name - the nearest parts of the apeiron immediately began to be drawn in and limited by the Limit. But since they are dealing with cosmogony and wish to speak physically, it is right to consider them under physics, not metaphysics as here.

Aristotle repeats the guess about seed at Met. 1092 a 32, expressing his own objection to such a theory thus:

> But nothing can come from that which is indivisible.

As I said on p. 88, I am prepared to accept this guess about seed, for it is characteristic of Pythagoreanism as of all early Greek thought including that of Anaximenes (v. pp. 48 and 50 sup.) to regard the universe as a living, breathing, creature, and the seed is the start of life. A passage of Hippolytus (Ref. I 2, 6) shows how the seed probably fitted into the Pythagorean theory:

> The beginning of numbers is the first unit, which is male and like a father begets all the other numbers; while the number 2 is female, also called the Even.

Note that it was a common Greek belief that the father alone generated the offspring: the mother merely provided 'living-room'.

I cannot accept the additional guess of Cornford (Op. cit. p. 19): "This view could be combined with the previous suggestion (sc. planes or surface). The four units composing the pyramid might be regarded as 'seed'; if the living world is to grow from this first body into all three dimensions". This is an unnecessary complication, and it spoils the analogy between the generation of number, which definitely proceeds from a single point, and that of the universe - the method of generation is the same in both cases, so that we should expect the points of origin to be analogous also.

The method of generation is in each case the so-called 'breathing-in', which Aristotle describes in Phys. 213 b 22, D. 58 B 30: *

> εἶναι δ' ἔφασαν καὶ οἱ Πυθαγόρειοι κενόν, καὶ ἐπεισιέναι αὐτῷ τῷ οὐρανῷ ἐκ τοῦ ἀπείρου πνεῦμά τε ὡς ἀναπνέοντι καὶ τὸ κενόν, ὃ διορίζει τὰς φύσεις, ὡς ὄντος τοῦ κενοῦ χωρισμοῦ τινος τῶν ἐφεξῆς καὶ διορίσεως· καὶ τοῦτ' εἶναι πρῶτον ἐν τοῖς ἀριθμοῖς· τὸ γὰρ κενὸν διορίζειν τὴν φύσιν αὐτῶν.

Stobaeus (Ecl. I 18, 1, D. 58 B 30) quotes this passage and immediately afterwards refers to Aristotle's Frag. 201:

> ἐν δὲ τῷ Περὶ τῆς Πυθαγόρου φιλοσοφίας πρώτῳ γράφει τὸν μὲν οὐρανὸν εἶναι ἕνα, ἐπεισάγεσθαι δὲ ἐκ τοῦ ἀπείρου χρόνον τε καὶ πνοὴν καὶ τὸ κενόν, ὃ διορίζει ἑκάστων τὰς χώρας ἀεί.

Compare also this passage of Aëtius (II 9, 1): **

> οἱ μὲν ἀπὸ Πυθαγόρου ἐκτὸς εἶναι τοῦ κόσμου τὸ κενόν, εἰς ὃ ἀναπνεῖ ὁ κόσμος καὶ ἐξ οὗ.

It is in connexion with this notion of the existence of a boundless breath outside the universe that the

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* The readings adopted by Diels and Ross differ, but the difference, though great, does not affect the theory described.

** Cf. also Met. 1091 a 12, p. 92 sup., and Phys. 203 a 6, D. 58 B 28, which applies the process to number.

disagreement of Xenophanes (see p. 90) is relevant. *
He would not accept an external store of matter that could be breathed in by the universe, but to the Pythagoreans the universe was a living creature and so could breathe and grow like any other living creature (see p. 93).

In the sphere of arithmetic, then, numbers are a congeries of units, akin to limit, that are held apart by the unlimited, which is 'drawn in' from outside; this is one aspect of the unlimited: another aspect of it is that substance which the universe breathes in in the sphere of cosmogony and physics. This is given various names (time, breath, the void), and it plays the part of the Milesian unlimited external store. But just what is it?

To Cornford (Op cit. p. 18) it 'unmistakably corresponds to the boundless Air of Anaximenes, that breath

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* Ps. Plut. (Strom. 4, D. 21 A 32) and Hipp. (Ref. I 14, 21 A 33) both state that Xenophanes' earth is not surrounded by aer, which contradicts the external store that the theories of the Milesians and Pythagoreans shared. D.L. (ix 19, 21 A 1), referring to Xenophanes' God, though I shall show in Sec. ii of this chapter that in fact the passage deals with the universe, says μὴ μέντοι ἀναπνεῖν (using the same word for 'breathing' as in the passages on p. 94), which contradicts the Milesian and Pythagorean theories of a living, breathing, universe. While these sources are, as will be seen in Sec. ii, confused, I nevertheless feel that they do represent the thought of Xenophanes on these points, if not his actual words.

or air which encompasses the whole cosmos and is compared to the human soul, which is also air'. For him the early cosmogony has two primitive factors: "Fire or Light, associated with limit, and the dark Air, identified with unlimited void, the 'Night' of pre-scientific cosmogonies". But whereas Anaximenes' Air is the ultimate substance of all things, the Pythagoreans' is rather 'the empty space not occupied by body but separating bodies and their parts'. Thus Cornford definitely identified aer and void in this context as did Burnet, who identified the unlimited with 'air, night or the void'.

Raven has a different interpretation: air and the void and time (cf. Arist. Frag. 201, p. 94 sup.) * are different manifestations of the unlimited, each distinct in

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* Raven, Op. cit. p. 48, points out that it has been claimed that Phys. 213 b 22 (Diels' reading) and Frag. 201 distinguish between breath and the void (and time in the latter) by joining them with the word καί. Since both passages say that breath and the void are drawn in 'from' the unlimited, it may look as if they are separate things, neither identical with the unlimited but both derived from it. Thus Raven believes that both Cornford and Burnet oversimplified. However, he says, καί can mean 'i.e.', and in any case our authorities know that aer and void are not identical and so would automatically insert καί unless writing with historical precision, so that this objection to the identity of breath and void is not very strong. But the mention of time nevertheless tells against the complete identity of all four concepts.

its own field, but within that field representing, and so virtually identified with, the unlimited. With this I agree as far as the relationship with the unlimited is concerned. Raven would say that the void has its function as that which separates the points in numbers, and aer as the breath of the physical cosmogony. This is a possible interpretation; but I feel that there is more to be said on the subject.

The true corporeal existence of air in the modern sense of the word had not yet been proved by Empedocles, although Anaximenes had guessed at the possibility of an invisible type of aer. I should agree, therefore, with Cornford that we are dealing with something akin to the aer of Anaximenes, but should add that we may be dealing with just the invisible form of it. Since it is invisible it appears to the primitive observer as if there is nothing in its place at all, as Aristotle points out in several contexts:

δοκεῖ γὰρ εἶναι κενὸν ὁ ἀήρ. (de An. 419 b 34.)

τὸ γὰρ κενὸν καλούμενον ἀέρος πλῆρές ἐστι. (de Part. An. 656 b 15.)

οἱ δ' ἄνθρωποι ,.. φασὶν ἐν ᾧ ὅλως μηδέν ἐστι, τοῦτ' εἶναι κενόν, διὸ τὸ πλῆρες ἀέρος κενὸν εἶναι. (Phys. 213 a 27.)

There was in fact during the sixth and early fifth centuries a very real confusion in men's minds about void and emptiness. The Greeks found the notion of totally empty space, of a vacuum, difficult to grasp, and the possibility of the existence of τὸ μὴ ὄν remained a hotly contested point throughout the classical period.

Parmenides was the first to state openly that τὸ κενόν must be τὸ μὴ ὄν (whose reality he was concerned to disprove), and Empedocles was the first to show experimentally that invisible aer is fully corporeal: until that time the common view may perhaps have been that the so-called void was filled with a sort of invisible aer, like that of Anaximenes only not fully corporeal in the sense that the standard misty aer was, nor yet absolutely non-existent in the way that τὸ μὴ ὄν of Parmenides was.

This may perhaps have been what the Pythagoreans meant when they spoke of 'breath and the void'. This semi-real substance may have had about the same degree of reality as had the void of Leucippus, which was consciously adopted as something somehow real in spite of the Parmenidean arguments, and used to keep the atoms apart just as it kept the Pythagorean points apart. Leucippus, of course, would have been aware, as the Pythagoreans would not, of the way in which this semi-reality differed from true reality.

On the other hand, we know that there were differences of opinion within the school, among contemporaries as well as between successors, so that individuals may have inclined, some towards a true void (like Leucippus' in use but fully real) or towards a semi-real void (as above), others towards invisible but fully corporeal aer (like the guess of Anaximenes), and yet others towards darkness (a corporeal substance - aer, in the sense in which the word was used by the pre-scientific speculators and Anaximander), each notion perhaps being opposed to fire or light. The result is, if this be true, that our authorities, who were writing a considerable time later, will have summed up in the phrases that seem to identify breath, void, and the unlimited, the various opinions of a school rather than a single theory.

Whether or not this breath was conceived of in any of the above ways, it cannot at any rate have been meant as the standard misty aer, employed along with fire in a physical dualism of principles in the Milesian sense of the word, a dualism intended to replace the Milesian monism. Aristotle in Phys. 203 a 1sqq. draws a distinction between the Pythagoreans and the physicists that rules out such an interpretation. The Pythagoreans, he says, make the infinite a substance in its own right (present in sensible things and also existing outside the heavens) while the physicists assign to the infinite an underlying nature, that of one of the 'elements', e.g. water or aer.

As with breath and the Unlimited, there may also have been differences of opinion over the physical manifestation of Limit, namely between those who did and those who did not think that it was fiery in nature. Cornford, after describing his pyramidal seed (p. 93 sup.) draws attention to Ross' note on Met. 1091 a 15. Ross illustrates the formation of the universe from the first unit by quoting two fragments of Ps. Philolaus (D. 44 B 7 and 17) and Anatol. p. 30 Heib.:

> ἐοίκασι δὲ κατά γε τοῦτο κατηκολουθηκέναι τοῖς Πυθαγορικοῖς οἵ τε περὶ Ἐμπεδοκλέα καὶ Παρμενίδην καὶ σχεδὸν οἱ πλεῖστοι τῶν πάλαι σοφῶν, φάμενοι τὴν μοναδικὴν φύσιν ἑστίας τρόπον ἐν μέσῳ ἱδρῦσθαι καὶ διὰ τὸ ἰσόρροπον φυλάσσειν τὴν αὐτὴν ἕδραν.

Ross' own interpretation is this: "The One is thought of as being in the centre of a shapeless mass of air or vapour and gradually introducing shape and limit into it, working from within outwards. ... The number One is identified with the central fire, as two was with the earth and seven with the sun".

Cornford, however, after distinguishing between the Philolaic central hearth around which the earth revolves from the central earth of the earlier theory, refers to Hilda Richardson, who claims that early Pythagoreanism 'conceived of fire as existing at the heart of their central, spherical earth'. * She adduces Simplicius' statement that this fire 'endowed the earth with life and heat'. ** She too cites the passage of Anatolius quoted by Ross; a little earlier in the context the μοναδικὴν φύσιν had been called a ἑναδικὸν διάπυρον κύβον. Like Cornford Miss Richardson agrees with Burnet's statement that Pythagoras identified the Limit with fire (E.G.P. p. 109); so she concludes that the cosmogonical first unit with magnitude was this fiery central unit, round which the boundless mist or darkness has 'condensed to form the hard solidity of earth'.

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* Hilda Richardson, in C.Q. XX (1926) p. 119.

** Simpl. de Caelo, 512, 9, D. 58 B 37. Simplicius has just contrasted the theory of a central fire around which revolve the earth and the antichthon with this central earth theory.

Rejecting the cube in favour of his own pyramidal seed, but accepting the rest of her conclusion, Cornford adduces a parallel to his fiery seed and womb theory in a medical theory attributed to Philolaus by Menon, Anon. Londin. 18, 8 31, D. 44 A 27: according to this our bodies, and in particular the seed and the womb, are hot; after birth we draw in breath from outside; this is cold, and so it cools our bodies. This idea Cornford believes to have been older than Philolaus.

Raven agrees that Miss Richardson has made out a good case for the early Pythagoreans' having fire in the middle of a central earth, but like myself he is not persuaded that the first unit was pyramidal, nor that it, in its function as seed, was also fiery. Burnet, on the other hand, believes that the first unit was indeed a point but was also fiery. Cherniss, apart from a very hesitant admission (Op. cit. p. 27 n. 102) that Burnet may be correct in conjecturing the identification of fire with limit, ignores fire altogether in his account of the Pythagorean units.

If, now, we accept my thesis that there may have been differences of opinion on this point within the school there are a number of possible theories that could have been current in it. Some will perhaps have believed simply in unit points having magnitude (some perhaps saying that they were generated from a 'seed' unit and others that they were ungenerated - the theory of Cherniss), points that are held apart by real or semi-real void that has been drawn in from the Unlimited; others in similar points held apart by invisible aer, while some again confused aer and void completely; yet others will perhaps have postulated points that were fiery in nature and held apart by that form of aer that the early Greeks believed darkness to consist of. The latter would then believe that the universe was, in Burnet's words (Op. cit. p. 109): "A field of darkness or breath marked out by luminous units, an imagination the starry heavens would naturally suggest". The last point is a very strong one; but Burnet went on from there to import Parmenides' Way of Opinion into the early Pythagorean system and vice versa, and we must leave him. We may, however, follow Cornford a little further.

He believes that in the difficult Chap. V of the third book of De Caelo Aristotle is referring to the early Pythagoreans when he speaks of those who believe that fire is the sole element and that it has the finest shape.

This finest shape is pyramidal. Cornford quotes Simpl., 621, 6, where that author agrees that Pythagorean fire was pyramidal (which it certainly was for the post-Empedoclean school, v. Chap. 10) but not that it was the sole element. Cornford claims that he can make out a case for fire's being the sole element. It is so because aer is not so much a second element as just the vacancy that keeps the fiery pyramid-atoms apart. Thus 'the pyramid is the minimum solid and the fiery atom' and 'bodies will be aggregates of such atoms'.

He adds that water or earth could consist of such atoms packed more closely with less void between them, i.e. by a condensation like that of Anaximenes. He supports this interpretation by reminding us that Theophrastus attributed rarefaction and condensation to Hippasus and (wrongly) to Heracleitus (a pair of names mentioned by Simplicius shortly before the passage referred to above). Simplicius quotes this attribution: *

> Ἵππασος δὲ ... καὶ Ἡράκλειτος ... πῦρ ἐποίησαν τὴν ἀρχήν, καὶ ἐκ πυρὸς ποιοῦσι τὰ ὄντα πυκνώσει καὶ μανώσει ...

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* Phys. 23, 33, D. 22 A 5. Similar statements occur in Aët. I 3, 11, ibid. and I 5, 5, 18 A 7, and Arist. Met. 984 a 7, ibid. For the attribution to Heracleitus v. pp. 133, 149 and 158 inf..

Now with the exception of the pyramidal shape, which I reject for this stage of Pythagoreanism (but which by confusion with the later stage could have been interpolated, perhaps by Aristotle, so that the de Caelo passage could still be relevant), this is a tempting thesis; but my own feeling is that, although it may well have been the theory of Hippasus, so that Burnet would be thus far correct, Hippasus is notorious for his divergences from standard Pythagorean thought, and it is unsafe to attribute this theory to the whole early school. If we do accept that the school admitted differences of opinion, then let us say that Hippasus and his followers may have believed in fiery points and darkness/void and in qualitative differences caused by the density of the packing together of the points.

If, however, my contention that there were differences of opinion is not acceptable, and I must postulate just one theory for the whole early school, or if, granted the differences, I am asked what I believe to have been the theory most firmly or commonly held in the school, then I prefer with Raven to avoid too much emphasis on fire, and to consider the standard theory to have been that of a universe of unit points like the original seed unit separated by 'breath' (in the sense discussed on p. 98 sup.) - the position being analogous to that of modern atomism of a few decades ago when 'billiard-ball atoms' floated in that elusive thing, the 'ether'; the latter, always vague in conception, has now had to be abandoned, as had the ancient 'breathing-in' theory. Thus I agree with Cherniss' description of the universe, but not with his refusal to allow generation of the number series and of geometrical magnitude to be parallel to physical generation. I believe the seed theory because I believe that the universe was conceived of as a living creature.

The details of the universe thus generated, in other words the astronomy, so often a good source of information about the behaviour of aer, will not in this case be of much help (but cf. the theories of Alcmaeon, discussed shortly), for the school concentrated mainly on the application of its theory of harmony to positional astronomy rather than on astrophysics. In sublunary physics there is as yet no serious attempt to explain what we call 'chemical reactions and combinations'.

Raven would have qualitative differences explained by a λόγος μίξεως that dealt with the proportions of Limit and the Unlimited in different bodies. Cornford, as we saw, believed in condensation and rarefaction. Aristotle, who frequently points out that the school was not primarily concerned with things like fire aer water and earth, discusses the λόγος μίξεως in a long passage (Met. 1092 b 16sq.) that is inconclusive, but at least suggests that the formula concerns the proportionate amounts in the 'mixture' and is a ratio of numbers 'whether corporeal or of any other sort'. All that we can safely say is that qualitative differences were probably explained by a ratio whose nature has not been handed down to us or even, clearly, to Aristotle, and not by the degree of condensation, except possibly by Hippasus.

This is as far as we can follow the normal early Pythagorean tradition. There exists, however, in D.L. viii 24-33, D. 58 B 1a, a summary of Pythagoreanism extracted from Alexander Polyhistor, whose source was probably a contemporary of Plato. Although much of the theory in this extract is from later Pythagoreanism (v. Chap. 10) there do remain in it some early elements. It also exemplifies the microcosm-macrocosm analogy that is so important for the school. I quote here Cornford's translation of parts of Sections 26-28:

> The air (αἰθήρ) about the earth is stagnant and unwholesome, and everything in it is mortal; but the

> uppermost air is always in motion, pure and healthy, and everything in it is immortal and so divine. Sun, moon, and stars are gods; for in them preponderates the Hot, which is the cause of life. ... A ray from the sun penetrates through the 'cold aether' (as they call the air) and the 'dense aether' (as they call the sea and moisture). This ray descends even to the depths and thereby quickens all things. All things live, which partake of the Hot - that is why plants also are living creatures - but not all have soul. Soul is a detached part of both the hot and the cold aether, for it partakes of the cold aether also. Soul is distinct from life, and it is immortal because that from which it is detached is immortal.

Alexander appears to say that there were three strata of the 'aether', the hot, the region of the stars, the cold, the region of stagnant air, and the dense, the region of the sea. I suspect confusion here: these strata read suspiciously like Anaximenes, and the stars and that in which they move appear to consist of the same substance. I believe that the 'hot aether' should be fire, and the 'cold and dense aether' not the air and the sea, but the age-old pair, clearly referred to in the first sentence, the clear upper air and the misty lower air. The dense may, as mist, be moisture, but not sea, which I believe to be referred to only by the word 'depths'.

The sun will thus be 'hot aether' in a region of pure 'cold aether' that is above the stagnant 'dense aether' about the earth. The opposition between 'hot and cold aether' will be that between fire and pure air: the pair form the two material principles in so far as any materiate things can be called 'principles', so that they will naturally both be present in soul if the latter is corporeal (whereas Alexander's interpretation makes the soul consist of air, the unlimited, alone). We see no trace of the theory that the soul is a 'harmony' (cf. Plato, Phaedo): it may well be that an earlier theory is preserved here. The soul as air (if we follow Alexander) or as fire and air accords well with the 'breathing-in' theory and with early thought (cf. the Orphics and Anaximenes).

This is as far as Pythagorean number-cosmogony can take us for the moment. To sum up, there is not any very precise early cosmology or meteorology, but what ideas we can trace are not radically dissimilar to those of the Milesians, however different the cosmogony and 'elements' of the two schools. Pythagorean ideas about aer were confused - less clear-cut than those of Anaximenes; but in general we may say that they still dealt with the same type of thing, a substance that might be invisible, or visible as mist or even as darkness, but whose reality still awaited confirmation. Aer was still connected with life, not only as the breath of the universe and its creatures, but also as a constituent of soul. However the concept of 'void' had now nudged the mind and would have to be firmly dealt with by Parmenides - it was now explicit, and not merely implicit as with the Milesians who did not see that their theories implied it.

For me the importance of early Pythagoreanism lies not so much in its notions about the physical properties of aer as in its new viewpoint, the form or structure (pp. 91-2). Difficult to grasp as the thesis 'all things are numbers' may be, a new vista was yet opened up by this attempt to derive the properties of (e.g.) aer not just from the fact that it is aer and that it is its nature to appear and behave as it does, but rather from some other concept than matter per se; and in choosing for that concept number, above all number conceived of as pattern, the school contributed most valuably to the progress of science.

There was at least some resemblance between Pythagoreanism and Greek atomism. Now structure alone is not as fruitful a line of enquiry as structure studied quantitatively, and atomism was not, as was Pythagoreanism, concerned with the latter. Consequently the modern lay acclaim for Greek atomism as the pioneer of, as even a genuine anticipation of, our atomism is ill-informed. The modern theory was only accepted when it abandoned the manner of Democritus and used a more Pythagorean approach - when numerical and quantitative researches were made and structural hypotheses based on them succeeded in explaining the outcome of experiments and in predicting the quantitative results obtained from them.

We now leave the cosmogony and turn to a member of the school who was younger than Pythagoras but older than Parmenides: Alcmaeon of Croton. He was responsible for the fact that while the Milesians had showed some small interest in the soul Greek philosophy henceforward showed great interest in psychology and physiology.

Alcmaeon's theories are recognisably Pythagorean; yet in Met. 986 a 22 (D. 24 A 3) Aristotle, apparently not recognising him as one of the school, questions whether he learned the Table of the Opposites from it or it from him. He believed that human affairs go by opposites, but, says Aristotle, did not believe in the particular primary opposites postulated by the orthodox. At any rate he did believe in a dualism of a sort.

In astronomy he adopted from the genuine Pythagoreans suggestions about planetary motions that are well ahead of the Ionians', for they replace the single motion of a flat vortex by compound motions that imply a spherical heaven, cf. Aët. II 16, 2, D. 24 A 4:

> (τῶν μαθηματικῶν τινες) τοὺς πλανήτας τοῖς ἀπλανέσιν ἀπὸ δυσμῶν ἐπ' ἀνατολὰς ἀντιφέρεσθαι. τούτῳ δὲ συνομολογεῖ καὶ Ἀλκμαίων.

Aëtius tells us in II 22, 4 (D. ibid.) that he had a flat sun, like Anaximenes'; but in II 29, 3 (ibid.) that like Antiphon (D. 87) he adopted Heracleitus' 'bowls' theory of lunar eclipses (v. p. 171). This is typically Pythagorean (cf. the dissident Parmenides) - the main interest is not in matter but in concepts of a different nature (e.g. 'being' or structure), and while positional astronomy is a matter for original research, the composition of the stars and planets is of less importance, so that Ionian notions, when not in direct conflict with basic theory, are more or less uncritically taken over.

There is, however, one important point, which is brought out by Aristotle in de An. 405 a 29 (D. 24 a 12; cf. the supporting references given there):

> ... καὶ Ἀλκμαίων ἔοικεν ὑπολαβεῖν περὶ ψυχῆς· φησὶ γὰρ αὐτὴν ἀθάνατον εἶναι διὰ τὸ ἐοικέναι τοῖς ἀθανάτοις· τοῦτο δ' ὑπάρχειν αὐτῇ ὡς ἀεὶ κινουμένῃ· κινεῖσθαι γὰρ καὶ τὰ θεῖα πάντα συνεχῶς ἀεί, σελήνην, ἥλιον, τοὺς ἀστέρας καὶ τὸν οὐρανὸν ὅλον.

The same point is made by Diogenes Laertius in viii 83, A 1:

> ἔφη δὲ καὶ τὴν ψυχὴν ἀθάνατον, καὶ κινεῖσθαι αὐτὴν συνεχὲς ὡς τὸν ἥλιον.

This insistence by Alcmaeon that eternal motion implies immortality so that both soul and stars are immortal and therefore divine or akin to the divine became standard in Pythagoreanism, cf. the Alexander Polyhistor extract on p. 108. The word 'divine' is meant more literally here than by the Ionians (v. pp. 68sq. and 311). This idea was adopted by Plato, cf. Phaedrus 245 C:

> ψυχὴ πᾶσα ἀθάνατος. τὸ γὰρ ἀεικίνητον ἀθάνατον...

(Cf. also Timaeus 40 B concerning the stars' divinity.) From Plato the idea passed on to Aristotle, cf. de Caelo 286 a 10: only, however, as regards the stars - the soul is not in eternal motion.

Alcmaeon's greatest work, which had much influence on his successors, was in psychology and physiology, with particular reference to sensation. He believed the brain to be the common sensorium and that 'pores' led sensations to it. Hippocrates and Plato followed him in choosing the brain, but Empedocles, Aristotle, and the Stoics substituted the heart, a more primitive notion. I translate the account of Theophrastus, de Sensu 25sq., D. 24 A 5.

> We hear, he says, with the ears, because there is void in them; for this is resonant - the source produces sound in the cavity (sc. of the outer ear) and the aer (sc. of the inner ear) resonates to this. We smell with the nostrils, leading the breath to the brain with the inhalation. ... That the eye has fire is clear, for on being struck it flashes. But we see with the gleaming and diaphanous substance (sc. water) when it reflects, and the purer the substance the better the sight. All the senses are in some way linked to the brain; so if it is disturbed and shifts they are maimed, for this affects the pores through which they reach the brain.

This 'pores' theory comes, if we can trust Chalcidius (D. 24 A 10), from dissections performed by Alcmaeon that revealed what we call the optic nerves (the Greeks never identified nerves as such). The details of the vision theory are collected in D. 24 A 10: he combined the idea of a visual ray coming from the fire in the eye (a Pythagorean concept, deduced from the flashing phenomenon) with that of an image coming from the object and reflected in the water in the eye (a concept adopted by e.g. Anaxagoras, deduced from the 'image in the pupil'). Alcmaeon's combination of these two ideas is unconvincing.

The theory of hearing is of great interest; the sound reaches the cavity of the outer ear by the entrance of πνεῦμα (Aët. IV 16, 2, D. 24 A 6), i.e. aer. * This

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* For sensation I am indebted to Beare: Greek Theories of Elementary Cognition. For πνεῦμα meaning aer, above all aer in motion, cf. D. 13 B 2, p. 50 sup. and Hippoc. de Flat. 3, p. 317 inf.

makes the contents of the inner ear resonate: Theophrastus refers to these as aer and as void (Aëtius says void), and this may reflect Pythagorean confusion of the two: in fact this is the context where Aristotle made the comment quoted on p. 97 (de An. 419 b 34): "For the aer seems to be void". He continued: "And it is this that causes hearing when it is moved as one continuous mass". After affirming that external aer is the medium of sound transmission and that the inner ear contains aer he concluded: "That is why they (sc. Alcmaeon and others) say that we hear by the void and resonant, because we hear by that which has aer enclosed in it".

We have now, therefore, added two more properties of aer to the list of those recognised by the Greeks: it is the medium for sound and light, and in enclosed spaces it resonates - both statements are, of course, correct.

Smell is correctly connected with inhaled breath, but apart from the fact that this proceeds to the brain no details are given. This is not surprising: the mechanics of smell are not fully understood today.

The remainder of Alcmaeon's theories are not relevant to aer, and we may temporarily leave the Pythagoreans.

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Section ii.

We must now discuss a man who was, like Pythagoras, a religious thinker, but who was far less a scientist. Xenophanes, of uncertain date, but born if Burnet is right (E.G.P. p. 114) in 565 B.C. in Colophon, was a younger contemporary of Pythagoras, and belonged to the generation before Heracleitus.

His main concern was to discredit the traditional religion and its anthropomorphic gods, and to substitute a religion that should pay more attention to ethics than to divine love affairs. He had a certain interest in science, however, and produced a few good ideas; but he had not the ability (or, indeed, the concentrated interest) to weld them into a consistent system. As Miss K. Freeman wrote * Xenophanes "was a Poet and threw out fruitful ideas which he did not always trouble to work out in detail or support with cogent intellectual argument".

Unfortunately, the 'One God' of Xenophanes (D. 21 B 23) εἷς θεός, ἔν τε θεοῖσι καὶ ἀνθρώποισι μέγιστος,

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* Here and later I refer to her Companion to the Pre-Socratic Philosophers, pp. 88sq..

οὔτι δέμας θνητοῖσιν ὁμοίιος οὐδὲ νόημα.

is described in terms similar to those used by Parmenides (D. 28 B 8) so that he has been wrongly regarded as the founder of the Eleatic school. Commentators then read into his work typical Eleatic ideas that he did not in fact hold, in my opinion, and built up for him a hopelessly self-contradictory system. Most at fault was the ps.-Aristotle de M.X.G.; but Aristotle himself contributed to the confusion, and the whole doxographical tradition must be handled with care.

One source of trouble is the passage Arist. Met. 986 b 21, D. 21 A 30:

> Ξενοφάνης δὲ πρῶτος τούτων ἑνίσας (ὁ γὰρ Παρμενίδης τούτου λέγεται γενέσθαι μαθητής) οὐδὲν διεσαφήνισεν, οὐδὲ τῆς φύσεως τούτων οὐδετέρας ἔοικε θιγεῖν, ἀλλ' εἰς τὸν ὅλον οὐρανὸν ἀποβλέψας τὸ ἓν εἶναί φησι τὸν θεόν.

Zeller and Burnet think that the unclear point was whether the universe is finite or not: I, with Ross and Cherniss, think that it was the nature of his cause. The trouble, however, lies in the last clause. Burnet, Bailey, and others, like Cicero (D. 21 A 34), interpret it that with a view to the whole universe he said that the one was god. Burnet's interpretation culminates in regarding Xenophanes as if he were an inefficient monist who maintained that God was identical with a spherical finite universe containing an infinite earth and an infinite air! "That comes of trying to find science in satire" says Burnet. We shall return later to the shape and size of the universe: for the moment I am only concerned with its relation to God.

Ross and Cherniss also translate in the way I have indicated, and both take οὐρανόν in the third sense of the word given by Aristotle in de Caelo 278 b 9sq., to which Ross refers, viz. the whole universe. Cherniss, however, points out (Op. cit. p. 220) that it is Aristotle's decision that Xenophanes made this identification for this reason. Cherniss also (p. 201) says: "The fragments give no reason to suppose that he identified God with the world; and it is likely that the notion of a 'spherical' god was inferred for him" on the Eleatic analogy. With this I fully agree.

For me, then, Freeman makes more sense of Xenophanes by an interpretation that could give Aristotle's words a different meaning. If we take οὐρανόν in either of the first two senses of the de Caelo passage, the outer heaven or the region of the planets, sun and moon, i.e. the sense of 'heavens' in Psalm 8 (a somewhat similar passage) - "When I consider thy heavens, the work of thy fingers, the moon and the stars" - we may perhaps say that Xenophanes, impressed by the sight of the sky, decided that there was a (single) god - not no god at all as the rationalists thought. We may say with Freeman that his work fell into two halves, unconnected except by this emotion, namely theology and science. Passages that speak of a spherical or finite God confuse the two halves because of fancied Eleatic parallels.

It is by this suggested separation of Xenophanes' thought into two independent sections that we rescue him from contradictions between monism and dualism and between a motionless god (Frag. 26) and a universe that is god and yet has motion, contradictions that reduced the traditional account to babblings worthy of an idiot. His religion contrasted with both Milesian and Homeric ideas, and was (pace Burnet) of an ethical character. He wanted to be a monotheist but could not achieve the conception of a purely transcendent god: his religious feelings did not however close his mind to science. No metaphysician, he could not bind all his ideas into a coherent system; but we should do him the honour of regarding the individual parts of his theory as worthy of serious consideration. Some, at least, of his physical ideas were important.

First I quote the physical fragments, and then the relevant portions of the doxographical tradition.

27. ἐκ γαίης γὰρ πάντα καὶ εἰς γῆν πάντα τελευτᾷ.

28. γαίης μὲν τόδε πεῖρας ἄνω παρὰ ποσσὶν ὁρᾶται
ἠέρι προσπλάζον, τὸ κάτω δ' ἐς ἄπειρον ἱκνεῖται.

29. γῆ καὶ ὕδωρ πάντ' ἐσθ' ὅσα γίνοντ(αι) ἠδὲ φύονται.

30. πηγὴ δ' ἐστὶ θάλασσ(α) ὕδατος, πηγὴ δ' ἀνέμοιο·
οὔτε γὰρ ἐν νέφεσιν <γίνοιτό κε ἶς ἀνέμοιο
ἐκπνείοντος> ἔσωθεν ἄνευ πόντου μεγάλοιο
οὔτε ῥοαὶ ποταμῶν οὔτ' αἰ<θέρος> ὄμβριον ὕδωρ,
ἀλλὰ μέγας πόντος γενέτωρ νεφέων ἀνέμων τε
καὶ ποταμῶν.

31. ἠέλιός θ' ὑπεριέμενος γαῖάν τ' ἐπιθάλπων.

32. ἥν τ' Ἶριν καλέουσι, νέφος καὶ τοῦτο πέφυκε,
πορφύρεον καὶ φοινίκεον καὶ χλωρὸν ἰδέσθαι.

33. πάντες γὰρ γαίης τε καὶ ὕδατος ἐκγενόμεσθα.

Ξενοφάνης ἐκ νεφῶν πεπυρωμένων εἶναι τὸν ἥλιον. Θεόφραστος ἐν τοῖς Φυσικοῖς γέγραφεν ἐκ πυριδίων μὲν τῶν συναθροιζομένων ἐκ τῆς ὑγρας ἀναθυμιάσεως, συναθροιζόντων δὲ τὸν ἥλιον.

Aët. II 20, 3, D. 21 A 40.

φησὶ δὲ καὶ τὸν ἥλιον ἐκ μικρῶν καὶ πλειόνων πυριδίων ἀθροίζεσθαι. ... ἀποφαίνεται δὲ καὶ τὴν γῆν ἄπειρον εἶναι καὶ μὴ κατὰ πᾶν μέρος περιέχεσθαι ὑπὸ ἀέρος· γίνεσθαι δὲ ἅπαντα ἐκ γῆς· τὸν δὲ ἥλιόν φησι καὶ τὰ ἄστρα ἐκ τῶν νεφῶν γίνεσθαι.

Ps.Plut. Strom. 4, D. 21 A 32.

τὸν δὲ ἥλιον ἐκ μικρῶν πυριδίων ἀθροιζομένων γίνεσθαι καθ' ἑκάστην ἡμέραν, τὴν δὲ γῆν ἄπειρον εἶναι καὶ μήτε ὑπ' ἀέρος μήτε ὑπὸ τοῦ οὐρανοῦ περιέχεσθαι. καὶ ἀπείρους ἡλίους εἶναι καὶ σελήνας, τὰ δὲ πάντα εἶναι ἐκ γῆς.

Hipp. Ref. I 14, 3, A 33.

Ξ. ἐκ νεφῶν μὲν πεπυρωμένων (τ.ε. τοὺς ἀστέρας)· σβεννυμένους δὲ καθ' ἑκάστην ἡμέραν ἀναζωπυρεῖν νύκτωρ καθάπερ τοὺς ἄνθρακας.

Aët. II 4, 11, A 37.

Ξ. τοὺς ἐπὶ τῶν πλοίων φαινομένους οἷον ἀστέρας, οὓς καὶ Διοσκούρους καλοῦσί τινες, νεφέλια εἶναι κατὰ τὴν ποιὰν κίνησιν παραλάμποντα.

Aët. II 18, 1, A 39.

Ξ. ἀπὸ τῆς τοῦ ἡλίου θερμότητος ὡς ἀρκτικῆς αἰτίας τἀν τοῖς μεταρσίοις συμβαίνειν. ἀνελκομένου γὰρ ἐκ τῆς θαλάττης τοῦ ὑγροῦ τὸ γλυκὺ διὰ τὴν λεπτομέρειαν διακρινόμενον νέφη τε συνιστάνειν ὁμιχλούμενον καὶ καταστάζειν ὄμβρους ὑπὸ πιλήσεως καὶ διατμίζειν τὰ πνεύματα.

Aët. III 4, 4, A 46.

Ξ. πάντα τὰ τοιαῦτα (τ.ε. κομήτας, διάιττοντας, δοκίδας) νεφῶν πεπυρωμένων συστήματα ἢ κινήματα.

Aët. III 2, 11, A 44.

Ξ. ἀστραπὰς γίνεσθαι λαμπρυνομένων τῶν νεφῶν κατὰ τὴν κίνησιν.

Aët. III 3, 6, A 45.

The statements of D. 21 A 36 that Xenophanes was a monist with earth as his element go back to Frag. 27. Galen points out that this was never said by Theophrastus, and Met. 989 a 5 of Aristotle is relevant:

> οὐθεὶς γοῦν ἠξίωσε τῶν ἓν λεγόντων γῆν εἶναι στοιχεῖον, δηλονότι διὰ τὴν μεγαλομέρειαν.

Frag. 27, then, does not imply this. In fact Frags. 29, 30 and 33 show that water was as important to Xenophanes as was earth: he was no traditional monist. Frags. 27, 29 and 33 probably referred to the origin of life, for like Anaximander Xenophanes had a theory of the evolution of life from primaeval slime. * There is a full discussion of this point on pp. 324-5 inf..

Frags. 30-32 reveal that Xenophanes was familiar with the evaporation cycle and attached great importance to it; and the doxographers confirm this. Aer is evaporated from the sea to form clouds and wind: these substances, therefore, are still conceived of as they were by the Milesians, and his aer has similar properties to theirs.

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* Frag. 27 might just possibly be a reply to the Orphic and Pythagorean tenet that Zeus is 'the beginning and the end'. The de M.X.G. (D. 21 A 28 at 977 b 4) and Simplicius (A 31 at Sec. 5) both say that he equated not-being with the apeiron since it has no beginning middle or end, which shows that Xenophanes was familiar with such Pythagorean sayings.

D. 21 A 40 tells us that the sun is from clouds on fire (from Posidonius) but that Theophrastus said that it was from 'sparks' or 'little fires' collected from the 'moist exhalation', to which no cause is here assigned. D. 21 A 32 also says that the sun is a collection of sparks, as does A 33. Now if the sun is made of clouds on fire (as indeed are the stars, A 38, and the phenomenon known as the Dioscuri, A 39) there is a vicious circle, for Frag. 31 talks of the sun swinging over the earth and warming it, Frag. 30 gives the sea as source of clouds, and A 46 gives the sun's heat as the cause of the evaporation that gives rise to clouds. Consequently a cloud (the sun) is the source of clouds! It would appear, then, that the alternative explanation for the sun is to be preferred. The sun is a collection of sparks that are kindled at dawn and quenched at dusk so that as A 33 says there are innumerable suns (and moons) and as A 41a says each region has its own sun, which may be eclipsed by falling into holes in uninhabited parts of the earth.

This last sounds fantastic, but it is in the spirit of the times. Heracleitus (Frag. 32) likewise stated: "The sun is new every day", and his explanation of eclipses is no more lacking in humour to our ears.

With the source of the solar sparks given by Theophrastus, the moist ἀναθυμίασις, we are on much more serious ground. The concept of exhalations is an important one, and it plays, as we shall see, a considerable part in some later theories. We are not given any explanation of Xenophanes' exhalation by our source, and it is very unlikely that the word ἀναθυμίασις itself was actually employed by Xenophanes; but we can at least note this, the first occurrence of the concept later so called, and assure ourselves that with the importance that Xenophanes undoubtedly assigned to evaporation and to clouds as major factors in meteorology it is very likely that Theophrastus has preserved a genuine ingredient of his theory, and not committed an anachronism - again, as with the many suns, similar ideas are used by Heracleitus. Just what an exhalation is will be discussed under the latter (Chap. V).

The next point of interest is that it is motion that makes clouds luminous so that they appear to us as the Dioscuri (St. Elmo's Fire), A 39, as comets etc., A 44, and as lightning, A 45. This recalls the statement of Anaximenes that motion is one of the causes that makes aer visible. But whereas Anaximenes was mainly concerned with the relation between temperature and density so that motion was rather incidental, Xenophanes seems to come closer to modern kinetic theory by connecting motion and temperature as cause and effect. The resemblance is only apparent; for it is atomic motion and not motion on the macroscopic scale that is connected with temperature fundamentally. On the latter scale the heating of a fast moving body is due to friction rather than to the motion itself (there would be no heat if it moved through a vacuum). But granted this, Xenophanes' explanation is at least possible, though not in this case correct.

We now turn to the earth. Apart from the apparent confusion mentioned by Burnet (cf. p. 118 sup.) over a spherical finite universe that contains an infinite earth, confusion has also been introduced into the tradition by the de M.X.G., which says that Xenophanes stated that the world is neither finite nor infinite, neither at rest nor in motion.

A tradition that goes back to Theophrastus and the * de M.X.G. states that the universe (equated with or simply

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* Cf. Simpl. Phys. 23, 18, and 22, 22, D. 21 A 31, quoting Alexander and Theophrastus; de MXG 997 b 1, 987 a 20, A 28; Hipp. Ref. I 14, 2, A 33; Cic. Acad. II 118, A 34; D.L. IX 19, A 1.

called God in this connexion) is spherical and finite because, as Simplicius says and the tradition confirms, it was 'equal every way'. Burnet accepts this, but also the infinite earth and even infinite aer (the sun goes on to infinity), and so says that Xenophanes contradicted himself by using the phrase 'equal every way', and that the whole affair is just an attempt to get rid of Ouranos and Gaia, whose story 'was always the chief scandal of the Theogony'. He concludes: "We are entitled to disbelieve that it was in a cosmological poem such startling contradictions occurred."

Freeman more correctly accepts that this is cosmology; but she accepts the infinite earth which implies rejection of the finite universe. Cherniss adopts the same position, maintaining that Theophrastus referred only to his god (not equated with the universe) as spherical and that this was mere inference from Eleatic notions.

Let us examine the material in detail in an attempt to arrive at a more satisfactory interpretation. D. 21 A 32 and 33 (pp. 120-1) both contain in almost the same words the sentence: "He states that the earth is apeiron and not completely surrounded by aer" (Hippolytus adds "or by the ouranos"). The infinite earth comes, of course, from 21 B 28, which states that the earth has an upper limit at our feet, but goes down ἐς ἄπειρον. Simplicius in Phys. 22, 22sq., D. 21 A 31, accepts for the god-world the 'neither finite nor infinite' theory, but quotes Nicolaus on the side of infinity and Alexander on that of finiteness and sphericity; but in his comment on Arist. de Caelo 294 a 21 admits that he is baffled about the earth, not having seen Xenophanes words on the point. Aristotle, loc. cit., speaks of Xenophanes' earth as being infinitely 'rooted', and refers to Frag. 39 of Empedocles, which attacks 'infinite depths of earth', and may or may not also attack an infinite air (the Greek is ambiguous). Simplicius states that while the earth may remain at rest (the point of Aristotle's discussion) because it is infinitely rooted, it might also do so because it is carried upon an infinite body of air below it, and, he says, Empedocles' words could bear that sense. The tradition supports Aristotle. On this interpretation Xenophanes will have been correcting Thales and Anaximander concerning the reason why the earth stays where it is.

Xenophanes' own words, however, can bear another, and altogether easier, interpretation. Diels says of the word ἄπειρον in Frag. 28: "indefinitum, nicht infinitum". In other words, 'the earth goes down a distance that is immeasurable - immeasurably great, perhaps, but not necessarily infinite'. Since it is not surrounded by air or ouranos it is not bounded by them, and is thus in that sense 'boundless'. Accepting Diels' suggestion, then, the earth I find no obstacle to a limited spherical universe. * What of the air?

The evidence for an infinite air is twofold: first there is one interpretation (but not the only possible one) of the words of Empedocles; second there is the sun's going on to infinity. The former point is doubtful anyway, and the latter need not be taken literally - it comes from a statement of an optical illusion, and in any case it does not accord well with the sun's being quenched at dusk. I conclude that air is not infinite.

The most definite statement about aer is that quoted on p. 126 and referred to above: the earth is not completely surrounded (περιέχεσθαι) by aer. With this cf. D.L. ix 19, D. 21 A 1:

> οὐσίαν θεοῦ σφαιροειδῆ ... ὅλον δὲ ὁρᾶν καὶ ὅλον ἀκούειν, μὴ μέντοι ἀναπνεῖν.

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* Robin, who is also unwilling to accept an infinite earth, less plausibly refers the fragment to the horizon's appearance. Wherever we stand, or look, it is always appearing to our senses to recede to infinity.

Both statements have been referred to on p. 95 sup.: they are those that oppose the infinite store of matter and the 'breathing in' of the Pythagoreans (and Anaximenes). Diogenes has, through the traditional identification of God and the universe, conflated Frag. 24, which states that God sees and hears as a whole, with a cosmological denial of the breathing in theory. How, Xenophanes would ask, can the universe breathe in when not even the whole earth is surrounded by aer?

My conclusion is that Xenophanes' universe is spherical (and his God is not). By false analogy with Parmenides the tradition has confused God and the universe. Now Anaximenes believed that the earth was surrounded by and floated on aer, but that celestial phenomena occurred only in a hemisphere above the earth (cf. p. 67 sup.). Xenophanes in Frag. 28 agrees that there is aer above the upper, limiting, surface of the earth, but he denies that there is aer below the earth, that aer surrounds the earth. This implies that the aer forms the upper hemisphere of a spherical system whose lower hemisphere must therefore be the earth, as immeasurably deep as the aer is high, and 'rooted' to the spot, i.e. motionless. The earth is not, in fact, bounded by anything into which it could move.

On the flat surface of this hemispherical earth lay the sea; and the water and earth combined to form the slime from which life sprang. Note the recurrence of the fossil motif here: Xenophanes was more of an observer than some of the other Greek 'scientists' - for example he makes use of St. Elmo's fire near at hand to forge an explanation for distant celestial phenomena. He was no typical Ionian physicist: he was a poet. Not only must we not say that his earth was a monist's element, we must not even say that earth and water formed a dualism: they were just substances of, literally, vital importance. They were not mutually exclusive; more than one authority tells us that the sea was gradually encroaching on the earth: similarly the sea is the source of clouds and wind, and presumably also of the 'moist exhalation', substances connected with aer. Fire came from clouds in motion or from sparks collected from the moist exhalation. There is no Ionian elementary theory here. Xenophanes was in theory as in date intermediate between the Milesians and Heracleitus, to whom we turn next. He was part theologer and part speculator about nature. He could not absolutely separate the two sides of his work and the commentators inextricably confused them.

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CHAPTER FIVE

HERACLEITUS

Introductory Note:-

This chapter was originally written before the publication of G.S.Kirk's 'Heracleitus The Cosmic Fragments'. Kirk attacks the traditional interpretation of Heracleitus on a number of points, and proposes a radically different interpretation of his whole cosmic theory. My own opinions are considerably nearer to the traditional ones than to Kirk's, and I consider that he has by no means proved his case. At times he seems to me to do violence to certain fragments in order to make them fit his scheme. On one or two points he has indeed caused me to amend my views, but on the whole I still adhere to my former views.

I do not wish to criticize the interpretation of Kirk in detail in the course of this dissertation, for that would make this chapter of inordinate length, and much of the comment would be irrelevant to aer. I have, therefore, allowed the bulk of this chapter to remain in its form as originally written. I have rewritten the text of only such portions as deal with points about which Kirk has convinced me or raised a doubt in my mind; and I have otherwise indicated points of difference in footnotes without detailing the arguments on either side unless the disagreement is of major importance, in which case I have inserted comments on Kirk's views.

I do, however, think that Kirk has done some very sound work on textual criticism of the fragments and on their translation, and in some cases, as indicated, I have adopted his text or translation rather than the text of Diels-Kranz and the translation of it that is usually accepted.

We return to Heracleitus after having seen the birth in the West of new ideas that affected Ionian thought in turn after Ionian ideas had been transplanted to the West. We left him (pp. 72-3 sup.) facing certain factors inherent in any monistic system of the Milesian type that raise difficulties: the infinite external store of matter, that which 'encompasses' the universe, and the problem of the One and the Many - the seemingly unreal nature of substances that differ to the senses from water or apeiron or aer, if they are to be explained as merely different manifestations of the one substrate, or element.

Heracleitus of Ephesus, floruit circa 504-1 B.C., was later than Pythagoras and Xenophanes but earlier than Parmenides. He was not a continuer of Milesian specul- ation, but a man of a very original cast of thought. He disagreed violently with all his literary and philosoph- ical predecessors, many of whom committed the offence of πολυμαθία. He felt himself to be a man with a message, and adopted an aphoristic style that makes his work seem σκοτεινός. The difficulty is increased by ancient misin- terpretations of him. Aristotle makes of him just one more monist, an error that has persisted even into modern times. The Stoics, to which school we are indebted for much of our information, misinterpreted him as a Stoic before his time. They were, like Aristotle, inclined to 'accommodate' the views of others to their own (cf. Cicero, de N. D. I 41). In addition, Hippolytus, whose Ref. IX is the source for many of our fragments of Heracleitus, used for the relevant part of Ref. I an authority that, perhaps because Aristotle and Theophrastus had mentioned Heracleitus and Hippasus in the same breath (cf. p. 104 sup.), regarded Heracleitus as a Pythagorean. *

Our fullest commentary is that of Diogenes Laertius who both carries on the misinterpretation of Aristotle and relies on Stoic sources. Thus even this account has to be used with care. Even some of the fragments themselves have become contaminated with Stoicism, while the text of many is uncertain. Even when the text is certain, there is still the difficulty that, lacking original punctuation marks, the Greek is at times open to more than one translation even before interpretation proper begins.

Heracleitus claimed to have discovered one Word (Kirk: "Formula of things") that according to Burnet's interpretation of Frag. 1 is eternally true but which men are not capable of understanding. The reason for this is that κακοὶ μάρτυρες ἀνθρώποισιν ὀφθαλμοὶ καὶ ὦτα

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* For the authorities cf. Burnet, E.G.P., p. 142.

βαρβάρους ψυχὰς ἐχόντων (Frag. 107) and that φύσις κρύπτεσθαι φιλεῖ (Frag. 123). This λόγος is not just 'my discourse', or even 'the content of my discourse', and it is certainly not 'divine reason'. Rather it is the ordered formula or plan according to which the universe operates, as discovered and expounded by Heracleitus. The Word is a convenient one-word symbol for this expression (somewhat like the metaphorical use of the word 'law' in the phrase 'law of nature'); it has some of the same meaning as the word κόσμος as used by Heracleitus, but it is a symbol of wider content than the latter symbol, for it applies to the microcosm as well as to the macrocosm. As we shall see, Heracleitus' terminology is, perhaps because of his aphoristic style, full of symbolism.

Opinions fail to agree on what could be called the basic principle, the central point, of the Logos. Some, e.g. Burnet and Bailey, take it to be the identity of the One and the Many (together with the Harmony of Opposites), others, e.g. Baccou and Rey, take it to be Flux, incessant change, while Kirk prefers Stability.

My own idea is that it was the underlying Unity of the universe both in the sense that there is a One that underlies the Many and that there is a permanence that underlies change. In other words, I believe that the basic principle was a broader one than the choice of either Burnet or Kirk, and included both of these. Our senses present us with a constantly changing universe that contains a plurality of things, but behind this plurality there lies a unity: for all the change, there is just one permanent universe, a unity that preserves its identity throughout all the changes of its contents. Not only does the stability (the permanence of the universe) underlie the apparent change - as Kirk maintains - but also change underlies stability, for things that appear to us to be permanent are really changing. *

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* Kirk maintains that the 'river fragments' (Frags. 12, 49a, which he rejects, and 91, of which he accepts only the second part) refer to the preservation of the river's identity that is due to the regularity and balance of the change of its parts, and that Plato mistakenly created, on the basis of a misinterpretation of these fragments, for Heracleitus a 'flux' theory that he never held. G. Vlastos (On Heraclitus: A.J.P., LXXVI, 4, 1955, p337sq.) defends that traditional interpretation, to which I still adhere, against Kirk.

I believe that Heracleitus did believe that 'everything is in motion and nothing is still....' (Plato, Crat. 402 A) and did illustrate this by the river.

Kirk also maintains that the 'way up and way down' are just roads uphill or downhill. Vlastos defends the view that the phrase has cosmological purport, and I entirely agree with this. Kirk accepts the arguments of Reinhardt, (Hermes 77, 1942) - I find them very weak.

I regard Frags. 30 and 50 as expressing the basic content of the Logos: *

30. κόσμον τόνδε, τὸν αὐτὸν ἁπάντων, οὔτε τις θεῶν οὔτε ἀνθρώπων ἐποίησεν, ἀλλ' ἦν ἀεὶ καὶ ἔστιν καὶ ἔσται πῦρ ἀείζωον, ἁπτόμενον μέτρα καὶ ἀποσβεννύμενον μέτρα.

50. οὐκ ἐμοῦ, ἀλλὰ τοῦ λόγου ἀκούσαντας ὁμολογεῖν σοφόν ἐστιν ἓν πάντα εἶναι,

Heracleitus presents us with a 'world-order' that is universal, uncreated and eternal, and equated to an 'everliving fire' (for which v. inf.); and the essence of that world-order is that 'all things are one'.

In other words, the relation of the One and the Many is not a problem, as it was for the Milesians; rather, it is the key to the universe. This is explained in the controversial Frag. 51.

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* Kirk in Frag. 30 omits τὸν αὐτὸν ἁπάντων, and punctuates differently. I accept the reasons of Vlastos (Op. cit.) for retaining Diels' text.

Kirk contends that κόσμον does not mean 'world', as e.g. Burnet renders it (stating that use to be Pythagorean - cf. Aët. II 1, 1, D. 14, 21 - E.G.P., p. 134, n. 3), but something like 'things plus order'. Vlastos, while not accepting the statement of Aëtius, still maintains that the meaning 'world' was not new in the Fourth Century, and that Burnet was right to adopt it. I render it 'world-order' and take it to be a symbol for the world or universe but not a synonym - it refers to the universe considered as a well-ordered whole; like λόγος, the word covers more than one idea.

I give Frag. 51 in the text of Kirk: *

οὐ ξυνιᾶσιν ὅκως διαφερόμενον ἑωυτῷ συμφέρεται· παλίντονος ἁρμονίη ὅκωσπερ τόξου καὶ λύρης.

Kirk's translation is: "They do not apprehend how being

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* Kirk reads συμφέρεται for ὁμολογέει following Zeller, Brieger, Gigon, and Walzer; with this I agree, as does Vlastos. Kirk reads παλίντονος with Brieger, Burnet, and Walzer. Vlastos follows the majority and reads παλίντροπος. Kirk, like Burnet, understands παλίντονος to refer to opposite tensions: the arguments for this are very attractive. Vlastos, however, reaffirms that tension in Heracleitus is not proven, and Kirk admits that his rendering is 'questionable'. Vlastos, of the many renderings that have been given for παλίντροπος, prefers the idea that the process of stretching the string is reversed at the moment when the arrow is fired or the note played - continuous effort without such a reversal of direction would effect nothing. He points out the importance for Heracleitus of the τροπαί of fire, and refers to the opposite directions of the ways up and down. He states with surprise that Brieger arrived at much the same idea from παλίντονος.

I feel, with Kirk, that the idea of tension is Heracleitan, even though this is not provable. But the picture that Kirk builds up from this idea is static (cf. his opposition to the 'flux' interpretation); whereas my view of Heracleitus is more dynamic. Vlastos believes that the 'harmony' consists in change in opposite directions within a contrariety (v. inf.): I believe that lack of balance between opposing tensions would achieve this, but I believe that Vlastos is asking us to accept an interpretation of παλίντροπος that would be far from obvious to Heracleitus' contemporaries. I therefore prefer the above text while yet preferring the overall dynamic interpretation of Heracleitus to the static one of Kirk. For arguments against the various other interpretations of either reading I refer the reader to the relevant passages in the works of Vlastos and Kirk.

at variance it agrees with itself: there is a connexion working in both directions, as in the bow and the lyre". Burnet rendered ἁρμονία by 'attunement'; but few would now allow the word any connexion with music here. Kirk says that the word has here its basic meaning 'connexion', and that in the simile of the bow and the lyre the 'connexion' is the string that connects the apparatus' extremes and is under tension, being pulled in opposite directions by those extremes.

The fragment, then, on this interpretation, states that something that is at variance with itself agrees with itself: there is (not 'it is' as in Burnet's rendering) a connexion between two extremes - and this applies in all categories. Every pair of opposites is a unity (the string pulls the ends of the bow towards each other and holds the whole bow together) as well as a duality (the ends of the bow pull on the string) and these aspects (tensions) are simultaneous (if one pull ceased, the bow would break, as it would if one pull were too strong - the pulls must balance exactly, according to Kirk). So opposites are the extremes of one single continuum as well as being two separate entities. With most of this interpretation I agree, but it does not go far enough.

The tensions, we are told, have to balance; they hold the whole together, and maintain its stability, that which Kirk holds to be of prime importance for Heracleitus. Now opposites do have an essential connexion between them, this I agree: the connexion is not necessarily the same in the case of each pair, this Kirk admits.

Some fragments give us examples of connexion by succession (e.g. Frag. 57: day and night), others by relativity to different observers or different standards of judgement (e.g. Frag. 61: sea water is drinkable and safe for fishes but undrinkable and poisonous for men), and so on. Kirk groups the relevant fragments according to the type of connexion, Op. Cit., Groups 2 - 5. His explanation of all these types is static, and this is where I commence to disagree.

In some types of contrariety, those whose very nature is stable and those where it is a case of relative judgements for example, the explanation of the connexion given by Kirk is excellent; but in other types, where there is change, or succession, or even an apparently static state that conceals an underlying change, it is not adequate. Vlastos (Op. cit.) says that ἁρμονία does not mean simply 'connexion', but rather 'adjustment', which he explains as happening through change that takes place in opposite directions within a contrariety. There is in such cases a process whose direction continually reverses itself (cf. the ways up and down), so that things change from one opposite to the other.

This accords with the view of Cherniss (Op. cit., p. 382): "It is then the process which is the real Being, and all the distinctions men see are but fleeting phases of the process...", and (p. 383): "...identity consists in difference since each individual object is constantly changing in different directions, each part of the whole, like the whole world-fire itself, kindling in measure and in measure going out".

Thus Kirk has not succeeded in weaning Vlastos, or myself, from the traditional 'flux' view of Heracleitus; but I am willing to concede to Kirk that exactly balancing 'tensions' will explain static contrarieties. I feel that the traditional view is too entirely dynamic, just as I feel that Kirk's view is too wholly static. *

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* The scientific side of Heracleitus, my main concern, is dynamic. Consequently I shall give my interpretation of this without constant reference to Kirk's views on the relevant fragments, since they depend on his rejection of the flux theory, which I accept.

Some things in the world are stable (though there is change underlying them) and some are changing (though there is an underlying permanency): static-dynamic is a contrariety that would have appealed to Heracleitus and I see nothing contrary to the spirit of Heracleitus in my accepting Kirk's explanation for one type of contrariety, one aspect of the world, and the traditional one, reaffirmed by Vlastos, for the other.

Just as the connexion between a pair of opposites, whether static or dynamic, implies that the continuum of which they are the extremes may be regarded as a unity or a duality according to the viewpoint (synthetic or analytic), so too the whole universe can be regarded synthetically or analytically as a unity or as a plurality. In fact unity and plurality are but two aspects of the same thing: unity manifests itself as a difference (due to the coexistence of opposite tensions or opposite processes), and plurality manifests an underlying unity.

This identity consisting in difference applies in every category and in every sphere: in physics, as we shall see; in life, for 'as the same thing exists in us x

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x For this and Frag. 32, p. 142, I give Kirk's version.

living and dead and the waking and the sleeping and young and old...' (Frag. 88; cf. Frags. 48 & 62); in ethics, for 'good and evil are one' * ; in religion, for 'one thing, the only truly wise, does not and does consent to be called by the name of Zeus' (Frag. 32). All this is summed up in Frag. 10: **

> συλλάψιες ὅλα καὶ οὐχ ὅλα, συμφερόμενον διαφερόμενον, συνᾷδον διᾷδον· ἐκ πάντων ἓν καὶ ἐξ ἑνὸς πάντα.

Whether we are dealing statically with tensions pulling against each other with equal force, or dynamically with tensions pulling unequally so that a process of change occurs in one direction or the other, there exists an opposition that may be symbolised as 'strife' or 'war': it can also be described as 'injustice', as it was by Anaximander (D. 12 B 1, p. 31 sup., passage no. 1). These descriptions, taken at their face value, do not satisfy

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* This is a fair inference, even if we do not accept Bywater's 'Frag. 57' as genuine, as Diels-Kranz do not, printing it as context to Frag. 58.

** Kirk's text - to be understood: things (mentally) taken together (i.e. belonging to the same category, and especially pairs of true opposites) are (in one sense) wholes (sc. continua) and (in another sense) not wholes (but separate and opposed). In one sense they tend to unity, in another to plurality. In one they are in tune, in another out of tune. A unity is made up of all things and all things issue from a unity.

Heracleitus, who makes the following observations on the subject:

> εἰδέναι δὲ χρὴ τὸν πόλεμον ἐόντα ξυνόν, καὶ δίκην ἔριν, καὶ γινόμενα πάντα κατ' ἔριν καὶ χρεών.

> Homer was wrong in saying: "Would that strife might perish from among gods and men!". He did not see that he was praying for the destruction of the universe; for, if his prayer were heard, all things would pass away. *

In Frag. 80 Kirk takes 'justice' as subject and 'strife' as complement, and interprets 'justice' as bearing its original sense of 'the normal course of events'; he then shows that the fragment has a structure of this nature: war-strife (a) is everywhere (b); normal-course-of-events (c) is war-strife (a); everywhere (b) things happen by war-strife (a) and normal-course-of-events (c) - 'necessity' being equivalent in sense to 'justice'.

Kirk interprets war and strife as being the interaction of opposites, the normal, and in fact the only, way in which change occurs. The fragment is thus a correction of Anaximander. Vlastos complains that here Kirk does not go far enough. For Anaximander not only erred

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* The first passage is Frag. 80. The second is Burnet's translation of his reading of Bywater's so-called Frag. 43, reconstructed from D. 22 A 22.

in thinking that the interchange of opposites was 'injustice' not 'justice', the point that Kirk allows, but also in thinking that the interaction was occasional and intermittent (encroachment, that is, injustice, is followed by eventual reparation, that is, justice). To Heracleitus the interaction is universal. Frag. 80 describes War as ξυνός, and Frag. 53 asserts that it is 'father of all and king of all'. Strife, which is change, is universal, so that if it were injustice, the latter would be universal; but, as Frag. 80 says, it is justice. For Anaximander strife (injustice) existed but justice was nevertheless eventually preserved; but for Heracleitus strife exists because justice is universally and all the time preserved.

Frag. 94 tells us that the sun, and by analogy any other part of nature, will not overstep his measures. Kirk occasionally, e.g. p. 320, speaks of 'long-term' excesses which are eventually balanced by a corresponding deficiency; but this idea is rather Anaximander's than Heracleitus'. Since 'all things happen in accordance with strife and rightful necessity' there can be no long or short term excesses: Anaximander relied on the equality of the opposites and eventual reparation for the preservation of justice, but to Heracleitus there exists as a matter of course an equilibrium since encroachment and reparation are concurrent not successive (cf. Frags. 31 and 36, discussed inf.); each one of the three main masses (v. inf.) is always losing as much as it gains. But the equilibrium is not, as with Anaximander, a case of equality between the main masses (there is not an equal amount of fire, water, and earth in the world) but rather a case of equipollent change - the important point is the balance of processes rather than the amounts. In the universe as in rivers and flames this equilibrium is stable. There are, it is true, dried up rivers and quenched flames, but, then, some changes manifest themselves as successive alternations: there is a constant overall λόγος preserved in the totality of changes - the 'measure' of fire, which is, as it were, τὸ ξυνόν in the whole series (cf. Frags. 31 and 90).

With this argument of Vlastos I entirely agree. I shall have more to say about the physical aspects shortly, but must first reaffirm my belief in the 'flux' theory in the face of Kirk. * I believe in it in the sense that

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* I entirely agree with Vlastos' arguments in Op. cit. p. 135 sup., and in his review of Kirk's book in A.J.P., LXXVI, 3, which has only just become available to me.

every individual thing is changing, constantly, but the measures of change are invariant. Underlying the apparent permanence of some phenomena is an equilibrium of opposite processes (symbolized in some cases as the ways up and down). In some cases our senses may not appreciate that change is occurring, but it nevertheless is. In other cases we can visualise both manifestations, permanence and change, for example in the river and the flame. We learn from Frag. 84 that change (which seems to be tiring) is restful and genuine permanence is wearisome; in fact things that seem to be 'at rest' are changing. Kirk (p. 376) attacks Aristotle's comment in Phys. 253 b 9 that the constant change is of a type that 'escapes our perception'. Admittedly Heracleitus believed our senses, if interpreted correctly, to be reliable. In cases like the river and the flame we do in fact see the change occurring. But what of a tree? After an interval we see that it has grown, but we cannot see the growth occurring, for it is too slow. We cannot see the erosion of a rock, the rotting of timber made from the tree, evaporation (when not accompanied by mist) from water, actually happening. The idea of imperceptibles that are due to the weakness of our senses is not at all inappropriate to a Pre-Socratic philosopher: it is specifically stated in Frag. 21 of Anaxagoras, and Heracleitus himself says that sense data have to be interpreted. Of course we are not meant to look for imperceptible change as well as change that is obvious in one and the same thing; but in cases where we do not see any change, there is change occurring nevertheless.

The river, then, is used by Heracleitus to demonstrate how a thing can be both permanent and changing. The fragments concerned, which I accept along with Vlastos in face of Kirk's attack, are these:

12. ποταμοῖσι τοῖσιν αὐτοῖσιν ἐμβαίνουσιν ἕτερα καὶ ἕτερα ὕδατα ἐπιρρεῖ· καὶ ψυχαὶ δὲ ἀπὸ τῶν ὑγρῶν ἀναθυμιῶνται. *

49a. ποταμοῖς τοῖς αὐτοῖς ἐμβαίνομέν τε καὶ οὐκ ἐμβαίνομεν, εἶμέν τε καὶ οὐκ εἶμεν.

91. ποταμῷ οὐκ ἔστιν ἐμβῆναι δὶς τῷ αὐτῷ. ... σκίδνησι καὶ πάλιν συνάγει ... καὶ πρόσεισι καὶ ἄπεισι.

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* Kirk does not accept the clause about 'souls' as a part of the fragment (p. 371), believing that it may be a paraphrase of Frag. 36. I am prepared to accept the clause as Heracleitan, though not necessarily as having been continuous with Frag. 12. It certainly represents a Heracleitan doctrine, v. pp. 168 and 176 inf..

The flame analogy turns out to be even more fruitful. Struck by the fact that it is always in motion, yet always in existence in the same place as the fuel passes through it on the way to becoming fumes and smoke, Heracleitus used Fire as the symbol for the change that is intimately bound up with the unity and permanence of the world. I disagree most strongly with those who follow Aristotle (if, indeed, any still do, as Burnet did, for example) and believe that Fire was a substrate, an 'element' like the water or aer of Thales and Anaximenes. *

There is no need for a cosmogonical explanation of how the Many were generated from the One, for they are one and the same thing - the world is one and many simultaneously. (Cf. p. 136 sup., and, especially, Frag. 30, which asserts that the world is uncreated.)

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* In this I am in agreement with Cherniss, Op. cit. (p. 380), who rightly rejects the explanation that Fire was chosen as being the rarest material. Kirk accepts both this and the explanation given above (cf. Arist. de An. 405 a 27), but rejects the view that fire is a symbol. While granting that it may have symbolic overtones he says (p. 318): "The cosmological fire must be thought of primarily as αἰθήρ", describing the latter in similar terms to those applicable to Aristotle's quintessence; unlike terrestrial fire it is immortal (in the sense that the Milesians' elements were so), but it is not unique - it "was prior in importance" (p. 326) to the others, water and earth. Vlastos rejects this ether idea utterly, and I reject it also.

If we take fire to be a substrate, it is difficult to decide whether Heracleitus imagined change to be qualitative or quantitative. We are led to reading into his theory the ideas of his predecessors, with whom he professed to disagree, for example the idea of condensation and rarefaction. True, Aristotle, always eager to show how others were stumbling towards his own system, includes him among those who believed in one 'material cause'; but this is Aristotle not Heracleitus, and it is because of this that Lucretius in I 635sq. uses Heracleitus' fire as the typical monist's element. Heracleitus is thus accused of failing to solve the problems mentioned on p. 132 sup., problems which we have seen reason to believe to have been uppermost in his mind.

It is, however, possible to distinguish between fragments that use fire as a symbol and fragments that use fire as the name for one of three substances that are the major constituents of the physical world (we could, in fact, subdivide Kirk's 'cosmic fragments' into cosmic-symbolic and physical-chemical). As a symbol for the cosmic process, fire is spoken of in similar terms to the logos, as the following fragments show:

ἓν τὸ σοφόν, ἐπίστασθαι γνώμην, ὀτέη ἐκυβέρνησε πάντα διὰ πάντων. Frag. 41.

I adopt Vlastos' view of the text, and Burnet's rendering: "Wisdom is one thing. It is to know the thought by which all things are steered through all things". As Vlastos says, γνώμη is both a thought and a thinking thing - abstracts and concretes have not yet been firmly distinguished. It corresponds to λόγος, which has symbolic meaning (p. 134, sup.), but which is similarly, as something of which real existence is postulated, in some sense concrete, just as is κόσμος (footnote to p. 136).

τὰ δὲ πάντα οἰακίζει Κεραυνός. Frag. 64.

Kirk, pp. 349 sq., discusses in detail the connexion between this fragment and the context of Hippolytus in which it appears. Suffice it to say here that the Κεραυνός is a symbol for eternal fire (but may also be connected with Zeus, who is also connected with ἓν τὸ σοφόν, cf. Frag. 32). This fire may well have been conceived of as φρόνιμον in fact, though Hippolytus' comment is clearly influenced by Stoicism. The words κυβερνῶ and οἰακίζω are clearly used synonymously.

Although I do not agree with Kirk's interpretation of Frag. 41, I do agree with his conclusions about the interrelations between Frags. 32, 41, and 64. I quote part of p. 396: "The Logos was discovered to be more than a principle: it is a materialized formula, an aspect of the operation of fire. ... The cosmos _is_ a fire, ... fire ... is the embodiment of the Logos, ... and it is wise. It is not surprising, then, that ψυχή in its unadulterated form is fiery". We shall examine later the fact that fire and the soul are connected. I mention it here because Vlastos uses it in his examination of the status of Fire.

He rejects both extreme rarity and changeability (cf. p. 148, sup.) as Heracleitus' reason for choosing fire. He has been arguing that Heracleitus shows considerable Milesian influence; and claims that the reason for the pre-eminence of fire is that the soul is fiery, and that Anaximenes had identified his principle (aer) with soul: the ἀρχή is the substance of which soul is made; Heracleitus' soul is fiery; therefore Heracleitus' ἀρχή must be fire. This ἀρχή is, however, he claims, conceived of differently from Anaximenes'; for it is not infinite, nor does it encompass the universe (conservation - v. p. 145 - not the presence of an infinite encompassing store of matter -cf. p. 132- gives the universe its permanence).

This argument comes after that quoted on p. 145 where Vlastos states that fire is τὸ ξυνόν in the series of physical changes. Thus he comes close to attempting to reinstate Heracleitus as a monist with fire as his ἀρχή , albeit an ἀρχή differing from the Milesian type. I cannot accept this any more than I can accept Kirk's conception of fire as αἰθήρ. I still adhere to the view that there is no monistic ἀρχή, but that fire is a symbol, just like logos and cosmos, in certain fragments but the name of one of three equally important substances in other fragments of a different character.

Let us, then, turn to these fragments, which I have called 'physical-chemical'. They include the following:

> πυρὸς τροπαί πρῶτον θάλασσα, θαλάσσης δὲ τὸ μὲν ἥμισυ γῆ, τὸ δὲ ἥμισυ πρηστήρ. ... <γῆ> θάλασσα διαχέεται, καὶ μετρέεται εἰς τὸν αὐτὸν λόγον, ὁκοῖος πρόσθεν ἦν ἢ γενέσθαι γῆ. (Frag. 31) *

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* Kirk interprets τροπαί as sudden and complete changes as opposed to gradual and minute ones (p. 328): the processes and intermediate forms of matter (e.g. aer) are ignored. He shows that the fragment deals with the series of changes fire - sea - earth .. earth - sea - fire; and says (p. 332): "The equality of the changes is expressed for two of the stages: half of sea is moving up, half changing to fire; the same amount of earth is dissolved into sea as formerly (πρόσθεν refers rather to priority in the logical schema than strictly to temporal priority) turned from sea to earth. The only stage for which this balance is not asserted is fire, but the balance can easily be inferred, and is carefully stated in a different form in Frag. 90." On p. 331 he says, however: "...sea is being constantly replenished by the liquefaction of earth proportionally with its diminution by condensation into earth." True though this may be, it is not, as Vlastos says, what Heracleitus says: he says that any part of earth that becomes water is equal to its mass before (temporally not logically) it became earth - in other words the subject is the proportions of changes in earth, not in water. Taking πρόσθεν temporally we can see this even without ἢ γενέσθαι γῆ, which Vlastos thinks probably a gloss.

Ἥλιος γὰρ οὐχ ὑπερβήσεται μέτρα· εἰ δὲ μή,
Ἐρινύες μιν Δίκης ἐπίκουροι ἐξευρήσουσιν. (Frag. 94)

ὁδὸς ἄνω κάτω μία καὶ ὡυτή. (Frag. 60) *

τὰ ψυχρὰ θέρεται, θερμὸν ψύχεται, ὑγρὸν αὐαίνεται,
καρφαλέον νοτίζεται. (Frag. 126) **

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* I reject Kirk's claim that this fragment refers just to the identity of the way up and down a hill, and adhere to the cosmological (not cosmogonical, v. Kirk p. 107) interpretation; the two ways are the two processes mentioned in reverse order on my p. 152, Frag. 31 note.

** Kirk, following Snell, Hermes 61 (1926) 356sq., interprets the pairs of opposites here as contrarieties known from personal experience within the body; so that the fragment gives a generalisation concerning the everyday behaviour of things, not a scientific principle. The neuters should therefore be translated 'cold things' etc., not 'the cold' etc.; and the verbs should be taken as middle: thus the fragment stresses the reciprocity of changes in general, and perhaps also the fact that they are going on all the time and balancing each other. The latter is the opinion of Vlastos, C.P. 42 (1947) p. 165.

Reinhardt, Parmenides p. 223, on the other hand, concluded that Heracleitus already knew the later canonical 4 opposite qualities; while Gigon, Untersuchungen zu Her. p. 99, even took the fragment to refer to the four elements and accepted aer in Frag. 76 (p. 155 inf.) as genuine and original. Kirk rightly says that Anaximander posited these as two especially important pairs of opposites that separated out from the apeiron (as Heracleitus would know) while the 4 elements are definitely original with Empedocles. He is doubtful about the purpose of the fragment. I take it that Heracleitus was using the already familiar Anaximandrian pairs of 'quality-things' (Cornford's name for these opposites) and showing how they fit into his own scheme. They fit both into his general theory of opposites and into the scheme of changes described in Frags. 31, 36, and 76.

πυρός τε ἀνταμοιβὴ τὰ πάντα καὶ πῦρ ἁπάντων ὅκωσπερ χρυσοῦ χρήματα καὶ χρημάτων χρυσός. (Frag. 90) *

ψυχῇσιν θάνατος ὕδωρ γενέσθαι, ὕδατι δὲ θάνατος γῆν γενέσθαι, ἐκ γῆς δὲ ὕδωρ γίνεται, ἐξ ὕδατος δὲ ψυχή. (Frag. 36) **

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* Kirk's interpretation is that fire is exchanged for water and earth both as cosmological world-masses and, in mixture, as components of individual things. The latter is Kirk's inference: it may be so, but it is not specifically stated. The balance is emphasized by the simile - the goods equal the gold in value. He rightly rejects the ecpyrosis interpretation of the fragment, and the ecpyrosis itself. Vlastos says that the fragment asserts that fire is constant in all changes, i.e. its measure is the same: "that same amount of fire which is the common thing - τὸ ξυνόν - in all the different things that compose the series". I agree that it does assert the balanced measure of fire in changes (cf. note to Frag. 31, p. 152 sup.) but I do not agree that fire itself is concerned in all changes (cf. p. 145 and 151); it is not directly concerned in changes between water and earth, nor does it itself change directly into or out of earth.

** Kirk rightly rejects Gigon's application of this fragment to the microcosm, which takes earth to mean flesh and water blood. This fragment has soul (which is connected with fire, v. inf.) in place of fire, but confirms Frag. 31 in the details of the two rectilinear processes of change between the three world-masses, while replacing the 'turnings' metaphor with the 'death' metaphor, which also appears in Frag. 76 (p. 155). Kirk rightly quotes Philo, de Aet. Mundi, 21: θάνατον οὐ τὴν εἰς ἅπαν ἀναίρεσιν ὀνομάζων ἀλλὰ τὴν εἰς ἕτερον στοιχεῖον μεταβολήν. The substitution of soul adds the extra point that the soul is not annihilated at death, nor does it survive unchanged, but it suffers a chemical change, as do the other constituents of the body. Thus the fragment has both cosmological and psychological significance.

ζῇ πῦρ τὸν γῆς θάνατον καὶ ἀὴρ ζῇ τὸν πυρὸς θάνατον, ὕδωρ ζῇ τὸν ἀέρος θάνατον, γῆ τὸν ὕδατος.

πυρὸς θάνατος ἀέρι γένεσις, καὶ ἀέρος θάνατος ὕδατι γένεσις.

ὅτι γῆς θάνατος ὕδωρ γενέσθαι καὶ ὕδατος θάνατος ἀέρα γενέσθαι καὶ ἀέρος πῦρ καὶ ἔμπαλιν.

Frag. 76. The three versions are, in order: Maxim. Tyr. XII 4 p. 489; Plut. de E 18, 392C; and Marc. IV 46. *

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* Since aer is not one of Heracleitus' world-masses, Kirk adheres to the common view that this group of quotations that forms Diels' Frag. 76 is actually a group of Stoicized versions of Frag. 36 (p. 154) with aer inserted by the Stoics on the analogy of their own theories.

Gigon (loc. cit. p. 153 sup.) defended the authenticity of the presumed Heracleitan original on the assumption that Heracleitus believed in four main substances (even, perhaps, four elements, v. p. 153).

Note that in Maximus' version the (impossible) change from earth to fire gives us a cyclical series instead of the two 'ways'. Tocco's emendation (DK p. 168, note) - translated without acknowledgement by Burnet in E.G.P. p. 135 - transposing the genitives of aer and earth restores the rectilinear series that the other two versions clearly describe. Plutarch's gives us the 'way down' and Marcus Aurelius' gives us the whole double series, with the 'way up' described in detail.

Kranz' restoration of the hypothetical unstoicized original, including only the three world-masses, and with the double potentiality for change of water (into fire or earth) stated, is very tempting, but of course cannot be proved to be correct. It has the disadvantage that the double change of water does not appear in that form in Frag. 76 in any version. The restoration is as follows:

ζῇ πῦρ τὸν ὕδατος θάνατον, ὕδωρ ζῇ τὸν πυρὸς ἢ γῆς θάνατον, γῆ τὸν ὕδατος.

These fragments describe a system in which all things, not only fire as those who make of Heracleitus a monist would say, and in particular three main masses, fire water and earth, are continually changing and interchanging, while there are measures of the interchanges. In Frag. 126 the interchanges are expressed in terms familiar from the work of Anaximander, namely the pairs of 'opposites', the 'quality-things': the hot, the cold, the wet, the dry.

As Kirk points out (p. 344): "One of the strangest features of his system is the lack of specific interrelation between his special analysis of cosmological change (between fire, water and earth) and his general analysis of change as between opposites". However the relevant point here is that no special emphasis is laid upon the hot in Frag. 126.

The same applies to Frag. 36 and fire (apart from the connexion with soul, which is irrelevant to the consideration of the physical-chemical changes involved) and to the group known as Frag. 76 together with its hypothetical original. Even in Frag. 31 fire is only prominent as one terminus of the series, and earth is equally prominent in the second half of the fragment.

There is, then, quite a different feel about the use of fire here from that about its use in the 'cosmic-symbolic' fragments. We have seen the reasons for its prominence there: now we are dealing with it purely in its literal sense as the name of one of three substances. There is no 'substrate' in this physical system. All three substances take part in two rectilinear series of changes, described figuratively as 'the way up and the way down', in which fire or earth can change into water, and vice versa, but earth cannot change directly into fire or vice versa. This point, I feel, tells strongly against the monistic interpretation.

These changes occur in such a way that the 'Law of the Conservation of Matter', to use a modern term for the 'measures', is obeyed (Frags. 30, 90, and 94). Frag. 31 (see my note ad loc. p. 152) gives the quantitative rules for this conservation.

There is some resemblance between the changes in this system and those in Aristotle's (especially if we recall Kirk's statement that Heracleitus did not bother with intermediate stages, and if we then follow the stoicizers of Frag. 76 and put aer in its logical position between fire and water). In both systems we are given a consistent theory of change from fire to earth and back again that does not need to employ either separation or rarefaction and condensation. In both systems, again, contrarieties have importance (though not in quite the same way). The major differences are, firstly that Aristotle's changes are cyclical while Heracleitus' are in two opposite equipollent rectilinear series, and secondly that aer is on a par with the other transmuting substances in Aristotle's system but subordinate in Heracleitus'.

Aristotle was, in my opinion, influenced by Heracleitus (cf. pp. 161sq.); but he had the advantage of familiarity with the four elements of Empedocles. To quote Kirk: "It is often said that Empedocles simply identified traditional basic pairs of opposites with particular kinds of matter, but his procedure was more complicated than that: we may infer that he first had to prove the substantiality of air. It may be that Heracleitus' omission of air is a direct criticism of Anaximenes' acceptance of it".

I remarked on p. 157 that the stoicizers of Frag. 76 put aer in its logical position between fire and water. Was aer, then, to Heracleitus just an unimportant intermediate stage in the process of change from the one to the other? Or did he, in rejecting Anaximenes' idea that aer was the element, reject the existence of aer as a real substance altogether? To both questions I answer: no. I believe that Heracleitus realised that aer is not a single substance, not an element in either the ancient Greek or the modern English sense of the word, but a mixture, and that he therefore naturally refrained from treating it as one of the main world-masses.

In order to support this contention I shall now examine Heracleitus' theory of 'exhalations'. The best source of information is in Diogenes Laertius IX Sec. 8sq., though the early part of this account is contaminated by Aristotelian and Stoic errors. In Sec. 8 he affirms that fire is the element and that things come into being by rarefaction and condensation. After giving the traditional interpretation of the 'rivers fragments' and stating that the universe is limited and a unity, he describes the 'ecpyrosis' that the Stoics falsely attributed to Heracleitus. He ascribes becoming to war and strife and the ecpyrosis to agreement and peace, and concludes the section with the statement that change is the way up and down and the cosmos is generated according to the latter. The opposition between war and peace assumes a contrariety of causes like Empedocles' Love and Strife, acting alternately - in spite of Frag. 10 and the clear statement of simultaneous action of the opposites in the well-known passage Plato, Sophist 242 D. The cosmogonical interpretation of the way up and down is to be rejected in favour of the cosmological (v. note to Frag. 60, p. 153).

In Sec. 9 Diogenes explains the ways up and down in detail (incorrectly giving rarefaction and condensation as the mechanism). The way down comes first, and is followed by this passage:

> πάλιν τε αὖ τὴν γῆν χεῖσθαι, ἐξ ἧς τὸ ὕδωρ γίνεσθαι, ἐκ δὲ τούτου τὰ λοιπά, σχεδὸν πάντα ἐπὶ τὴν ἀναθυμίασιν ἀνάγων τὴν ἀπὸ τῆς θαλάττης· αὕτη δέ ἐστιν ἡ ἐπὶ τῷ ἄνω ὁδός. γίνεσθαι δὲ ἀναθυμιάσεις ἀπό τε γῆς καὶ θαλάττης, ἃς μὲν λαμπρὰς καὶ καθαράς, ἃς δὲ σκοτεινάς. αὔξεσθαι δὲ τὸ μὲν πῦρ ὑπὸ τῶν λαμπρῶν, τὸ δὲ ὑγρὸν ὑπὸ τῶν ἑτέρων. * τὸ δὲ περιέχον ** ὁποῖόν ἐστιν οὐ δηλοῖ· εἶναι μέντοι ἐν αὐτῷ σκάφας ἐπεστραμμένας

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* If fire were the element, it would be strange to find it being 'increased' from something else.

** For the external store of matter that encompasses the universe cf. p. 151 sup. Heracleitus' universe did not need any such store: it was limited and a unity, as Diogenes says. The latter, not finding, therefore, any reference to such an external store, mistakenly thought that Heracleitus believed in one but could not explain its nature.

κατὰ κοῖλον πρὸς ἡμᾶς, ἐν αἷς ἀθροιζομένας τὰς λαμπρὰς ἀναθυμιάσεις ἀποτελεῖν φλόγας, ἃς εἶναι τὰ ἄστρα.

(10) ... * ἡμέραν τε καὶ νύκτα γίνεσθαι καὶ μῆνας καὶ ὥρας ἐτείους καὶ ἐνιαυτοὺς ὑετούς τε καὶ πνεύματα καὶ τὰ τούτοις ὅμοια κατὰ τὰς διαφόρους ἀναθυμιάσεις.

(11) τὴν μὲν γὰρ λάμπρὰν ἀναθυμίασιν φλογοθεῖσαν ἐν τῷ κύκλῳ τοῦ ἡλίου ἡμέραν ποιεῖν, τὴν δὲ ἐναντίαν ἐπικρατήσασαν νύκτα ἀποτελεῖν· καὶ ἐκ μὲν τοῦ λαμπροῦ τὸ θερμὸν αὐξόμενον θέρος ποιεῖν, ἐκ δὲ τοῦ σκοτεινοῦ τὸ ὑγρὸν πλεονάζον χειμῶνα ἀπεργάζεσθαι. ἀκολούθως δὲ τούτοις καὶ περὶ τῶν ἄλλων αἰτιολογεῖ. περὶ δὲ τῆς γῆς οὐδὲν ἀποφαίνεται ποία τίς ἐστιν, ἀλλ' οὐδὲ περὶ τῶν σκαφῶν.

In this passage we meet with two exhalations in contrast to one 'moist exhalation' for Xenophanes from which, in Theophrastus' account, sparks were collected to form the sun (p. 124 sup.). Heracleitus accepts the idea of an exhalation that can explain the light of the heavenly bodies without the conception of ignition by motion's being required. But he also posits a second exhalation that can explain other phenomena.

One exhalation is 'bright and pure': the other is 'dark'. At first sight it appears as if these are just the same exhalations as those in Aristotle's Meteorologica, of which one is a moist, cold, cloudy vapour, evaporated

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* I omit an astronomical passage as irrelevant. It concerns the 'bowls'.

from the moisture within the earth and on its surface, and the other a hot, dry, smoky, highly combustible substance given off by the earth itself, which Aristotle admits to be difficult to envisage (Meteor. 341 b 15), but which is in some states fiery and in others not unlike what we mean by a 'gas'. According to Aristotle's theory, the moist exhalation is responsible for rain, dew, frost, snow, etc., and the dry one for meteors, thunder and lightning, wind, etc. (cf. Meteorologica, passim).

It has been said, then, that Aristotle borrowed his exhalations direct from the Heracleitans, and that the 'bright' exhalation of Heracleitus was dry and originated from earth while his 'dark' one was moist and originated from the sea. This appears logical, indeed, for the earth is dry and the sea moist. Moreover the normal use of ὁ μέν and ὁ δέ for 'the former ... the latter' would seem to connect λαμπράς with γῆς and σκοτεινάς with θαλάττης in Sec. 9 of the passage quoted from Diogenes Laertius.

Now the equation of dark and moist is clear from τὸ δὲ ὑγρὸν ὑπὸ τῶν ἑτέρων (sc. σκοτεινῶν) in Sec. 9 and ἐκ δὲ τοῦ σκοτεινοῦ τὸ ὑγρον in Sec. 11. The clause immediately before the latter equates bright and hot, so that dry is a fit attribute for the bright exhalation.

To confirm the other part of the hypothesis, however, that Heracleitus' dry and bright exhalation like Aristotle's comes from the earth and his moist and dark one from the sea is not so simple. Diogenes says that the bright exhalation is collected in bowls * to form the flames that are the visible parts of the heavenly bodies: this should mean that the latter have their origin in a dry exhalation from earth. But this conflicts with the first two of the following passages of Aëtius, though not with the third:

> 'Η. ... ἄναμμα νοερὸν τὸ ἐκ θαλάττης εἶναι τὸν ἥλιον.
>
> Aët. II 20, 16; D. 22 A 12.

> σκαφοειδεῖς γὰρ ὄντας τοῖς σχήμασι τοὺς ἀστέρας, δεχομένους τὰς ἀπὸ τῆς ὑγρᾶς ἀναθυμιάσεως αὐγάς, φωτίζεσθαι πρὸς τὴν φαντασίαν.
>
> Aët. II 28, 6; D. 22 A 12

> 'Ηράκλειτος ... τρέφεσθαι τοὺς ἀστέρας ἐκ τῆς ἀπὸ γῆς ἀναθυμιάσεως.
>
> Aët. II 17, 4; D. 22 A 11.

The two passages in A 12 appear to agree: one says 'from the sea' and the other 'from the moist exhalation', and the doxographical tradition appears to confirm them against A 11, which says 'from the earth'. For example

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* N.b. ἀθροιζομένας, cf. συναθροιζομένων in 21 A 40, v. p. 120, re the theory of Xenophanes.

cf. the passages that follow:

διὸ καὶ γελοῖοι πάντες ὅσοι τῶν προτέρων ὑπέλαβον τὸν ἥλιον τρέφεσθαι τῷ ὑγρῷ.

Arist. Meteor. 354 b 33.

διὸ καί φασί τινες τῶν ἡρακλειτιζόντων ... ἐκ δὲ τῆς θαλάττης τὸν ἥλιον ἀναθυμιᾶσθαι.

Ps. Arist. Probl. 934 b 33; D. 66, 2, in a context perhaps dealing with Antisthenes.

The first passage deals with Heracleitus above all, as Cherniss shows, Op. Cit. p. 133; and the second shows that the idea concerned was maintained by his followers.

If, then, these passages are correct, and the sea is the origin of the heavenly bodies, they ought on the above hypothesis to be bowls full of the moist and dark exhalation, not the dry and bright as Diogenes says and common sense confirms. Consequently the tentative identification of the exhalations of Heracleitus and Aristotle breaks down over the origin though confirmed for the attributes bright and dry on the one hand and dark and moist on the other. It is unlikely that the one passage 22 A 11 is correct and all the rest of the tradition wrong.

Burnet begged the question of the origin of the exhalations. On p. 155 he said: "Diogenes tells us that fire was kept up by the bright vapours from land and sea, and moisture by the dark", and a few lines later speaks of the 'rise of darkness from earth and sea'. Kirk thinks, like Cherniss (even though he rejects Cherniss' reason for so thinking), that Heracleitus really had only one exhalation. He refers (p. 273) to the hypothetical identity of the two theories that I am questioning, and claims that the fact that Aristotle does not admit having borrowed his theory from Heracleitus means that there were not <u>two</u> exhalations to borrow. Kirk fails to see that the real reason for his omission was that the sources of his exhalations were not the same as those of Heracleitus', so that there was no direct borrowing.

Apparently confused by Aristotle's use of καπνός as a name for the dry exhalation (a name appropriate to one but not to all forms of it), Kirk falls into the error of assuming that Aristotle's land exhalation is dry and dark, and the other moist and bright. He gives these attributes to the respective exhalations of both men on p. 271, in the case of Heracleitus meaning, of course, the two exhalations that people other than Kirk himself believe Heracleitus to have employed. In other words, quite apart from the weakness of his case in claiming that there was only one such exhalation, he has grossly misinterpreted both the doxographical tradition about Heracleitus and the theory of Aristotle. He cannot aid us.

But if we replace the traditional hypothesis with one that suggests that the exhalations of the two men were identical in type (dry and bright, moist and dark, in each case) but of opposite origins, the difficulties disappear. I suggest that for Heracleitus the bright one was from the sea, and for Aristotle from the land, and vice versa. We can thus accept both Diogenes' statement that the bowls are filled with the bright and the doxographical tradition that the heavenly bodies' source is the sea, and at the same time explain the point that bothered Kirk: why Aristotle did not admit that his theory was identical with that of Heracleitus.

The key that opens the door to this hypothesis is the word τροπαί in Frag. 31: it means, as Kirk has said, 'sudden changes'. The sea is moist: it undergoes a 'sudden change' in the course of the way up (and evaporation is clearly a thing that occurs in an upward direction): what can the moist 'suddenly change' into? If we recall Heracleitus' interest in opposites the answer is obviously: into its opposite, viz. the dry.

It follows that once the act of evaporation has taken place the new substance that has originated from the sea is the bright dry exhalation that will arise as an ἄναμμα to become the flames of the heavenly bodies, the stellar fire: and Frag. 31 tells us that one of the τροπαί of sea is fire. Similarly the τροπή of <u>dry</u> earth must be moist, viz. the moist dark exhalation that appears to arise from the earth at nightfall to give us the darkness of night (cf. pp. 47-8 sup.). It may seem queer to modern ears to say that this moist exhalation, which will be seen to correspond to the Milesian aer, comes off the earth rather than the rivers and seas, and of course Aristotle reverts to the latter origin - but we must remember that Heracleitus is still living in a time when the difference between water vapour and air is unknown and is consciously disagreeing with the opinions of his predecessors, with whose theories he will have nothing to do.

It remains to dispose of the inconsistency between the passages of Aëtius in D. 22 A 11 and 12 (p. 163, sup.). I claim that in saying ἀπὸ τῆς ὑγρᾶς ἀναθυμίασεως in II 28, 6 Aëtius or his source made a careless error, but an error understandable in one familiar with Aristotle; he is meaning to refer to the exhalation that comes from the sea, and calls it the moist one, Aristotle's sea exhalation being moist. He should have said: ἀπὸ τῆς ἐκ τῶν ὑγρῶν ἀναθυμιάσεως, cf. Aët. IV 3, 12 where the soul is explained as ἀναθυμίασιν ἐκ τῶν ... ὑγρῶν (it is the bright exhalation that is meant), or the same phrase with ἀπό instead of ἐκ, so that the passage would then be parallel to Diogenes' τὴν ἀναθυμίασιν τὴν ἀπὸ τῆς θαλάττης, and to the phrase that Diels prints as the last part of Frag. 12: καὶ ψυχαὶ δὲ ἀπὸ τῶν ὑγρῶν ἀναθυμιῶνται.†

Once he had made this error it is also understandable how Aëtius could then in just one odd passage take himself literally, so to speak, and say in II 13, 8 ἀπὸ γῆς, since that is where Heracleitus' moist exhalation does come from. Alternatively he could again be confusing him with Aristotle, whose bright one does come from earth. There is yet another possibility: Aristotle later in the context quoted on p. 164 (viz. as 355 a 23) uses the word γῆ for the world rather than the dry land, and Cherniss (p. 134) in discussing the passage that I quoted uses the word 'earth' in the same sense; and it might be argued that Aëtius was doing the same.

Thus I claim that I can explain Aëtius' apparent self-contradiction by linking together Diels' A 11 and

II 28, 6 from A 12 as excusable slips in contrast to the other A 12 passage, which is correct, whereas the traditional interpretation that leads to the linking of Diels' arrangement can provide Aëtius with no such reasonable excuse, but rather exposes him to the charge of gross error in A 11 (unless he did mean 'the world' and not 'the land' in the latter).

Accepting the hypothesis that the land exhalation is moist and dark, then, while the sea one is dry and bright, let us examine the details of the system. The heavenly bodies are 'bowls' that collect the bright sea exhalation that produces their 'flames', in other words that collect matter that is on the last stage of its upward path towards fire. This corresponds to a stage when the rarest form of the aer of Anaximenes is just rarefying into what we call fire from what we call air. Meanwhile the dark moist earth exhalation is adduced to explain meteorological phenomena in the same manner as do the cloud-forming evaporation of Xenophanes and the dense aer of the Milesians.

It is doubtful, in fact unlikely, that Heracleitus (or Xenophanes) actually used the word ἀναθυμιασις, and it is possible that Heracleitus used either ἀτμίς or ἀήρ for the moist one: it has been claimed that he used the word καπνός for the other in view of the occurrence of the word in Frag. 7; but I think that this is a false inference, especially in view of the diffidence with which Aristotle names his dry exhalation πῦρ or καπνώδης ἀναθυμίασις in Meteor. 341 b 15, which contrasts sharply with the confidence with which he names the other ἀτμίς, a contrast repeated in 359 b 29, where the name καπνός is decided upon.

With regard to the astronomy and meteorology, the extant fragments give us little help. Frag. 99 tells us that if the sun did not exist it would be night for all the rest of the stars could do. Frag. 6 tells us that the sun is new every day (i.e. the bright exhalation in its bowl is quenched in the evening by the rise of the moist vapour, and rekindled in the morning). Frag. 3 says that the sun is as broad as a man's foot, if indeed Heracleitus is referring to real size and not apparent size, cf. Kirk p. 282. Frag. 57 asserts that day and night are a typical pair of interconnected opposites.

The astronomy is clear, however. The heavenly bodies are bowls that periodically collect the bright sea exhalation, and so shine, but their flames may be put out by moist vapour from earth that has not yet completed the 'way up' to fire, while the orientation of the bowls with respect to our line of sight produces phases or eclipses.

The meteorology is also clear. Diogenes tells us that daylight is produced by the enflaming of the bright exhalation in the bowl of the sun (cf. Frag. 99), while the preponderance of the dark vapour produces night. The latter idea corresponds exactly with the standard early Greek idea that darkness is a substance (one that we have so far called 'aer') that can actually be seen rising from the ground at eventide and progressively obscuring the landscape.

Summer, says Diogenes, is an increase of heat from the bright exhalation, and winter an increase of moisture from the dark one. This again is clear enough. We can add from our knowledge of Heracleitus' general theory of opposites and measures that day and night or summer and winter are quantitatively balanced phenomena.

For the rest, months and seasons and years and rains and winds, Diogenes just says that the explanations, on the exhalation theory, are similar. Details are unnecessary here, for the picture is quite clear. Diogenes says earlier that almost everything is explained by the sea exhalation; but, of course, wherever the sea exhalation has preponderated to produce a given phenomenon, there will have to be a balancing preponderance of the land one to preserve the overall measures. Kirk should not have taken this phrase of Diogenes to support his contention that there was only one exhalation; there are indeed many longish passages in Aristotle's work, for that matter, where the author speaks simply of 'the exhalation' rather than of 'one of the exhalations' since he is at the time only dealing with one, and it is clear which one.

From this consideration of the physical aspects of the exhalations we can see that Heracleitus has split the atmosphere, aer, into two different substances (cf. p. 159) so that he could no longer treat aer as a single world mass like fire water or earth. Anaximenes with his rarer and denser forms of aer produced the germ of the idea, Xenophanes with his moist exhalation pointed the way and Heracleitus finished the task. All that was now left to do was for Empedocles to perform his clepsydra experiment and prove the corporeal existence of invisible aer, water vapour being visibly corporeal. The confusion of 'fire', which is actually a phenomenon - gas heated to incandescence - with a substance remained in Greek thought, but apart from that if for 'invisible aer' we read 'oxygen' and for 'bright exhalation' we read 'incandescent oxygen' (for oxygen is the principle of combustion (v. p. 14) and is a main constituent of the atmosphere) and if for 'the moist exhalation' or 'dense aer' we read 'water vapour' (the principle of clouds and mists), and if we bear in mind that atmospheric nitrogen, neon, argon, crypton, and xenon are chemically inert and not discoverable except by laboratory techniques not available to the Greeks, we see that by a combination of elementary observation and pure thought the Greeks arrived at an analysis of the atmosphere that was not very wide of the mark. Henceforward, either in the guise of two exhalations, or of aether and aer, or even of fire and night, we shall consistently meet with this conception of atmospheric air as a mixture.

Unfortunately we find that the same concepts tend to crop up when the Greeks dealt with the soul, where to our way of thinking they are quite out of place. We find in Heracleitus the typical resemblance between the microcosm and the macrocosm. The exhalations are at work in psychology also, with their interchanges causing sleep and waking, death and life, just as in the macrocosm they cause day and night. Frag. 36 (v. p. 154 sup.) combines the microcosm and the macrocosm in one pronouncement and shows how the two link up. Soul replaces fire in the wording of a fragment that deals with the ways up and down. Thus soul is in some way connected with fire, and its origin is from water: it is a τροπή of water. This is a difficult subject, as Heracleitus tells us in Frag. 45:

> ψυχῆς πείρατα ἰὼν οὐκ ἂν ἐξεύροιο, πᾶσαν ἐπιπορευόμενος ὁδόν· οὕτω βαθὺν λόγον ἔχει.

Aristotle, however, in de Anima 405 a 24 says:

> καὶ Ἡράκλειτος δὲ τὴν ἀρχὴν εἶναί φησι ψυχήν, εἴπερ τὴν ἀναθυμίασιν, ἐξ ἧς τἆλλα συνίστησιν· καὶ ἀσωματώτατον δὴ καὶ ῥέον ἀεί.

In this passage the soul is identified with the ἀρχή of Heracleitus (cf. Vlastos' theory of the reason for the importance of fire, p. 151 sup.), or rather with 'the exhalation, from which he constructs all other things'. This is clearly the bright exhalation from the sea, the immediate τροπή of the sea, and the source of the fire of the heavenly bodies.

Since, then, soul is in its natural state made of the bright dry exhalation Heracleitus says in Frag. 118:

> αὔη ψυχὴ σοφωτάτη καὶ ἀρίστη.

On the other hand, an accession of the moist will tend to quench the fiery exhalation. Therefore it is not only chemically but also literally correct to say: ψυχῇσιν θάνατος ὕδωρ γενέσθαι (Frag. 36). An increase of the moist, e.g. by drinking, can lead progressively to drunkenness, sleep, and death. In Frag. 117 the drunken man is described as ὑγρὴν τὴν ψυχὴν ἔχων, and Frag. 77 (if genuine, v. Kirk p. 340) asserts:

ψυχῇσι τέρψιν ἢ θάνατον ὑγρῇσι γενέσθαι.

Aristotle is thus clearly correct in stating that the soul is made of the exhalation, though wrong in giving as the reason the fact that it is most incorporeal, for the incorporeality of the soul is definitely a post-Heracleitan idea. Some commentators did not follow Aristotle, however. Misled by the Stoic idea that aer fitted into Heracleitus' scheme in the way indicated in the so-called Frag. 76, they believed that soul replaced aer, not fire, in Frag. 36. For example Philo, de Aet. Mundi 21, p. 509, says of Frag. 36: ψυχὴν γὰρ οἰόμενος εἶναι τὸ πνεῦμα.

This error is bound up with another, that of supposing that the exhalation meant by Aristotle was the moist one that corresponds to the Milesian aer. This misconception appeared to be supported by the phrase that ends Arius' quotation of the river fragment, Frag. 12:

καὶ ψυχαὶ δὲ ἀπὸ τῶν ὑγρῶν ἀναθυμιῶνται. †

(Whether this is a genuine part of the fragment or a paraphrase of Frag. 36 - cf. Kirk p. 371 - is irrelevant here.) We have already (p. 168) noted a similar phrase, in Aët. IV 3, 12, D. 22 A 15: the whole sentence, which has obviously been influenced by Stoic ideas, is as follows:

Ἡ. τὴν μὲν τοῦ κόσμου ψυχὴν ἀναθυμίασιν ἐκ τῶν ἐν αὐτῷ ὑγρῶν, τὴν δὲ ἐν τοῖς ζῴοις ἀπὸ τῆς ἐκτὸς καὶ τῆς ἐν αὐτοῖς ἀναθυμιάσεως, ὁμογενῆ.

This sentence is repeated almost word for word in Nemesius de Nat. Hom. 2. We have already seen, however, that the true interpretation is not 'the moist exhalation', but 'the exhalation that comes from water', viz. the bright exhalation. Thus the comment of Philoponus (87, 11) on the passage from Aristotle's de Anima is more correct than the interpretation that Philo gave for Frag. 36; it reads:

πῦρ δὲ οὐ τὴν φλόγα φησὶν, ἀλλὰ τὴν ξηρὰν ἀναθυμίασιν.

If the soul were indeed aer or the moist exhalation, both of which consist of water vapour, how could the encroachment of water cause drunkenness sleep and death? Water added to water cannot make it any more wet! Moreover the fiery nature of the soul is supported by the connexion between fire and reason that we met when considering the cosmic fire, p. 150 sup..

The dry exhalation in the physical entity that is the soul considered as a corporeal substance is parallel to the reason in the psychological entity that is the soul considered as a spiritual concept. As Philoponus pointed out, in this context fire does not mean 'flames'.

Sextus Empiricus, adv. Math. VII 126sq., in a long passage, unfortunately contaminated with later ideas, especially those of Aenesidemus, claims that Heracleitus believed that by respiration we breathe in reason from what surrounds us (D. 22 A 16): this Heracleitus may well have thought, for we are surrounded by the atmosphere, which contains the bright exhalation as one of its constituents. Sextus adds a contrast between sleep and waking: in sleep the 'pores of the senses' (obviously a later idea) close and cut off the rational within us from the rational that surrounds us. This can surely not be a Heracleitan idea, even though Sextus gives a Heracleitan-sounding analogy with embers that glow held near a fire but go out when removed from it.

The furthest we could follow Sextus would be to say that when awake we absorb more of the bright exhalation from around us than when asleep, so that when asleep the moisture within us is the more able to quench it. The one essential thing is not to follow the commentators who thought that this passage, with its use of the word περιέχον, is evidence that Heracleitus did believe in some external store surrounding the universe - it is clear that Sextus is only referring to what surrounds our bodies, the atmosphere that we breathe.

It remains now to sum up in terms of my subject, aer, a discussion of Heracleitus that has had to be long both because of the obscurities in his own words (leading to the existence of many modern schools of thought on the subject) and because of the unreliability of our authorities.

Although in the system of Heracleitus aer is not one of the main world-masses, and is in fact rarely mentioned by name, his conception of it was, I believe, not greatly dissimilar to that of the other schools that we have discussed. It is not a separate world-mass, not a subject for explicit discussion, because it is no longer a unity. He has split it into two distinct substances instead of treating it as one substance capable of manifesting itself under different forms.

It is split into two exhalations, the bright one corresponding to the rarest form of the aer of Anaximenes in that it is about to turn into fire (though not considered as invisible), and the dark one corresponding to the normal misty or cloudy Milesian aer and to the moist exhalation of Xenophanes and to the darkness of the mythopoets and some of the Pythagoreans.

In the purely physical fragments fire is spoken of on the same level as water and earth, whereas aer is not mentioned; but the exhalations are given such importance in the physical system that Diogenes and Aristotle said that he explained (almost) everything by means of exhalation. The physical system is, I believe, a process of change known as the ways up and down that requires no element or hypokeimenon such as fire in the traditional account, but a process that is well symbolized by the word 'fire'. In this process the most obvious manifestation to the senses of the changes that are taking place is the balanced mutual encroachment of the two exhalations that gives rise to the various astronomical and meteorological cycles.

Heracleitus is indebted to his predecessors in part for the description of the properties of the exhalations, and perhaps also for the concept of Harmony that is so important for his general theory of opposites. He has, however, welded already familiar ideas into a completely new and original scheme, so that he can fairly claim to have disagreed with all his predecessors.

According to Sextus Empiricus, adv. Math. IX 360 et al., some commentators, e.g. Aenesidemus, said that Heracleitus made aer the first principle. This seems startling in view of the absence of aer from the list of world-masses, and is perhaps due to the mistaken view that aer formed a surrounding store from which reason was to be breathed in (p. 178). However, the exhalations are so definitely made the explanation of almost everything that if I were to believe that the system needed a hypokeimenon, which I do not, I should myself be inclined to say that this was aer in the sense that the latter as a mixture is the substance of which the exhalations are constituents, and therefore more appropriate to the task of being a hypokeimenon than fire in the sense of either the flame or the aether of Kirk, while fire is itself more suited to the task of being a symbol.

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CHAPTER SIX

THE ELEATIC SCHOOL

Heracleitus had, at any rate in pure science, no real school of followers. Men like Cratylus, for example, were more interested in the metaphysical or epistemological implications of his theory. On the other hand, we shall see that the exhalation theory, far more than the rest of Heracleitus' scientific thought, had a lasting influence, being adopted by more than one other school of thought. (We have already referred to the retention of the exhalation theory by a group probably including Antisthenes, cf. p. 164.)

The scene now shifts back again to the West: to Elea, and Parmenides. His date is a matter of dispute, since the traditional floruit (504-1 b.c.) conflicts with the statements of Plato. Suffice it to say that he probably wrote his extant work in the neighbourhood of 480 b.c.. Philosophically he was the most important of the early speculators, for his criticism of his predecessors, unlike that of Heracleitus, raised certain fundamental issues with which all subsequent thinkers, at least up to and including Plato, were forced to deal.

The conclusions that he reached appeared to rule out the evidence of the senses, a result that also appeared to follow from Heracleitus' flux theory (at least in the way in which it was understood in Plato's time), and the main concern of those of his successors that believed the senses to be in any way reliable was to σώζειν τὰ φαινόμενα.

Parmenides was ἀφύσικος, being a logician rather than a constructive scientific speculator. He took the premisses of monism, and from them proceeded by a process of rigid deduction to state their inescapable implications. As a result he showed once and for all that any monism <u>of the Ionian type</u> was untenable. (I say that his logic was rigid - it was according to his lights, but the science of logic was in its infancy, and Plato, especially in the Sophist, exposed certain defects in it, and it would not meet Aristotelian requirements.)

Much of the Way of Truth (for whose preservation we are largely indebted to Simplicius) is aphysical, and need not be considered in detail. Fortunately, when details are essential, we are at last in the position of having the ipsissima dicta instead of having to rely on the often dubious interpretations of ancient commentators.

The Way of Truth is very repetitive; it forms a circular chain of reasoning, and Parmenides himself says: "It is all one to me where I begin, for I shall come back there again". [x] The Way depends upon three premisses of which the first was assumed by all Parmenides' predecessors, the second, he claims, they ignored with fatal results, and the third is the basic premiss of Milesian monism:

1. The real existence of that which is.

ἡ μὲν ὅπως ἔστιν τε καὶ ὡς οὐκ ἔστι μὴ εἶναι,
Πειθοῦς ἐστι κέλευθος (Ἀληθείῃ γὰρ ὀπηδεῖ),

Line 35-36. Cf. 43, 57, 93-95.

2. The absolute non-existence of that which is not.

ἡ δ' ὡς οὐκ ἔστιν τε καὶ ὡς χρεών ἐστι μὴ εἶναι,
τὴν δή τοι φράζω παναπευθέα ἔμμεν ἀταρπόν·

37-38. The reason is as follows:

οὔτε γὰρ ἂν γνοίης τό γε μὴ ἐὸν (οὐ γὰρ ἀνυστόν)
οὔτε φράσαις. τὸ γὰρ αὐτὸ νοεῖν ἐστίν τε καὶ εἶναι.

39-40. Cf. 44, 72-73.

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[x] D. 28 B 5. To save space I shall hereafter refer to Karsten's line numeration (given in Diels-Kranz) rather than to fragment number and line. Because of the repetitiveness I shall not quote in full but shall give references to the several contexts in which a point occurs.

3. That which is, is one.

... ἐπεὶ νῦν ἔστιν ὁμοῦ πᾶν,
ἕν, συνεχές.

60-61. Cf. 95-96.

The existence of τὸ μὴ ὄν, which for brevity I shall call 'not-being', is impossible, and therefore it is impossible for anything to be created out of it: ex nihilo nihil fit is established as a permanent part of philosophical dogma:

πῇ πόθεν αὐξηθέν; οὐδ' ἐκ μὴ ἐόντος ἐάσσω
φάσθαι σ' οὐδὲ νοεῖν· οὐ γὰρ φατὸν οὐδὲ νοητόν
ἔστιν ὅπως οὐκ ἔστι.

62-64. Cf. 67-68.

Belief, however, in the reality of the sense world implies, although the Milesians failed to realise it, belief in the existence of not-being, whether one explains change and 'becoming' as growth and breathing in of the void as did the Pythagoreans (62-65, 67-68, 95-96 show that there is no void or anything else external to the universe), or as separation as did Anaximander (77-80, 89-92, and 105 show that there is no internal void and that 'being' cannot be split up), or as simultaneous going apart and coming together as did Heracleitus (91-92 use

Heracleitan terminology), or as the presence of more or less of the one real thing in a given volume as did Anaximenes (78-79 and 103-107 contest this), or by the assumption that being and not-being are the same and not the same (51-52, a disputed passage that may refer to Heracleitus).

Any monistic theory demands the existence of not-being either as an infinite external store from which the universe can grow (62-63, 67-68 and 95-96 abolish the external store and 81, 85-88 and 101-102 abolish the infinite), or as empty space for matter to move about in (59, 81, 84-85, 97, and 100 abolish motion, and in fact any sort of change), or as what could replace aer in a given volume when Anaximenes' rarefaction reduces the quantity of aer in that volume (78-79). Because, therefore, not-being does not exist, becoming and perishing, change and motion are impossible in a world that is monistic. Parmenides repeats many times the assertion that the universe must be uncreated and endless and there can be no becoming and perishing within it.

A further point (64-66) is that his predecessors had failed to show an efficient cause for their cosmogonies: why did the generative process start when it did?

This is, of course, a sound criticism; but there is, as Plato showed in the Sophist, error in the handling of not-being, and in fact τὸ μὴ ὂν ἔστι πως. The source of the error is confusion between the existential and copulative senses of the verb 'to be', which invalidates the logical treatment of the subject. Apart from that there is also the point that the mere fact that there happens to be no really existing thing in a certain space does not prove that the space itself does not exist. Emptiness and τὸ μὴ ὂν are not identical.

Again, the criticism of motion is not sound. It is not a necessary condition for motion that empty space be available for a thing to move into. Motion by mutual displacement is not only equally possible, but also the most common type of motion - as we walk or a fish swims the air or water displaced from in front of us flows round us and fills up what would otherwise have been an empty space behind us (in this I ignore, of course, the presence of inter- and intra-atomic void in modern theory: the point is that no void external to the moving object is involved). Motion within an absolutely uniform and homogeneous plenum may be, and in fact is, meaningless and ineffectual, but it is not impossible.

The explanation of motion by mutual displacement was soon adopted, e.g. by Empedocles, but the remainder of Parmenides' thesis showed that any monism of the traditional type was bound to fail as an explanation of the universe, and appeared to cast grave doubts on the reliability of the senses in their presentation of the universe to us. The only alternatives for Parmenides' successors (before Plato and Leucippus rehabilitated not-being) were either scepticism concerning the sense world, a path that would lead to metaphysics, or an attempt to save the phenomena by postulating an entirely new type of physical theory. Both alternatives were in fact tried, as we shall see.

First, however, we must pass from Parmenides' destructive criticism to his constructive thought. The logical treatment of the three premisses of p. 183 sup. led Parmenides to the conclusion that reality is uncreated and imperishable, complete immovable and without an end in time; it is in fact timeless; it is one continuous unity (58-61). It is indivisible and homogeneous (77). It is constant and unchanging, and finite (84-88). It is like a sphere in shape (101-108) and of uniform density throughout, being a plenum (77-80 and 102-108). It does not even manifest colour (100). This last point appears to deny visibility, for how can a thing be seen without colour? It may even be intended to deny any sensible quality, and certainly Parmenides earlier (54-55) attacks not only the eye but also the ear and the tongue as instruments of judgement.

It is often claimed (e.g. by Burnet and Bailey) that the One of Parmenides is corporeal. It has, however, none of all the attributes and properties that are normally associated with the corporeal (except that it is <u>like</u> a sphere - he never says that it <u>is</u> a sphere). Not only are colour, specifically, and the other sense qualities, by implication, denied it, but also it has not even the property of duration - it is timeless:

οὐδέ ποτ'ἦν οὐδ' ἔσται, ἐπεὶ νῦν ἔστιν ὁμοῦ πᾶν.

What has happened is that Parmenides has realised that the existence of matter as we know it cannot be proved by rigid logic from his premisses. He has proceeded as far as he can by logic, and then stopped short before error slips in with the admission of corporeality. The sensible qualities of matter are not rational and are not logical consequences of 'being'.

The One, then, is not entirely physical nor entirely abstract. It is eternally now; i.e. it is removed from time but left in space. Parmenides never calls it 'body' but does give it a shape. Plato in discussing his spherical 'body of the world' (Timaeus 31 B) says that it must 'be bodily, and so visible and tangible; and nothing can be visible without fire, or tangible without something solid, and nothing is solid without earth'. This contrasts sharply with Parmenides' account. The latter is not concerned with the physics of matter. It is the first step on the path to metaphysics, the second being the removal of the Real from space as well as time.

With this shattering of the Milesian interpretation of matter, we find aer or the infinite or the void deprived at one blow of the all-important position of being the breath of the universe or the infinite store of matter. After Parmenides (except in the theories of reactionaries like Diogenes of Apollonia, Chap. 9) we may expect philosophy to be either metaphysical or pluralistic - until a monism of a new type is postulated in atomism. So from now on aer and other substances known to us to be gases will no longer be considered as primary and unique, but as equal in status and individuality to other things.

According to Parmenides the error of the Ionians was that they illogically accepted the sense world as real (thought not the senses is the criterion of truth, lines 54-56). The error of the Pythagoreans was that they identified mathematical objects with material objects. The Sphere of Parmenides is a perfect mathematical figure, but it has no fire or earth as did that of Plato's Timaeus. The Way of Truth stops short just at the very point where the perfect sphere of being timelessly occupying the whole of space is established, before illegitimate concepts appear, such as time and generation, sensible quality and matter.

At this point we have the transition to the Way of Opinion. This is extremely fragmentary, and some of the fragments that have survived are unfortunately of the nature of introductions to detailed passages that have not survived, and tell us little or nothing.

The Way of Opinion is a cosmology; in other words it lies across the same gap between mathematical or logical figure and sensible body as did the Pythagorean cosmology: but whereas the latter bridged that gap by a bald statement of identity, Parmenides bridged it by a transition from what is claimed as valid to what is admitted to be invalid but plausible. It is logically unprovable and cannot be called true, in some respect like a Platonic myth.* In effect Parmenides separated metaphysics and physics as two distinct studies, and it was left to Plato to attempt to reunite them into a unified theory that would restore some reality to the sense world while still asserting the more truly real nature of the world of Ideas. The latter is removed from space as well as from time, but permitted life (soul) and motion, while the former is a half way stage between being and not-being, and is the object of opinion, cf. Republic Book V, 478D:

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* I follow Aristotle (Met. 986 b 27) and Cornford (Op. cit. pp. 50sq.) in regarding the Way of Opinion as Parmenides' own work. Burnet (E.G.P. pp. 182sq.) is clearly wrong in claiming it to be Pythagorean. Nor can it be the opinion of laymen (Theophr. quoted by Alexander in D. 28 A 7, and Zeller), for it is too elaborate, nor eclectic (Diels and Freeman) for it is too closely knit.

It is the opinion of 'mortals' because the speaker is a goddess, and I believe it to be original speculation of Parmenides about the sense world, whose lack of validity he is careful to emphasize. I am not convinced by the arguments of Freeman and G.E.L.Owen that its purpose is to afford an example for criticism. (Owen, in an unpublished paper read to the Northern Association for Ancient Philosophy, tried to prove that it is an example of a normal cosmology given to show how to expose the presuppositions of such cosmologies, namely by exposing the duality involved - thus the structure of the poem, after the introduction, would be: first the antidote, and then an example of the poison.) I prefer to believe with Cornford that it is a serious and positive contribution.

οὐκοῦν ἔφαμεν ... τὸ τοιοῦτον μεταξὺ κεῖσθαι τοῦ εἰλικρινῶς ὄντος τε καὶ τοῦ πάντως μὴ ὄντος καὶ οὔτε ἐπιστήμην οὔτε ἄγνοιαν ἐπ' αὐτῷ ἔσεσθαι, ἀλλὰ ... δόξαν.

Parmenides would not have claimed that his speculation resulted in a system that has a definite relation with the Way of Truth, as Plato claimed in the case of the Timaeus for all that it was an εἰκὼς μῦθος.

We must now examine the Way of Opinion to find out what part gaseous substances play in it. The relevant fragments are:

μορφὰς γὰρ κατέθεντο δύο γνώμας ὀνομάζειν·
τῶν μίαν οὐ χρεών ἐστιν - ἐν ᾧ πεπλανημένοι εἰσίν -
τἀντία δ' ἐκρίναντο δέμας καὶ σήματ' ἔθεντο
χωρὶς ἀπ' ἀλλήλων, τῇ μὲν φλογὸς αἰθέριον πῦρ,
ἤπιον ὄν, μέγ' (ἀραιὸν) ἐλαφρόν, ἑωυτῷ πάντοσε τωὐτόν,
τῷ δ' ἑτέρῳ μὴ τωὐτόν· ἀτὰρ κἀκεῖνο κατ' αὐτό
τἀντία νύκτ' ἀδαῆ, πυκινὸν δέμας ἐμβριθές τε.
τόν σοι ἐγὼ διάκοσμον ἐοικότα πάντα φατίζω,
ὡς οὐ μή ποτέ τίς σε βροτῶν γνώμη παρελάσσῃ.

Lines 112-120, end of Frag. 8.

αὐταρ ἐπειδὴ πάντα φάος καὶ νὺξ ὀνόμασται
καὶ τὰ κατὰ σφετέρας δυνάμεις ἐπὶ τοῖσί τε καὶ τοῖς,
πᾶν πλέον ἐστὶν ὁμοῦ φάεος καὶ νυκτὸς ἀφάντου
ἴσων ἀμφοτέρων, ἐπεὶ οὐδετέρῳ μέτα μηδέν.

L. 121-124, Frag. 9.

αἱ γὰρ στεινότεραι πλῆντο πυρὸς ἀκρήτοιο,
αἱ δ' ἐπὶ ταῖς νυκτός, μετὰ δὲ φλογὸς ἵεται αἶσα·

ἐν δὲ μέσῳ τούτων δαίμων ἣ πάντα κυβερνᾷ·
πάντα γὰρ <ἣ> στυγεροῖο τόκου καὶ μίξιος ἄρχει
πέμπουσ' ἄρσενι θῆλυ μιγῆν τό τ' ἐναντίον αὖτις
ἄρσεν θηλυτέρῳ.

125-130, Frag. 12.

We find here a physical dualism with two 'elements' (of which it is not right to name even one *), each of which has a number of δυνάμεις, by which is meant active 'powers' proper to bodies enabling them to affect our senses: such powers are the hot and the cold etc. - we are still in the age of 'quality-things' before the concept of quality has been distinguished from that of substance. ** The elements are 'the etherial fire of flame' and 'dark night'. The powers of fire given in Frag. 8 are, if the reading given by Diels-Kranz be accepted, gentleness and lightness, with rareness as a gloss (but cf. ἀραιόν in D. 28 A 37 quoted inf.), and homogeneity: those of night are darkness, density and weightiness. Simplicius (Phys. 31, 3, D. p.240) quotes a scholium that adds to this list:

ἐπὶ τῷδέ ἐστι τὸ ἀραιὸν καὶ τὸ θερμὸν καὶ τὸ φάος

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* Line 113. So Gomperz and Cornford (Op. cit. p. 46), pace Dies, Burnet and Raven.

** Cf. Cornford, Op. cit. p. 47.

καὶ τὸ μαλθακὸν καὶ τὸ κοῦφον, ἐπὶ δὲ τῷ πυκνῷ ὠνόμασται τὸ ψυχρὸν καὶ τὸ ζόφος καὶ σκληρὸν καὶ βαρύ· ταῦτα γὰρ ἀπεκρίθη ἑκατέρως ἑκάτερα.

What are these two elements? Fire is plain, but what is night? Aristotle identifies φάος and νύξ with τὸ θερμόν and τὸ ψυχρόν in several places, * which is reasonable; but also with πῦρ (correctly) and γῆ, for example in Met. 986 b 34: **

> δύο τὰς αἰτίας καὶ δύο τὰς ἀρχὰς πάλιν τίθησι, θερμὸν καὶ ψυχρόν, οἷον πῦρ καὶ γῆν λέγων. τούτων δὲ κατὰ μὲν τὸ ὂν τὸ θερμὸν τάττει, θάτερον δὲ κατὰ τὸ μὴ ὄν.

Other commentators followed him; *** but Simplicius, who had the poem in front of him, corrects the identification in Phys. 25, 15, D. 28 A 34:

> Π. ... πῦρ καὶ γῆν ἢ μᾶλλον φῶς καὶ σκότος.

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* E.g. Met. 986 b 34, D. 28 A 24; de GC 336 a 3, A 35.

** Cf.: de GC 318 b 6, and 330 b 13, A 35, and Phys. 188 a 20.

*** E.g.: Theophr. Phys. Op. Fr. 6, A 7; Hipp. Ref. I 11, 1, A 23; D.L. ix 21, A 1; Cic.Ac. II 37, 118, A 35; (all these state that fire is the moving cause and earth the material cause, an obvious Aristotelian anachronism) Clem. Protr. 5, 64, A 33 (where fire and earth are called gods); Simpl. Phys. 30, 13 and 179, 31 both in the introduction to D. 28 B 7-8. On each occasion Simplicius also gives the correct pair 'light and darkness'.

'Night' cannot mean 'earth'. Aristotle identifies Parmenides' fire with his own, which is hot and active; gives, without Parmenidean authority, to night the contrary powers cold (plausible enough) and passivity: then the typically Aristotelian active/passive relationship is imported into Parmenides' theory by Aristotle or Theophrastus in the form of the moving/material cause opposition, and Aristotle himself also misapplies the being/not-being opposition. Finally Aristotle identifies his own contrary to fire, earth, which is cold and passive, with the contrary of fire in Parmenides' theory.

Aristotle's misinterpretation was the more plausible because Plato's sphere contained fire and earth (v. p. 189 sup.). Burnet tried to demonstrate a later Pythagoreanism with fire and earth as primary elements (E.G.P. p. 293), but as Cherniss points out (Op. cit. p. 48, n. 162) this 'can not explain why Aristotle, who takes the second part of the poem as representing Parmenides' own views and not Pythagorean theory, misquotes the text'.

Night must represent the aer of Parmenides' predecessors. He was a dissident Pythagorean, and as we have seen the early Pythagoreans had in their cosmology a dualism of fire and aer or void. Parmenides' major disagreement with the Pythagoreans would have been over the identification of mathematical and physical objects, and there is no reason why he should not have accepted what was plausible from their cosmology - he denied the void, of course, but to accept aer as a dark substance, viz. darkness itself or 'night', would not trouble him. Night is darkness and darkness is aer to all the early Greeks, as we have repeatedly seen. We shall shortly see that night plays a part in Parmenides' astronomy similar to that of aer in Anaximander's. Moreover fire and night in this sense form a dualism parallel to that of the light and dark exhalations of Heracleitus' cosmology.

In this connexion note that Plutarch (Adv. Col. 1114 B) says:

> ὅς γε καὶ διάκοσμον πεποίηται καὶ στοιχεῖα μιγνὺς τὸ <u>λαμπρὸν</u> καὶ <u>σκοτεινὸν</u> ἐκ τούτων τὰ φαινόμενα πάντα καὶ διὰ τούτων ἀποτελεῖ.

He uses here precisely the same words for 'light and dark' as Diogenes Laertius did about Heracleitus' exhalations (ix 9, p. 160 sup.). Thus although he dissented from Pythagoreanism, Parmenides could well retain this pair of primary substances since Heracleitus had confirmed their importance even though not admitting them as 'elements', and Xenophanes, to whose work his own bears some similarity, also appears to have pondered the idea of exhalations.

In other words, light and night were in this sense indeed 'the opinions of mortals', for Ionia, the Pythagoreans, and Xenophanes all employed them in their own ways. Even in Plato (Tim. 58 D) one form of aer is given the names ὀμίχλη and σκότος. The reason why Parmenides did not use the word 'ἀήρ' as the Pythagoreans did may have been that as a dissenter he preferred to use Ionian terms (ἀραιόν and πυκινόν are also Ionian terms).

Parmenides was not alone in choosing fire and aer as dualistic principles: we shall see later that the minor Ionian Oenopides of Chios also chose them.

These two substances are employed in the astronomical theory, see Frag. 12 sup., which is obscure by reason of its brevity, but is amplified (probably without the addition of any further genuine material) by Aëtius in a passage (II 7, 1, D. 28 A 37) that has to be used with caution - Aëtius' interpretation is not necessarily any more accurate than modern ones, and is itself obscure and difficult to interpret. The passage is as follows: *

> Π. στεφάνας εἶναι περιπεπλεγμένας, ἐπαλλήλους, τὴν μὲν ἐκ τοῦ ἀραιοῦ, τὴν δὲ ἐκ τοῦ πυκνοῦ· μικτὰς δὲ ἄλλας ἐκ φωτὸς καὶ σκότους μεταξὺ τούτων. καὶ τὸ περιέχον δὲ πάσας τείχους δίκην στερεὸν ὑπάρχειν, ὑφ' ᾧ πυρώδης στεφάνη, καὶ τὸ μεσαίτατον πασῶν στερεόν, περὶ ὃ πάλιν πυρώδης. τῶν δὲ συμμιγῶν τὴν μεσαιτάτην ἁπάσαις <ἀρχήν> τε καὶ <αἰτίαν> κινήσεως καὶ γενέσεως ὑπάρχειν, ἥντινα καὶ δαίμονα κυβερνῆτιν καὶ κληδοῦχον ἐπονομάζει Δίκην τε καὶ Ἀνάγκην.

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* The details are disputed, particularly the order of the bands, their identification with the heavenly bodies, and the position of the goddess. The latest discussion is J.S.Morrison's 'Parmenides and Er' (J.H.S. LXXV, 1955). He tends to hedge over the identification of night with aer or earth; and his interpretation of the system is ingenious rather than convincing.

Diels also vitiates his picture by taking night as earth. Burnet believed that the Pythagoreans took over Anaximander's theory of 'bicycle tyres' (with improvements about the relative position and order of the bands), that Parmenides is just quoting the Pythagoreans, and that the Timaeus and the Myth of Er are also practically pure Pythagoreanism. He thus considerably oversimplifies. I can not accept that the Pythagoreans adopted the tubes of Anaximander. The clearest interpretation is perhaps that of A.Rey (La Jeunesse de la Science Grecque, Chap. VIII). Heavenly motions are circumpolar (cf. Anaximenes, Heracleitus, Xenophanes). The narrowest (and farthest) bands are those nearest the pole, and the wider are nearer the celestial equator. Alternate bands are of fire and aer. No bands are themselves 'mixed'; fire runs radially across the dark bands not circumferentially, perhaps through Anaximandrian orifices. The mottled appearance of the moon and Milky Way may be due to mixture. The order of the bands is: Olympus (Frag. 11), i.e. outer wall; Milky Way and Common Heaven, i.e. stars and planets; sun and moon, detached from Milky Way; earth. The goddess is on the axis, not on a middle band.

The astronomical details need not detain us; what is relevant is the nature of the substances employed. Aëtius several times reaffirms that the heavenly bodies are of fire (D. 28 A 38, 39, 40a, 41, and 42) though he also states (A 43 and 43a) that the sun moon and Milky Way are mixtures of the rare and the dense or the hot and the cold, perhaps because of his confusion over 'mixed bands' or perhaps because of the mottled appearance of the last two. Clearly their light comes from the fire in the fiery bands, as it did with Anaximander, and penetrates the dark bands to reach our eyes perhaps, as A.Rey said (cf. footnote on p. 198), through Anaximandrian orifices. At any rate, whatever the details, the scheme is claimed by most scholars to be an improvement on that of Anaximander, and I agree. Night therefore plays the same part as did the aer of Anaximander, a further point in favour of the identification of night with aer rather than with earth. Its properties, then, will have been just those we have already attributed to the normal Ionian dense aer or to the dark exhalation of Heracleitus.

In the continuation of the passage quoted on p. 198 Aëtius tells us that aer is a vapour caused by the 'felting' of earth, while the sun and Milky Way are 'breathings-in' of fire. Ps. Plutarch (Strom. 5, D. 28 A 22, from Theophrastus) would appear however to be more correct, saying that earth originates from the dense (aer).

To sum up, the astronomy is an intermediate stage in the development from the system of Anaximander to that of the Myth of Er. It contains improvements due to the greater empirical knowledge of the Pythagorean school from which Parmenides dissented (especially the fact that the moon shines by reflected light, and the identity of the Morning and Evening Stars - Venus - Frag. 14 and D. 28 A 40a), but essentially fire and aer are still of the typically Ionian sort. Some Pythagoreans may have believed in the same type of aer, but not those who equated aer and the void.

Finally, certain of the fragments are physiological, but too scanty to be informative. From them and the doxology we can gather that the facts of life, reproduction, and thought are connected with the interaction of the hot and the cold, i.e. with fire and night. The influence of Alcmaeon may be seen in this physiological interest.

As far as the study of aer and other gases is concerned, Greek medical and physiological theories are not always relevant to this attempt to outline the development of knowledge of their nature and properties. They tell us not what aer is thought to consist of, but how the body is thought to make use of it in the processes of respiration and sensation. Medicine tends, naturally, to accept the current philosophical theories concerning the actual nature of the aer involved. I propose therefore from now on to postpone the medical and psychological theories of the natural philosophers (except when they are immediately relevant to the physical discussion) to an appendix in which I shall also include certain of the theories of the various schools of medicine. This appendix will be brief, covering rapidly the ground of a subject that I propose to make the contents of a future full-scale discussion.

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Section ii.

As we shall see, the arguments of Parmenides had a very considerable affect on the thought of subsequent Greek scientific speculators. Some of his arguments were so cogent that they gained immediate acceptance. Others, including some of equal cogency, were so awkward that in order for normal speculation to continue they had to be circumvented if they could not be disproved. While few apart from Diogenes of Apollonia still adhered to a monism of an Ionian type, many thinkers wished to proceed along the path of pluralistic science rather than that of metaphysics. The Way of Truth was a challenge to these.

The Pythagorean school accepted the challenge, made amendments to their system, but remained pluralistic. Moreover the challenge was accepted by two new figures, Empedocles and Anaxagoras, pluralists both. We shall be dealing with all these very shortly, but before doing so we must consider the remaining figures of the Eleatic school, Zeno of Elea and Melissus of Samos. Their purpose in life was to uphold Parmenidean principles against these opponents. When the arguments of Parmenides, so far from giving plurality the coup de grace, were actually accepted and even made the basis of new and more advanced pluralistic systems, the Eleatics attacked their new opponents by taking their basic assumptions and reducing them to absurdity by means of dilemma and paradox. They aimed to show that plurality is completely unworkable.

Consequently the major contribution of both Zeno and Melissus to philosophy was in the sphere of destructive criticism. For this reason, I propose only to make a few general remarks about them here: I shall discuss their arguments in detail as each becomes relevant while I am dealing with the opponent concerned.

The relative chronology of the main contestants in the debate is disputed - some of the traditional 'floruits' conflict with other evidence. Zeno's main opponents are clearly the Pythagoreans. However Suidas (D. 29 A 2) gives the name of one of his works as 'Commentary on Empedocles'. On the other hand, a case has been made out (v. Chap. 8 inf.) for the assumption that Anaxagoras was familiar with his arguments. Melissus is known to have been an admiral of the Samian fleet in 441 b.c., and patently refers to Anaxagoras. I shall therefore assume the following order of speakers in the debate, so to speak: Parmenides - Empedocles - Zeno - Anaxagoras -

Melissus - the Atomists ... with the Pythagoreans keeping up a running commentary all the while (v. Chap. 10).

Zeno's arguments against his immediate opponents were almost all mathematical or logical in character rather than physical. They concerned plurality, motion, indivisibility and infinite divisibility, and discreteness and continuity, for the most part. It is not so much the arguments themselves as the form taken by the physical theories of the opposition as a result of them that will be relevant to this discussion of aer.

Zeno was so much a destructive critic that we have practically no information about his holding any constructive opinions. There is just the statement of Diogenes Laertius in D. 29 A 1. The void is non-existent (cf. Parmenides). Basic in the world are the hot, the cold, the dry, and the moist; and these change into one another (cf. Anaximander). Men sprang from the earth (cf. Xenophanes). Soul was a mixture of the opposites with no one of them predominating (cf. certain Pythagoreans?). One may doubt this account - it accords ill with Zeno's Eleatic background.

Melissus too was mainly a destructive critic. He was, however, an Ionian by birth and probably by training.

As a convert to Eleatic doctrines, he has a fresh approach and a rather more open mind. He uses some of the same destructive arguments as Zeno; but he produces some constructive ideas as well. Moreover his arguments as a whole are more physical in character. In fact Aristotle says in Met. 986 b 18 sq. that he substituted a material One for the conceptual One of Parmenides, and Galen (D. 30 A 6) says that his followers called his One 'matter' since it was not equated with any one of the normal four 'elements'.

In fact his One is similar to that of Parmenides in many respects, especially in unity, immutability, and homogeneity. It is not, however, removed from time (Frag. 1, cf. Frag. 2). But the main difference is that it is not limited but infinite in space as well as in time. The reason for this striking amendment is that if limited it would be bounded by something else, sc. void, (Frag. 5). This very infinity gives a reason for unity and uniqueness such as Parmenides had failed to provide (Frags. 5 and 6).

The main targets of his destructive criticism were change, motion, the void, and lack of homogeneity. These concepts are, it will be seen, more physical than those chiefly attacked by Zeno.

Frag. 7 deals with change in the guises of perishing, growth, change of 'cosmos' (arrangement, structure), and pain or grief (terms apparently meaningful to Anaxagoras). All these contradict eternal existence (the law of identity) and homogeneity. Frag. 7 proceeds to deny the void, and to deny motion since there is no empty space and no room to enter into the full. Anaximenes' theory also stumbles over the non-existence of void, which rarefaction entails.

Frag. 8 denies plurality and change by demonstrating the fallibility of the senses and asserting the law of identity. The argument against the senses appears to be directed towards Anaxagoras, who admitted their weakness and yet accepted their evidence for plurality and change.

All these arguments will be dealt with in detail as and when they become relevant, and it will become apparent that Aristotle's poor opinion of Melissus was in fact unjustified. We shall see, in particular, how Frag. 8 gave a hint to the pluralists, especially the atomists, concerning the essential nature of their basic entities. With this in mind, then, let us leave the Eleatics and consider their opponents.

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CHAPTER SEVEN

EMPEDOCLES

We have seen how Parmenides showed not only that monism is impossible but also that logic cannot prove the existence of the material world. He had, as Plato saw, paved the way for the separation of physics from metaphysics. His immediate successors did not realise this, however, and concentrated upon trying to 'save the phenomena' and to avoid the consequences of his denial of the possibility of change and motion in a monistic universe.

They saw two possible solutions: dualism and pluralism. The Pythagoreans already had a dualism of a sort, but not one such as to satisfy the conditions laid down by Parmenides. To us, accustomed to modern physics, in which structure as expressed by mathematical equations is all-important even though the relevance of the latter to the sense world is not always apparent to the layman, the Pythagorean number-philosophy seems to have been on the right track: but they had not, of course, the mathematical equipment with which to succeed (the calculus as used by Leibnitz and Newton is necessary).

Another type of dualism was now tried: a physical dualism of the Ionian type that replaced the monists' one principle by a pair. Typical is Oenopides of Chios, a younger contemporary of Anaxagoras. Most of our information about him concerns descriptive astronomy and geometry, but in Sext., Pyrrh. Hyp. III 30, D. 41 A 5, we read that he made fire and aer the principles. This is the same pair that we find in the Pythagorean cosmology and in the Way of Opinion, but we may guess that he explained change in the Ionian rather than in the Sicilian manner. Such an explanation would be no more successful than Ionian monism. It merely contradicts Parmenides' statement that all is one without escaping from the monists' difficulties over explaining qualitative change. Earth seems just as illusory when we are told that it consists of fire and aer as when we are told that it is just aer.

It was not sufficient merely to increase the number of primary substances: it was also necessary to explain the precise process by which those substances could combine or interact to produce other substances differing in sensible properties from themselves. Moreover Parmenides had demanded that an efficient cause be given for motion, that is, if one refuses to accept the impossibility of motion itself and manages to explain how it could occur without introducing 'not-being' into the system.

The same objections are valid against Ion of Chios, the tragedian, who entered the philosophical lists with a theory of three elements, according to Isocrates and Philoponus (D. 36 A 6), namely fire aer and earth.

Such extensions of Milesian theory being inadequate, there were two alternatives open to those who wished to save the phenomena. They could either increase the number of primary substances to a finite number large enough to explain by their combination the existence of all the substances presented to the senses, and at the same time propose a theory of the mechanics of that combination and of motion and change, or postulate an infinite number of substances all different and all equally primary. Both of these courses were taken by different schools of thought. Later a third possibility revealed itself after they had failed fully to satisfy the requirements: a return to a monism of a different type. Instead of a single substance one could postulate a single type of entity of which large numbers exist, which could in various conditions and circumstances manifest various sensible properties: this entity is the atom.

The first of these solutions which was tried was that giving a finite number of principles, the solution of Empedocles. Empedocles of Akragas is again of uncertain date. He may have been born a little before 490 B.C., though his traditional floruit is 444 B.C.. Like Pythagoras and Heracleitus he regarded himself as a man with a religious message. His work falls into two parts, 'physics' and 'Purifications'; and it is not always easy to see how the two may be mutually consistent, or even not bluntly contradictory.

In physics he was a mediator between Parmenides and the senses. His attitude to the latter is reminiscent of that of Heracleitus. He admitted that we cannot trust the senses entirely (Frag. 2, Diels); but did not deny their use altogether, as did Parmenides. They can not, through the incompleteness of any one man's experience, he thought, give us a complete overall picture of the universe. Within each individual man's limited experience, however, understanding, reason, may make such use of the senses as it can, as Frag. 3, lines 9-13, says:

> ἀλλ' ἄγ' ἄθρει πάσῃ παλάμῃ, πῇ δῆλον ἕκαστον,
> μήτε τιν'ὄψιν ἔχων πίστει πλέον ἢ κατ'ἀκουήν
> ἢ ἀκοὴν ἐρίδουπον ὑπὲρ τρανώματα γλώσσης,
> μήτε τι τῶν ἄλλων, ὁπόση πόρος ἐστὶ νοῆσαι,
> γυίων πίστιν ἔρυκε, νόει δ'ῇ δῆλον ἕκαστον.

The senses, which we may thus up to a point trust, present us with a world in which plurality, motion, and change (becoming and perishing) occur. To explain this Empedocles started from the admission that 'being' must be as Parmenides described it and that 'not-being' does not exist; but he modified Parmenides' conception in such a way as to permit the possibility of plurality, motion, and change without necessitating the postulation of a void. In a homogeneous and uniform plenum like the sphere of Parmenides motion would be meaningless and useless. The final result of a motion would still be a homogeneous and uniform plenum. (We can, of course, only be considering motion within the plenum - the whole cannot move for there is nothing outside it and it fills the whole of the universe.)

If, however, we regard the plenum as containing a number of different entities to each of which we allot all the properties of the Parmenidean One except uniqueness, and if we deny the existence of void so that all these entities are in complete mutual contact within what is therefore still a genuine plenum, we can account for locomotion by a process of mutual displacement (cf. p. 186 sup.), and account for change by a given volume's having within it at one time a greater portion of this entity and at another time a greater portion of that. More of this and less of that or more of that and less of this is possible within a given volume, whereas Parmenides had complained (lines 78-79, p. 185 sup.) that more or less of the one and only thing was not, as Anaximenes thought, possible.

Change in general (of which the most obvious kind is becoming or perishing) is therefore the manifestation to our senses of the interchanges of position by mutual displacement of the primary entities. Change is illusory in the sense that there is no becoming out of, or perishing into, 'not-being': this is a good illustration of the way in which reason must be brought to the aid of our fallible senses. The entities which by their movements give the impression of becoming and perishing are themselves uncreated, imperishable, and immutable, and also individually homogeneous, full of 'being', and immune from internal movement. They are just a plurality of Parmenidean 'Ones' - and uniqueness was merely a premiss of Parmenides, the monistic premiss that he took from the predecessors whom he was criticizing. He did not really adduce very cogent proofs against plurality itself, only against accepting as real the apparent plurality of sense phenomena in a universe that was to be explained on the monistic hypothesis. His follower Melissus admits that if we accept sense data (which he did not) plurality is possible (Frag. 8), and after giving reasons why we should not accept them states the condition upon which those who do so may have their plurality:

> οὕτως οὖν, εἰ πολλὰ εἴη, τοιαῦτα χρὴ εἶναι, οἷόν περ τὸ ἕν.

This is just the condition that Empedocles has accepted. In Frags. 11 - 14 he repeats in almost Parmenidean language the Eleatic arguments against becoming and perishing, the void, and growth; and perhaps in Frag. 13 rarefaction and condensation is aimed at as well:

11. νήπιοι· οὐ γάρ σφιν δολιχόφρονές εἰσι μέριμναι,
οἳ δὴ γίγνεσθαι πάρος οὐκ ἐὸν ἐλπίζουσιν
ἤ τι καταθνῄσκειν τε καὶ ἐξόλλυσθαι ἁπάντῃ.

12. ἔκ τε γὰρ οὐδάμ' ἐόντος ἀμήχανόν ἐστι γενέσθαι
καί τ' ἐὸν ἐξαπολέσθαι ἀνήνυστον καὶ ἄπυστον·
αἰεὶ γὰρ τῇ γ' ἔσται, ὅπῃ κέ τις αἰὲν ἐρείδῃ.

13. οὐδέ τι τοῦ παντὸς κενεὸν πέλει οὐδὲ περισσόν.

14. τοῦ παντὸς δ' οὐδὲν κενεόν· πόθεν οὖν τί κ' ἐπέλθοι;

Like Parmenides, Empedocles is repetitive in style, and the same points are made explicitly or implicitly in other contexts too. Frag. 15 puts the argument against becoming and perishing from the human point of view, and Frag. 8 states that 'mingling' and 'interchange' are substituted for them as an explanation of change: *

ἄλλο δέ τοι ἐρέω· φύσις οὐδενὸς ἔστιν ἁπάντων
θνητῶν, οὐδέ τις οὐλομένου θανάτοιο τελευτή,
ἀλλὰ μόνον μίξις τε διάλλαξίς τε μιγέντων
ἔστι, φύσις δ' ἐπὶ τοῖς ὀνομάζεται ἀνθρώποισιν.

Frag. 9, whatever the meaning of the disputed words in the text, makes the same general point, and adds the idea of 'separation':

οἱ δ' ὅτε μὲν κατὰ φῶτα μιγέντ' εἰς αἰθέρ'ἵ<κωνται> †
ἢ κατὰ θηρῶν ἀγροτέρων γένος ἢ κατὰ θάμνων
ἠὲ κατ' οἰωνῶν, τότε μὲν τὸ <λέγουσι> γενέσθαι,
εὖτε δ' ἀποκρινθῶσι, τὸ δ'αὖ δυσδαίμονα πότμον·
ἣ θέμις <οὐ> καλέουσι, νόμῳ δ' ἐπίφημι καὶ αὐτός.

So far we know that we are dealing with a plurality of entities and that they obey the Parmenidean rules. We must now discuss their number and nature. They are four, fire air water and earth. It has often been said that in making his choice Empedocles quite naturally took

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* Cherniss (Op. cit. pp. 109 n. 446 and 243 n. 114) has triumphantly vindicated Plutarch in taking φύσις to be 'becoming' and most scholars in taking θανάτοιο τελευτή to be 'end in death' against Lovejoy and Burnet who interpret 'substance' or 'permanent nature' and 'end of death'.

the four traditional 'opposites', the quality-things, and turned them into 'elements', things pure and simple. It is not clear, however, just which opposite would correspond to which element. Aristotle's identification of each so-called element with one from each pair of opposites, e.g. fire is hot and dry, is clearer (de GC 330 a 30). Consequently I prefer the more recent hypothesis (of e.g. Kirk, v. p. 158[x] sup., and Cherniss, Op. cit. p. 399) that he took the three main world-masses of Heracleitus, and, after proving (more cautious scholars add: or adopting from someone else the proof) that air is corporeal, added it to the list.

These four substances he called πάντων ῥιζώματα (Frag. 6, v. inf.), but Plato used the word στοιχεῖα, first at Theaet. 201E, and again at Tim. 48B, where he says:

> But we speak as if men knew what fire and each of the others is, ἀρχὰς αὐτὰ τιθέμενοι στοιχεῖα τοῦ παντός, whereas one who has ever so little intelligence should not rank them in this analogy even so low as syllables.

This is a vitally important passage, for, as Burnet says (E.G.P. p. 230), it, together with Pythagorean criticism, made it virtually impossible for Aristotle to understand how Empedocles could have imagined the 'roots' to have been elementary, so that he misinterpreted them as being derivative from the Sphere which he takes as a substrate, thus making Empedocles just another monist. στοιχεῖον has as one of its meanings 'letter' (or better, according to Liddell and Scott s.v., a simple sound as the first element of language, a 'phone' rather than a 'letter'), but after Plato's use of it here and the atomists' use of letters to illustrate the arrangement of atoms the word was adopted as the technical term for an 'element'.

The 'roots' really were elements. An element was defined on p. 5 sup. as: "A distinct species of matter which cannot be converted by the action of heat, chemical reaction with other substances ... into two or more ... different kinds of matter". We added: "Every portion of matter consists of either a single pure substance or a mixture of two or more pure substances, each of which is either an element or a chemical compound". This is the language of modern chemistry, but it is the thought of Empedocles, as the fragments about to be quoted show. *

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* Aristotle's discussion of the four elements in de GC II 5-6 agrees closely with the above definitions. He believed that the 'simple bodies' cannot be dissolved into any more primitive corporeal entities; but he insists that they can be logically split into more primitive principles, matter and the contrary qualities. So too our modern elements can be split into sub-atomic entities, but are still 'elements' for the purposes of chemistry.

τέσσαρα γὰρ πάντων ῥιζώματα πρῶτον ἄκουε·
Ζεὺς ἀργὴς Ἥρη τε φερέσβιος ἠδ' Ἀιδωνεύς
Νῆστίς θ', ἣ δακρύοις τέγγει κρούνωμα βρότειον.

Frag. 6. For the identification of the 'roots' with the divine names we have several suggestions in D. 31 A 1, A 23, and A 33, some containing the Platonic and Theophrastean idea that Hera represented air and some the Stoic idea that she was earth. The latter identification is supported both by the epithet φερέσβιος, which is applied to earth in H. Hom. Ap. 341 and Hesiod Theog. 693, and by the idea of earth as a mother-goddess. Nestis is obviously water. Burnet points out (E.G.P. p. 229 n. 3) that αἰθήρ, that is, Zeus, though used to mean fire by Anaxagoras, means elemental air in Empedocles (v. inf.) and that Aedoneus is appropriate for fire in the terminology of a Sicilian used to volcanoes and hot springs.

δίπλ' ἐρέω· τοτὲ μὲν γὰρ ἓν ηὐξήθη μόνον εἶναι
ἐκ πλεόνων, τοτὲ δ' αὖ διέφυ πλέον' ἐξ ἑνὸς εἶναι,
πῦρ καὶ ὕδωρ καὶ γαῖα καὶ ἠέρος ἄπλετον ὕψος,
Νεῖκός τ' οὐλόμενον δίχα τῶν, ἀτάλαντον ἁπάντῃ,
καὶ Φιλότης ἐν τοῖσιν, ἴση μῆκός τε πλάτος τε...

ταῦτα γὰρ ἶσά τε πάντα καὶ ἥλικα γένναν ἔασι,
τιμῆς δ' ἄλλης ἄλλο μέδει, πάρα δ' ἦθος ἑκάστῳ,
ἐν δὲ μέρει κρατέουσι περιπλομένοιο χρόνοιο.
καὶ πρὸς τοῖς οὔτ' ἄρ το ἐπιγίνεται οὐδ' ἀπολήγει·
εἴτε γὰρ ἐφθείροντο διαμπερές, οὐκέτ' ἂν ἦσαν·
τοῦτο δ' ἐπαυξήσειε τὸ πᾶν τί κε; καὶ πόθεν ἐλθόν;
πῇ δέ κε κήξαπόλοιτο, ἐπεὶ τῶνδ' οὐδὲν ἔρημον;
ἀλλ' αὐτ(ὰ) ἔστιν ταῦτα, δι' ἀλλήλων δὲ θέοντα
γίγνεται ἄλλοτε ἄλλα καὶ ἠνεκὲς αἰὲν ὁμοῖα.

Frag. 17, l. 16 - 20 and 27 - 35. Cf. Frag. 39 (the one that Aristotle quotes against Xenophanes, v. p. 127 sup.), which denies the infinity of at least one element, and confirms the inference from line 27 sup. that the elements are finite in quantity, being 'equal'.

ἠέλιον μὲν λευκὸν ὁρᾶν καὶ θερμὸν ἁπάντῃ,
ἄμβροτα δ' ὅσσ' εἴδει τε καὶ ἀργέτι δεύεται αὐγῇ,
ὄμβρον δ' ἐν πᾶσι δνοφόεντά τε ῥιγαλέον τε·
ἐκ δ' αἴης προρέουσι θελεμνά τε καὶ στερεωπά.
ἐν δὲ Κότῳ διάμορφα καὶ ἄνδιχα πάντα πέλονται,
σὺν δ' ἔβη ἐν Φιλότητι καὶ ἀλλήλοισι ποθεῖται.
ἐκ τούτων γὰρ πάνθ' ὅσα τ' ἦν ὅσα τ' ἔστι καὶ ἔσται...

αὐτὰ γὰρ ἔστιν ταῦτα, δι' ἀλλήλων δὲ θέοντα
γίγνεται ἀλλοιωπά· τόσον διὰ κρῆσις ἀμείβει.

Frag. 21, l. 3 - 9 and 13 - 14. With l. 13 - 14 cf. Frag. 17, 34 - 35 sup., and Frag. 26, 3 - 4. Lines 3 - 6 of Frag. 21 list the four elements in poetic language, cf. Frag. 22:

ἄρθμια μὲν γὰρ ταῦτα ἑαυτῶν πάντα μέρεσσιν,
ἠλέκτωρ τε χθών τε καὶ οὐρανὸς ἠδὲ θάλασσα,
ὅσσα φιν ἐν θνητοῖσιν ἀποπλαχθέντα πέφυκεν.
ὡς δ' αὔτως ὅσα κρῆσιν ἐπαρκέα μᾶλλον ἔασιν,
ἀλλήλοις ἔστερκται ὁμοιωθέντ' Ἀφροδίτῃ.
ἐχθρὰ <δ' ἃ> πλεῖστον ἀπ' ἀλλήλων διέχουσι μάλιστα
γέννῃ τε κρήσει τε καὶ ἔιδεσιν ἐκμάκτοισι,
πάντῃ συγγίνεσθαι ἀήθεα καὶ μάλα λυγρά
Νείκεος ἐννεσίῃσιν, ὅτι σφίσι γένναν ἔοργεν. †

ἐν δὲ μέρει κρατέουσι περιπλομένοιο κύκλοιο,
καὶ φθίνει εἰς ἄλληλα καὶ αὔξεται ἐν μέρει αἴσης.
αὐτὰ γὰρ ἔστιν ταῦτα, δι' ἀλλήλων δὲ θέοντα
γίνοντ(αι) ἄνθρωποί τε καὶ ἄλλων ἔθνεα θηρῶν
ἄλλοτε μὲν Φιλότητι συνερχόμεν' εἰς ἕνα κόσμον,
ἄλλοτε δ' αὖ δίχ' ἕκαστα φορούμενα Νείκεος ἔχθει,
εἰσόκεν ἓν συμφύντα τὸ πᾶν ὑπένερθε γένηται.
οὕτως ᾗ μὲν ἓν ἐκ πλεόνων μεμάθηκε φύεσθαι
ἠδὲ πάλιν διαφύντος ἑνὸς πλέον' ἐκτελέθουσι,
τῇ μὲν γίγνονταί τε καὶ οὔ σφισιν ἔμπεδος αἰών·
ᾗ δὲ τάδ' ἀλλάσσοντα διαμπερὲς οὐδαμὰ λήγει,
ταύτῃ δ' αἰὲν ἔασιν ἀκίνητοι κατὰ κύκλον.

Frag. 26. With lines 5 - 12 cf. Frag. 17, 7 - 13 which are practically identical.

... ἐπεὶ Νεῖκος μὲν ἐνέρτατον ἵκετο βένθος
δίνης, ἐν δὲ μέσῃ Φιλότης στροφάλιγγι γένηται,
ἐν τῇ δὴ τάδε πάντα συνέρχεται ἓν μόνον εἶναι,
οὐκ ἄφαρ, ἀλλὰ θελημὰ συνιστάμεν' ἄλλοθεν ἄλλα.
τῶν δὲ συνερχομένων ἐξ ἔσχατον ἵστατο Νεῖκος. *
πολλὰ δ' ἄμεικτ' ἔστηκε κεραιομένοισιν ἐναλλάξ,
ὅσσ' ἔτι Νεῖκος ἔρυκε μετάρσιον· οὐ γὰρ ἀμεμφέως
τῶν πᾶν ἐξέστηκεν ἐπ' ἔσχατα τέρματα κύκλου,
ἀλλὰ τὰ μέν τ' ἐνέμιμνε μελέων τὰ δέ τ' ἐξεβεβήκει.
ὅσσον δ' αἰὲν ὑπεκπροθέοι, τόσον αἰὲν ἐπῄει
ἠπιόφρων Φιλότητος ἀμεμφέος ἄμβροτος ὁρμή·
αἶψα δὲ θνήτ' ἐφύοντο, τὰ πρὶν μάθον ἀθάνατ' εἶναι,
ζωρά τε τὰ πρὶν ἄκρητα διαλλάξαντα κελεύθους.
τῶν δέ τε μισγομένων χεῖτ' ἔθνεα μυρία θνητῶν,
παντοίαις ἰδέῃσιν ἀρηρότα, θαῦμα ἰδέσθαι.

Frags. 35 and 36; the latter is substituted for line 7 in the former since that line is repeated at line 16. *

ἦ γὰρ καὶ πάρος ἔσκε†, καὶ ἔσσεται, οὐδέ ποτ', οἴω,
τούτων ἀμφοτέρων κενεώσεται ἄσπετος αἰών.

Frag. 16, which Hipp., Ref. VII 29, says, in quoting it, to refer to Love and Strife.

These fragments add to the list of four 'roots' two further basic entities, Love and Strife. They are Empedocles' answer to Parmenides' query concerning the nature of the 'efficient cause', with which the Milesians had not dealt because their matter was 'divine' in the sense that it contained its own source of motion, while Empedocles' 'roots' are inert, dead matter.

Aristotle, Met. 1075 b 3, says:

> ἀτόπως δὲ καὶ Ἐμπεδοκλῆς· τὴν γὰρ φιλίαν ποιεῖ τὸ ἀγαθόν, αὕτη δ' ἀρχὴ καὶ ὡς κινοῦσα (συνάγει γὰρ) καὶ ὡς ὕλη· μόριον γὰρ τοῦ μίγματος. εἰ δὴ καὶ τῷ αὐτῷ συμβέβηκεν καὶ ὡς ὕλῃ ἀρχῇ εἶναι καὶ ὡς κινοῦντι, ἀλλὰ τό γ' εἶναι οὐ ταὐτό. κατὰ πότερον οὖν φιλία; ἄτοπον δὲ καὶ τὸ ἄφθαρτον εἶναι τὸ νεῖκος· τοῦτο δ' ἐστὶν αὐτὸ ἡ τοῦ κακοῦ φύσις.

We need not discuss the moral implications (discussed also in Met. 984 b 32): they follow from Empedocles' religious views, although Aristotle, as ever, puts his own interpretation upon them. But are the two causes material or not? Aristotle takes them to be both efficient and material because they are 'a part of the mixture'; in other words part of what Aristotle believed the Sphere to be, a truly homogeneous compound (v. inf.): to him that must imply corporeality. Burnet and Ross (note ad loc.) say that the passages about their being equal in Frag. 17, especially equal in length and breadth, make their corporeality clear. But, as Ross himself says, the notion of incorporeal forces did not yet exist; and I would go further: the incorporeal in general, whether a force or not, had just been ruled out of court by Parmenides, so that if Love and Strife are to be real they must, whatever attributes they may have in addition, at least have the same type of existence as have the four 'roots'. Thus they are corporeal faute de mieux because of the logic of the age. I believe (as does Cherniss, p. 108) that Empedocles was nevertheless aiming at the description of two forces but had not succeeded in completely depriving them of corporeality for the reason just given, and that the 'equality' phrases do not necessarily prove that they are 'material no less than the other elements' (Ross, loc. cit.). As Cherniss points out, they can be seen with the mind alone (cf. Frag. 17). We shall see that much the same arguments apply to the 'mind' of Anaxagoras.

These forces, perforce described in material terms, correspond to some extent to the 'War and Peace' of Heracleitus; but, as Plato says in the well known passage Soph. 242 D, the latter worked simultaneously while these work alternately. They get the upper hand in turn, and so bring about the amazing double cosmogony, with which we need not deal in detail. Suffice it to say that one stage is a Sphere with Love in control - like that of Parmenides except that instead of being a homogeneous unity it contains the four elements in a mechanical mixture like painters' pigments (Empedocles' simile) or wheat and barley (Aristotle's) that gives the appearance of homogeneity. Frags. 27 - 29 describe the Sphere in terms reminiscent both of Xenophanes' God and Parmenides' One.

Strife enters and breaks up the mixture (Frag. 30 and 31) and a world is formed and then decays until, when Strife is in complete control and the last remnants of Love are gone, there is a moment when there is absolutely no mixture. The entire quantity of each element has come together into a separate mass. The four resultant masses are arranged concentrically in the traditional order. Then, as Love reenters and assumes control and Strife passes out (Frags. 35 and 36 sup.), another world is produced, which finally decays back into the homogeneous Sphere. *

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* Aristotle fails to realise that there are only two phases when there is not at least some of both causes at work. On the assumption that each acts alone in turn he attempts to show that both rest and motion are impossible, and to show that Empedocles needed chance as an extra cause. Moreover he complains that Love segregates and Strife combines; while Burnet speaks of a separate 'attraction for like to like' that is important for the formation of a world. Cherniss (p. 188sq.) effectively disposes of these points at length. Burnet's attraction is an example of what Eddington called a 'sham physical law', like the layman's 'Law of Gravity' compared with Einstein's assertion that there is no such thing as gravity per se. It is an apparently separate law that really depends on quite a different principle.

Cherniss (p. 174-5) argues that Aristotle errs in assuming four periods in the cycle, and shows that there is one period of rest, the Sphere, and one of motion, all the rest of the cycle, for the phase of concentric masses is only momentary - an instantaneous turning point. *

To sum up, the two causes are active forces, but are to some extent treated as material and on a par with the four elements because of the limitations of contemporary thought and terminology. In their action they are immanent ('running through' as part of the mixture), not transcendent. The elements (together with the causes in so far as they are treated materially) are eternal, finite, equal in quantity, and individually homogeneous; they are each 'a distinct species of matter which cannot be converted ... into two or more ... different kinds of matter' (cf. p. 216 sup. and Frag. 17). Aristotle tries to show (e.g. de GC 330 b 19 and Met. 985 a 33, D. 31 A 36 & 37) that fire is opposed to the other three, but while it may have an especially important role in astronomy or biology, it is certain that this was not Empedocles' intention in general. Frag. 17 is definite upon this point.

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* A discussion of the dynamics of this cycle will be found on pp. 381-384, where Empedocles and Plato are compared.

We are not told whether the four elements are divisible or particulate. Cherniss says (p. 399): "It is evident that the great flaw in the theory is the neglect of the problem of part and whole; when 'Love' has 'thoroughly mixed' the four roots, it appears that there must be minimal parts of these roots, but Empedocles does not consider this". Aristotle in de GC 324 b 35sq., a passage giving the background to atomism, says that the Eleatics claimed that their arguments were valid not only against those who posit a plurality and void (probably the Pythagoreans) but also against those who hold that the world is not continuous but consists of discretes in contact. If it is divisible everywhere, they claimed, there is no 'one' and therefore no 'many' but all is void (cf. Anaxagoras). If it is divisible at some points only, why so? Such a theory also entails, they said, the impossibility of motion. Cherniss and Joachim (On Coming-to-be and Passing-away, p. 160-1) say that the theory attacked is Empedocles', and that the attack was perhaps by Zeno, who is said by Suidas to have written an attack on Empedocles.

This would show at least that Aristotle believed that Empedocles posited minimal parts in contact, and he also hints at something of this sort in de Caelo 305 a 1:

> εἰ δὲ στήσεταί που ἡ διάλυσις, ἤτοι ἄτομον ἔσται τὸ σῶμα ἐν ᾧ ἵσταται, ἢ διαιρετὸν μὲν οὐ μέντοι διαιρεθησόμενον οὐδέποτε, καθάπερ ἔοικεν Ἐμπεδοκλῆς βούλεσθαι λέγειν.

It is, however, probably a case of reading into Empedocles what he thought that he ought to find; and Cherniss is probably correct in saying that Empedocles did not consider the fact that his theory entails minimal parts.

This will become clearer when we have examined Empedocles' account of the mechanism of the mixing and interchange of the elements. Having chosen his four elements and given them the properties that Parmenides had shown to be essential to that which exists, Empedocles had to show how all the different forms of matter in the sense world are derived from them. He quickly realised that straightforward one-to-one mixture of them is not adequate: to put it mathematically, there is only a limited number of permutations and combinations of four entities taken one, two, three, or four at a time; and this is not as great as the number of forms of matter that exist according to the senses.

He made, therefore, another great advance equal in achievement to his discovery of the principle of 'element', namely the principle of mixture in various but constant proportions not necessarily containing only one unit of a given element. The relevant fragments are these:

ὡς δ' ὁπόταν γραφέες ἀναθήματα ποικίλλωσιν
ἀνέρες ἀμφὶ τέχνης ὑπὸ μήτιος εὖ δεδαῶτε,
οἵτ' ἐπεὶ οὖν μάρψωσι πολύχροα φάρμακα χερσίν,
ἁρμονίῃ μείξαντε τὰ μὲν πλέω, ἄλλα δ' ἐλάσσω,
ἐκ τῶν εἴδεα πᾶσιν ἀλίγκια πορσύνουσι,
δένδρεά τε κτίζοντε καὶ ἀνέρας ἠδὲ γυναῖκας
θῆράς τ' οἰωνούς τε καὶ ὑδατοθρέμμονας ἰχθῦς
καί τε θεοὺς δολιχαίωνας τιμῇσι φερίστους·
οὕτω μή σ' ἀπάτη φρένα καινύτω ἄλλοθεν εἶναι
θνητῶν, ὅσσα γε δῆλα γεγάκασιν ἄσπετα, πηγήν,
ἀλλὰ τορῶς ταῦτ' ἴσθι, θεοῦ πάρα μῦθον ἀκούσας.

Frag. 23. Cf. Frag. 71:

εἰ δέ τί σοι περὶ τῶνδε λιπόξυλος ἔπλετο πίστις,
πῶς ὕδατος γαίης τε καὶ αἰθέρος ἠελίου τε
κιρναμένων εἴδη τε γενοίατο χροῖά τε θνητῶν
τόσσ', ὅσα νῦν γεγάασι συναρμοσθέντ' Ἀφροδίτῃ...

ἡ δὲ χθὼν ἐπίηρος ἐν εὐστέρνοις χοάνοισι
τὼ δύο τῶν ὀκτὼ μερέων λάχε Νήστιδος αἴγλης,
τέσσαρα δ' Ἡφαίστοιο· τὰ δ' ὀστέα λευκὰ γένοντο
Ἁρμονίης κόλλῃσιν ἀρηρότα θεσπεσίηθεν.

Frag. 96. Note the technological metaphor from welding (or perhaps inlaying, v. Liddell and Scott s.v. κόλλησις), or glueing, repeated in Frag. 34, ἄλφιτον ὕδατι κολλήσας, an illustration from baking. Cf. also illustrations from metallurgy in Frag. 92 and dyeing in Frag. 93: the latter is reminiscent of the Milesians' use of the felting metaphor. Empedocles shows himself familiar with contemporary technology, and you find this practical interest also reflected in the clepsydra experiment, Frag. 100.

ἡ δὲ χθὼν τούτοισιν ἴση συνέκυρσε μάλιστα,
Ἡφαίστῳ τ' ὄμβρῳ τε καὶ αἰθέρι παμφανόωντι

Κύπριδος ὁρμισθεῖσα τελείοις ἐν λιμένεσσιν,
εἴτ' ὀλίγον μείζων εἴτε πλεόνεσσιν † ἐλάσσων·
ἐκ τῶν αἷμά τε γέντο καὶ ἄλλης εἴδεα σαρκός.

Frag. 98. Cf. Frag. 73:

ὡς δὲ τότε χθόνα Κύπρις, ἐπεί τ' ἐδίηνεν ἐν ὄμβρῳ,
εἴδεα ποιπνύουσα θοῷ πυρὶ δῶκε κρατῦναι...

ἡ δὲ φλὸξ ἱλάειρα μινυνθαδίης τύχε γαίης.

Frag. 85. With the interest in the composition of parts of the body shown in Frags. 85, 96 and 98 cf. Alcmaeon sup. and Anaxagoras inf..

γόμφοις ἀσκήσασα καταστόργοις Ἀφροδίτη.

Frag. 87. The 'bolting' metaphor also occurs in Frag. 33.

Thus at one blow Empedocles has raised Greek science from primitiveness to a chemistry complete with elements and formulae that reads like ours would if we gave allegorical names to all our elements. Water (H_2O) might then read 'two parts of Nestis to one of gleaming Zeus'. Qualitative phenomena are now not merely explained on a quantitative theory (as they were by Anaximenes) but in such a way that the quantities may be numerically expressed - mensuration is conceivable. We may measure material substances, not just pure numbers as with Pythagoreanism.

On p. 5 sup. we defined a compound as 'a homogeneous substance with a fixed proportion of certain elements in its composition that can only be split into its constituent elements by the application of fairly intense ...energy', and a mixture as 'a substance that may be homogeneous or heterogeneous, that has no constant proportional elementary composition, and that may be divided into its constituent substances by comparatively feeble forces'. Empedocles' compounds are conceived of in the same way as ours. If Aristotle's contention that he conceived of minimal parts of the elements were true, then the correspondence would be very close, for our compounds are made of juxtaposed elementary atoms; and Empedocles' compounds will also divide again - by the agency of Strife. *

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* Aristotle is not satisfied by Empedocles' account; and his conception of a compound is accordingly even more strict than our own. In de GC I 10 we find that while a mixture (σύνθετον) occurs by the juxtaposition of portions below the limit of visibility or of minimal particles (in which he does not himself believe), in which case οὐδ' ἕξει τὸν αὐτὸν λόγον τῷ ὅλῳ τὸ μόριον 328 a 10 - (cf. our definition), in a true compound (μῖγμα) two or more distinct substances combine to form a single resulting substance into which they are fused. This must have different properties from those of the ingredients, and it must be homogeneous in fact - and not just appear so as a mixture may (as in our definition: "homogeneous or heterogeneous") - so that every part has the same proportion of ingredients as the whole. The ingredients must be recoverable from the compound. Our compounds, and Empedocles', are thus closer to Aristotle's conception of mixtures except that they are necessarily homogeneous and of fixed constant proportion.

In Aristotle's account of compounds we read at 328 b 1sq. that some materials are more suited by their form to enter into composition than others (e.g. liquids). This is reminiscent of Empedocles' Frag. 22 lines 4 - 9 (p. 218 sup.) and Frag. 91, which states that water is more miscible with wine than with oil. We must now see in what way the form affects the composition.

Frags. 17, l. 34-5, 21, l. 13-4, and 26, l. 3-4, all state in practically identical wording that elements enter into composition by 'running through one another'; and we find from further fragments, 84 and 100, that Empedocles has adopted Alcmaeon's theory of 'pores'. Aristotle discusses this in de GC 324 b 26sqq. (which I quote in English because of its length):

> Some think that each thing is acted upon when the proximate (the most proper) agent enters through certain pores and that we also see and hear and exercise our other senses in this way; things are seen through air and water and the transparent because they have pores, invisible through their smallness, but close-set and in rows, and the more this is so the more transparent they are.
>
> Some, then, e.g. Empedocles, held this theory about certain bodies, not only about those acting and acted upon, but also they say that mixture occurs between bodies whose pores are symmetrical with one another.

Cherniss (p. 94) takes the last phrase to mean that the pores of one body must be proportionate to the particles of the other.

There now follows the passage summarised at p. 224 sup., after which Aristotle comments at 325 b 6:

> Empedocles too is practically bound to say the same as Leucippus; for he must say that there are certain solids and that they are indivisible, unless there are continuous pores throughout. But the latter is impossible; for then there will be nothing solid over and above the pores, but the whole will be void. It is necessary, then, for the contiguous discretes to be indivisible, while the interstices between them - which he calls pores - must be void. This is also Leucippus' view ...

Thus Aristotle's whole argument is that Empedocles tried and failed to answer Parmenides without positing void, and subsequently Leucippus openly posited it.

After another passage about the atomists Aristotle returns to Empedocles at 326 b 6 - 28, a passage that may be summarised thus:- If the pores are filled, action (sc. penetration) is not facilitated by them and we might just as well call the whole body continuous. His explanation of sight will fail if the pores are full in the transparent medium (penetration will not even be possible between the inner surface of the pores and the surface of the contents). If the pores are empty _qua_ pores (i.e. in thought), but in fact always full of matter, the result is the same. And if they are too narrow to admit any body, that is tantamount to saying that infinitesimal voids exist while denying the existence of 'big' voids. So pores are superfluous. If action is not by contact, pores are irrelevant, and if it is, then contact is possible even without the postulate of pores.

Aristotle misses the point, however. Admittedly Empedocles did not mean his pores to be empty, and the point about narrowness is only relative - some bodies are prevented from entering while others are admitted. But Aristotle has assumed that the pores are always filled with the same matter, while Empedocles' idea was surely that there is a continual flow of fresh matter through them (cf. the phrase 'running through' and v. Frag. 100 inf.): in other words the mechanism is, as with motion, mutual displacement by contiguous discretes. Intrusion is effected by balancing extrusion.

However it is clear from this whole discussion that Empedocles had not fully worked out all the implications of his theory, and that it is not absolutely self-consistent.

Having now examined the basic theory of the six primary entities and their interactions, we may now proceed to examine Empedocles' cosmogony and cosmology in order to discover the physical properties of his air.

The relevant fragments are, as with Parmenides, scanty and not very informative, while the doxography is confused. It seems, however, that like his predecessors Empedocles gave a cosmogony to explain the astronomical phenomena, one that shows the influence of the Milesians' δίνη and of Anaximander's ἀπόκρισις.

Fragment 38 reads like an introduction to this section of Empedocles' work:

> εἰ δ' ἄγε τοι λέξω πρῶθ' † ἥλιον ἀρχήν †,
> ἐξ ὧν δῆλ' ἐγένοντο τὰ νῦν ἐσορῶμεν ἅπαντα,
> γαῖά τε καὶ πόντος πολυκύμων ἠδ' <u>ὑγρὸς ἀήρ</u>
> <u>Τιτὰν ἠδ' αἰθὴρ</u> σφίγγων περὶ κύκλον ἅπαντα.

The outlines of this cosmogony are given in the following:

> Ἐμπεδοκλῆς τὸν μὲν αἰθέρα πρῶτον διακριθῆναι, δεύτερον δὲ τὸ πῦρ, ἐφ' ᾧ τὴν γῆν, ἐξ ἧς ἄγαν περισφιγγομένης τῇ ῥύμῃ τῆς περιφορᾶς ἀναβλύσαι τὸ ὕδωρ· ἐξ οὗ θυμιαθῆναι τὸν ἀέρα, καὶ γενέσθαι τὸν μὲν οὐρανὸν ἐκ τοῦ αἰθέρος, τὸν δὲ ἥλιον ἐκ τοῦ πυρός, πιληθῆναι δὲ ἐκ τῶν ἄλλων τὰ περίγεια.

Aët. II 6, 3, D. 31 A 49. Cf. Philo, de Provid. II 60 p. 86, ibid.:

eodem modo etiam mundi partes confici videntur, ut dicit Empedocles. postquam enim secretus est aether, aer et ignis sursus volaverunt et caelum formatum quod in latissimo spatio circum-ferebatur. ignis autem, qui caelo paulo inferior manserat, ipse quoque in radios solis coacervatus est. terra vero in unum concurrens et necessitate quadam concreta in medio apparens consedit. porro circa eam undique aether,

> quia multo levior erat, volvitur neque umquam desistit. quietis autem inde causa per deum (?), non vero per sphaeras multas super se invicem positas, ... quia circa eam (sc. terram) circumiectus est typi cuiusdam gyrus mirabilis, ... ideo nec hus nec illuc cadit ista.

Noteworthy in these passages is the distinction between air (Τιτὰν αἰθήρ) and water vapour (ὑγρὸς ἀήρ). Aëtius says that aer θυμιαθῆναι from water, and so this word has for Empedocles a connotation derived from its original meaning of 'mist'. It really is water vapour, produced by evaporation, and quite distinct from the elementary air, whose name is 'ether'. (The commentators sometimes fail to observe this distinction in nomenclature, as we shall see.) We shall when discussing Frag. 100 see that 'ether', the element, is invisible, but yet corporeal, atmospheric air - so in discussing Empedocles I can employ the normal English spelling.

The compression of the earth by rotation implies a centripetal rather than a centrifugal force, which we should have expected. The Ionian δίνη operates more like a whirlpool, where the tangential velocity is the greater the nearer to the centre, than like a cup whirled round on a string. Aristotle, in de Cael. 295 a 10sq., says that in liquids and in the air (or, as we should say, in gases) larger and heavier things move towards the centre of a vortex, and he is correct. The process of separation, by rotation, would have been expected by modern minds to imply that heavy bodies, having more momentum, would be flung off further than light ones under the operation of centrifugal force. The opposite theory, of whirlpool-like action, was imposed on the Greeks by the necessity to save the phenomena, for fire or ether is at the circumference and earth at the centre of their cosmos.

Aristotle (loc. cit.) goes on to mention the point raised at the end of my quotation from Philo. He says that Empedocles and his followers said that the speed of motion of the rotating heaven prevents motion on the part of the earth. He says that they compared the fact that water in a cup does not fall out when the latter is swung round in a circle. The point of this comparison is not to demonstrate centrifugal force, but to show the tendency of rapid motion to counteract a tendency to fall. In reality the theory explains why the heavens do not fall rather than why the earth is at rest. *

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* We of course know that centrifugal force is what keeps the objects in the solar system from falling into the sun; but this force is really only a name for a tendency to fly off at a tangent - cf. Newton's Laws of Motion.

Fragments 51, 53, and 54 may perhaps refer to the cosmogonical process that we are considering. The subject of Frag. 51 is fire and of 53 air, we are told in the respective contexts:

51. καρπαλίμως δ' ἀνόπαιον ...

53. οὕτω γὰρ συνέκυρσε θέων τοτέ, πολλάκι δ'ἄλλως.

54. αἰθὴρ <δ' αὖ> μακρῇσι κατὰ χθόνα δύετο ῥίζαις.

The shape of the outer firmament of the universe produced by this process is apparently that of an egg (cf. the Orphic Egg?), according to Aëtius, II 31, 4, A 50:

... διὰ τὸ ᾠῷ παραπλησίως τὸν κόσμον κεῖσθαι.

However there are within it two interesting if confusing hemispheres as we are told in Ps. Plut. Strom. ap. Eus. P. E. I 8, 10 (n.b. aer is wrongly employed for ether):

ἐκ πρώτης φησὶ τῆς τῶν στοιχείων κράσεως ἀποκριθέντα τὸν ἀέρα περιχυθῆναι κύκλῳ· μετὰ δὲ τὸν ἀέρα τὸ πῦρ ἐκδραμὸν καὶ οὐκ ἔχον ἑτέραν χώραν ἄνω ἐκτρέχειν ὑπὸ τοῦ περὶ τὸν ἀέρα πάγου. εἶναι δὲ κύκλῳ περὶ τὴν γῆν φερόμενα δύο ἡμισφαίρια τὸ μὲν καθόλου πυρός, τὸ δὲ μικτὸν ἐξ ἀέρος καὶ ὀλίγου πυρός, ὅπερ οἴεται τὴν νύκτα εἶναι. τὴν δὲ ἀρχὴν τῆς κινήσεως συμβῆναι ἀπὸ τοῦ τετυχηκεναι κατά <τι> τὸν ἀθροισμὸν ἐπιβρίσαντος τοῦ πυρός. ὁ δὲ ἥλιος τὴν φύσιν οὐκ ἔστι πῦρ, ἀλλὰ τοῦ πυρὸς ἀντανάκλασις ὁμοία τῇ ἀφ' ὕδατος γινομένῃ. σελήνην δέ φησιν συστῆναι καθ' ἑαυτὴν ἐκ τοῦ ἀποληφθέντος ἀέρος ὑπὸ τοῦ πυρός.

τοῦτον γὰρ παγῆναι καθάπερ καὶ τὴν χάλαζαν. τὸ δὲ φῶς αὐτὴν ἔχειν ἀπὸ τοῦ ἡλίου.

We shall deal with the various details in this description piecemeal. First, then, is the (egg-shaped) heaven. This is crystalline, cf. Diog. Laert. VIII 77:

> καὶ τὸν μὲν ἥλιόν φησι πυρὸς ἄθροισμα μέγα καὶ τῆς σελήνης μείζω· τὴν δὲ σελήνην δισκοειδῆ, αὐτὸν δὲ τὸν οὐρανὸν κρυσταλλοειδῆ,

It is in fact composed of solidified air, as a group of authorities tell us, D. 31 A 51, of which the most informative is Aët. II 11, 2:

> 'Ε. στερέμνιον εἶναι τὸν οὐρανὸν ἐξ ἀέρος συμπαγέντος ὑπὸ πυρὸς κρυσταλλοειδῶς, τὸ πυρῶδες καὶ τὸ ἀερῶδες ἐν ἑκατέρῳ τῶν ἡμισφαιρίων περιέχοντα.

Again the word 'aer' is wrongly employed. The solidifying power of fire is affirmed by Fragment 56:

> ἅλς ἐπάγη ῥιπῇσιν ἐωσμένος ἠελίοιο.

and referred to in Fragment 73:

> ὡς δὲ τότε χθόνα Κύπρις, ἐπεί τ' ἐδίηνεν ἐν ὄμβρῳ,
> εἴδεα ποιπνύουσα θοῷ πυρὶ δῶκε κρατῦναι ...

Within this heaven are the two hemispheres, one for day and one for night, caused to rotate by the preponderance of fire in the former. A similar preponderance of air in a certain region caused the tilting of the celestial axis. Burnet (E.G.P. p. 237), presumably relying on Frags. 51, 53, and 54 sup., says: "In its upwards rush Fire displaced a portion of the Air in the upper half of the concave sphere formed by the frozen sky. This air then sunk downwards, carrying with it a small portion of the fire. In this way, two hemispheres were produced". With this I am disposed to agree. Day and night are therefore explained without explicit reference to the sun. But the darkness of night is not a substance - the air in the nocturnal hemisphere is not the aer of the Milesian theories, but the elementary invisible air, solidified so as to form a support for the fixed stars, which consist of lumps of the 'small portion of the fire', fixed to it, in contrast to the freely moving planets:

> 'Εμπεδοκλῆς πύρινα (τ. ε. εἶναι τὰ ἄστρα) ἐκ τοῦ πυρώδους, ὅπερ ὁ ἀήρ ἐν ἑαυτῷ περιέχων ἐξανέθλιψε κατὰ τὴν πρώτην διάκρισιν.
>
> Aët. II 13, 2, D. 31 A 53.
>
> 'Εμπεδοκλῆς τοὺς μὲν ἀπλανεῖς ἀστέρας συνδεδέσθαι τῷ κρυστάλλῳ, τοὺς δὲ πλανήτας ἀνεῖσθαι.
>
> Aët. II 13, 11, A 54.

The darkness is in fact at last correctly explained as the absence of light caused by the shadow of the earth when we are on the side of it opposite to the source of daylight, as Frag. 48 affirms:

νύκτα δὲ γαῖα τίθησιν ὑφισταμένη φαέεσσι <ἠελίου>.

Frag. 94 (preserved in Latin only) confirms that darkness is just shadow:

et niger in fundo fluvii color exstat ab umbra,
atque cavernosis itidem spectatur in antris.

Here, then, we have a great advance. We have already seen that air and water vapour have been distinguished in Frag. 38, and now darkness is distinguished from both. The properties of either 'air' or 'aer' are now very far from the same as those of either the Milesian aer-darkness or the Pythagorean aer-void. (There is no void at all.)

So much for night and the stars. What of day and the sun? Here we are on very slippery ground. The Ps-Plutarch passage appeared to say that daylight is due to the fiery hemisphere, and not to the sun itself. The latter is 'not fire, but a reflection of fire like that which comes from water'. Plutarch, in the context to Frag. 44, de Pyth. Or. 12, p. 400 B, says:

ὑμεῖς δὲ τοῦ μὲν Ἐμπεδοκλέους καταγελᾶτε φάσκοντος τὸν ἥλιον περὶ γῆν ἀνακλάσει φωτὸς οὐρανίου γενόμενον αὖθις

'ἀνταυγεῖ πρὸς Ὄλυμπον ἀταρβήτοισι προσώποις.'

It would appear, then, that the light from the fiery hemisphere round the earth is reflected back from the earth to the hemisphere in such a way that the rays are concentrated so as to throw a disc-like image upon it, the earth acting as a mirror. Aëtius, however, in II 20, 13, D. 31 A 56, says that Empedocles had two suns; one, the archetype, was the fire of the whole fiery hemisphere, the other, the phenomenal sun, was its reflexion in the dark hemisphere, the earth reflecting it because it is round. This cannot be right, for it would put the phenomenal sun in the nocturnal hemisphere. The reflection must be in the diurnal one.

In fact Empedocles, who knew of the recent discovery that the moon has a reflected, 'borrowed' light (Frags. 43, 45, and 47; cf. Parmenides Frag. 14), has in typical Greek enthusiasm for a new theory extrapolated from the known to the unknown, and misapplied the explanation to the light of the sun. One should not ask for complete consistency in a hypothesis so far removed from the true explanation. Certain Pythagoreans too seem to have made a similar extrapolation.

The moon is, according to Ps. Plutarch, sup., made from the air cut off by the fire and solidified by its heat as was the heaven, cf. the passages in D. 31 A 60, which also inform us that it was not spherical but disc-shaped. Once the true nature of darkness and shadow has been understood, the problem of eclipses is easily understood too. Empedocles' Frag. 42 (in Diels' text) gives the correct explanation of solar eclipses, including the fact that the eclipse is not everywhere visible: the moon intercepts the rays of the sun and casts her disc-shaped (conical) shadow upon a portion of the earth's surface:

... ἀπεστέγασεν δέ οἱ αὐγάς,
ἔστ' ἂν ἴῃ καθύπερθεν, ἀπεσκνίφωσε δὲ γαίης
τόσσον ὅσον τ' εὖρος γλαυκώπιδος ἔπλετο μήνης.

In connexion with the theory of the reflection or interception of light, we must note that light travels, even though we do not see it doing so because of its high velocity, and that it is corporeal. Aristotle frowns on this:

οὐκ ὀρθῶς 'Εμπεδοκλῆς οὐδ' εἴ τις ἄλλος οὕτως εἴρηκεν, ὡς φερομένου τοῦ φωτὸς καὶ γιγνομένου ποτὲ μεταξὺ τῆς γῆς καὶ τοῦ περιέχοντος, ἡμᾶς δὲ λανθανόντος.

Ar. de An. 418 b 20, cf. de Sensu 446 a 26, D. 31 A 57.

The corporeality of light is added by Philoponus' commentary on the de Anima passage:

> 'Ε. ὃς ἔλεγεν ἀπορρέον τὸ φῶς σῶμα ὂν ἐκ τοῦ φωτίζοντος σώματος γίνεσθαι πρῶτον ἐν τῷ μεταξὺ τόπῳ τῆς τε γῆς καὶ τοῦ οὐρανοῦ, εἶτα ἀφικνεῖσθαι πρὸς ἡμᾶς, λανθάνειν δὲ τὴν τοιαύτην αὐτοῦ κίνησιν διὰ τὴν ταχυτῆτα.
>
> Phil. de An. 344, 34, D. 31 A 57; cf. Cod. Atheniens. 1249 XVIII 110, ibid.

We must agree with Empedocles against Aristotle. Light does travel; its velocity has been measured, and is in fact one of the fundamental constants of the relativistic explanation of the universe. Moreover light, in 'photons', acts in some respects in the same way as the (sub-atomic) particles of matter, while the latter in turn manifest some of the wave-motion properties of light. In fact both photons and sub-atomic particles have alike been described by the portmanteau word 'wavicles'.

Sublunar phenomena are dealt with in the normal contemporary manner by Empedocles and add little that is relevant to our enquiry, except that winds are presumably made of ether (air) not aer (mist), and the cause of their motion is the opposite motions of the two hemispheres (Olympiod. in Meteor. A 13, 102, 1, D. 31 A 64). But one fresh phenomenon is dealt with by Empedocles: magnetism. Alexander (Quaest. II 23, p. 72, 9, D. 31 A 89) says that according to Empedocles there are effluences from iron and the lodestone, and the former are 'symmetrical' with the pores of the lodestone. The effluences from the latter push out the air from the pores of the iron and, so to speak, uncap them. The effluences thus released from the iron move into the pores of the lodestone, and the iron follows their motion.

To sum up, the main points that arise in the cosmology are the distinction between ether and aer and the explanation of darkness as shadow. The aer that is evaporated from water (p. 232 sup.) is no longer an element in its own right: the element is invisible (atmospheric) air, the proof of whose corporeal existence we shall soon examine. Like Heracleitus, Empedocles interpreted the atmosphere as a mixture, but instead of two constituents, the exhalations, he postulated three: fire gives light and heat, and acts as a solidifying agent; ether is the newly proved invisible air, whose existence was suspected by Anaximenes; and aer, the analogue of the dark exhalation, is just a by-form of the element water, and is the source of mists and clouds and rain. The element earth is a solid material, but not the only solid, for air is solidified to form the heavens and the moon's disc, and ice is frozen water.

Unfortunately the verbal distinction between ether and aer does not appear to have become standard. Because of the ancient use of the former for the bright upper air of the sky, the abode of the gods, and the latter for the misty air of the ground level, later writers tend to revert to the word aer for air in general, and to confine the word ether to things of a fiery nature. But from now on the word aer, even when used in its original sense of mist and not the new sense of atmospheric air, no longer contains the idea of substantial darkness.

To Empedocles, however, ether definitely is that air which, though invisible and (when at rest) intangible, transparent, non-inflammable, colourless, odourless, tasteless, and in fact devoid of almost all the qualities and properties normally associated with matter, is nevertheless material and corporeal. The only easily observable property of air is its resistance. We feel its pressure against us in a wind: it resists our attempts to move fast: it makes a balloon (or an inflated wine-skin, cf. Anaxagoras inf.) feel firm: it offers resistance to water when we perform very elementary experiments of a type that we should today call pneumatic or hydraulic. One such experiment was described by Empedocles (also ascribed to Anaxagoras). (Perhaps 'observation' would be a better word.) His reasons for describing it and some of the conclusions that he may have drawn from it were wrong (v. inf.) but it was nevertheless of paramount importance for Greek science, since it proved incontrovertibly that air is corporeal, and as a consequence that all that is invisible is not necessarily therefore composed of void.

Aristotle quotes Empedocles' description of the experiment in the de Respiratione immediately after a remarkable passage (473 a 2sq.) in which he rejects out of hand the theory that respiration occurs in order that the internal fire may be nourished by the breath - a theory that, although the Greeks could never have known it, is getting very close to the modern explanation of respiration as combustion, the inhaled breath supplying oxygen as ὑπέκκαυμα, to use Aristotle's own word, for the combustion.

Aristotle explains that Empedocles expressed the idea that breathing is through pores (Aristotle calls them 'veins'), not full of blood, but having openings to the air outside and giving an easy passage to air. The blood moves up and down and pumps the air out and in. Aristotle takes ῥινῶν in line 4 of Frag. 100, which he now quotes in full at 473 b 9, to be genitive of ῥίς, 'nostril', instead of ῥινός, 'skin'; and consequently asks how the fragment tallies with the facts of respiration through the nose and mouth. But Empedocles thought that the pores concerned were all over the skin, and a legitimate criticism would rather be to ask why we do not emit bubbles from all over the body when we are under water.

I now give the fragment in English because of its length and to indicate how I interpret its rather over-poetical vocabulary. (In line 13 I read αἰθέρος for ἀέρος with Stein and Burnet, believing that Aristotle's text contains a slip here since the rest of the passage has consistently αἰθήρ.)

> All things inhale and exhale in the following way. All have pipes of flesh, lacking in blood, extended over the surface of the body; and at the mouths of these the outer extremity of the skin is perforated clean through with close-set furrows (sc. pores) so as to seal off the blood, while an easy passage is cut for the air to pass through. Then, whenever the smooth blood rushes back, the air, bubbling, rushes down in with a raging surge; but when the blood courses up again, the air blows out again, just as when, when a girl, playing with a liquid-holder (clepsydra) of gleaming bronze, sets the orifice of the pipe upon her shapely hand and dips the vessel into the smooth mass of silver-white water, no water flows into the vessel, but the weight of air within, pressing upon the close-set holes,

> holds it back until she uncovers the compressed air-stream: but then as the air escapes an equal volume of water enters - and similarly, when water fills the whole depth of the vessel and the orifice and passage is blocked by human skin, the air outside, striving to enter, keeps in the water by holding firm the surface at the gates of the ill-sounding strainer until she lets go with her hand; but then, as the air enters again in the opposite direction to the previous one, an equal volume of water flows down and out. In just this way, then, when the smooth blood, surging through the limbs, rushes back to the interior, the broad stream of air goes down in, raging in its surge; but when the blood courses back up again, an equal volume of air blows back out again.

The κλεψύδρα in this context was not a water-clock but a device consisting of a metal body, hollow, with a strainer (ἠθμός) at the bottom and a narrow pipe (αὐλός) at the top. It was employed for taking up liquid from one vessel and transferring it to another, just as is done now with a pipette. The explanation of the action of the air given by Empedocles is correct: in the first instance the pressure of the trapped internal air prevents the water from entering, and in the second atmospheric pressure prevents it from emerging. What Empedocles did not know was that atmospheric pressure is due to the weight of the atmosphere above.

Ps. Aristotle in Problems 914 b 9sq. attributes the same observation to Anaxagoras, and accepts in the main the explanation for the first half given by Empedocles here, and by Anaxagoras, but adds the observation that if the clepsydra is plunged obliquely into the water the latter will enter even if the pipe is blocked because some of the holes in the strainer are above water and the air can escape through these. The Aristotelian school do not correctly understand gravity, so that the author of the Problems explains the emergence of water in the last part of the experiment not as due to its own weight but as in part due to a force exerted by the air. He has the clepsydra inverted at this stage so that the water emerges through the pipe, and says that the force of the air acting from above (through the strainer) is greater than the resistance of the air below, in the pipe, because of the narrowness of the latter, although theoretically it ought to be equal. He adduces the noise of ἐρυγμός as proof of the action of the air.

Burnet, with this passage in mind, and because of the epithet 'ill-sounding' and the varia lectio ἰσθμοῖο in line 19, thinks that Empedocles' clepsydra is also inverted so that the water emerges through the pipe. But this is clearly not 'in the opposite direction to the previous one', and the water must both enter and leave by the strainer to maintain the parallelism.

Admittedly the first half of the experiment works equally well with the clepsydra inverted, but the point of the second half would be missed, for then it would be a case of the hand itself preventing the egress of the water irrespective of whether the vessel was a clepsydra or not. Moreover the descriptions of this half of the experiment that appear in Hero (Pneumat. A vii, 160) and Philo (de Ing. Spir. xi, 310) make it plain that it was performed in the manner that I have described, not in that claimed by Burnet. Hero states definitely that in both halves of the experiment the air flows through the pipe and the liquid through the strainer.

Aristotle himself (Phys. 213 a 22sq., D. 59 A 68) blames those who performed this experiment (he names only Anaxagoras) for believing that they were disproving the existence of void. He says:

> ἐπιδεικνύουσι γὰρ ὅτι ἔστι τι ὁ ἀήρ, στρεβλοῦντες τοὺς ἀσκοὺς καὶ δεικνύντες ὡς ἰσχυρὸς ὁ ἀήρ, καὶ ἐναπολαμβάνοντες ἐν ταῖς κλεψύδραις.

In other words experiments such as this demonstrate that air is corporeal and has resistance, but just because one has shown that one apparently empty space in fact contains a corporeal substance, air, one has not necessarily shown that no really empty space exists at all. This is true, but Aristotle is being slightly unfair. Empedocles and Anaxagoras both accepted the logical arguments of Parmenides as proof that void does not exist. The precise purpose of the experiment in connexion with the void would not be to prove its absolute non-existence, as would be necessary if one were opposing the atomists, but rather to illustrate to opponents such as the Pythagoreans, who believed in the void because they thought that air-filled spaces were empty, that in one of the cases in which they claimed to recognise the presence of void they were in fact confusing it with air, which is corporeal. This is legitimate and we can at least absolve Empedocles from blame (although Anaxagoras' case is not so clear v. inf.). But Empedocles was really more concerned with his theory of respiration, which may explain Aristotle's failure to mention him by name.

The experiment succeeds in proving that air exists, but it does not, of course, really prove Empedocles' theory of respiration. What it has achieved, however, is to demonstrate the existence of the only one of his four elements that cannot be actually seen to exist, for the air in the experiment is the ether that is an element and has the properties listed on p. 243, properties that are also those of the substance denoted by our modern word 'air'. Empedocles, as we saw on p. 242, knew that the atmosphere is a mixture, and clarified the distinction between water vapour and the rest: he did not, and could not, know that 'the rest' was still a mixture of elements (oxygen, nitrogen etc.) and not itself an element.

Meanwhile he canonized as a real substance 'fire', which we know to consist of gas (like his ether) that is incandescent and not of any separate element. When one sees how the Greek concepts of earth, water, and aer or ether correspond to our concept of the three states of matter, solid, liquid, and gaseous, one is puzzled by their postulating a fourth state, 'fire'. This seems a queer extrapolation. But the true explanation of the states of matter (the kinetic theory of matter, v. Introduction) has not yet been given, though Anaximenes' progressive rarefaction is on the right track, since it depends on atomic theory, while fire continued to be a thorn in the flesh of science until comparatively modern times (when the phlogiston theory gave way to the explanation of combustion as oxidization).

Although this four element theory was a great advance, it was still open to criticism. Lucretius makes two very pertinent points against elemental pluralists in general and Empedocles in particular, among other points not so cogent, in Book I, lines 753sq.:

huc accedit item, quoniam primordia rerum
mollia constituunt, quae nos nativa videmus
esse et mortali cum corpore funditus, utque
debeat ad nilum iam rerum summa reverti
de niloque renata vigescere copia rerum;
quorum utrumque quid a vero iam distet habebis. ...

denique quattuor ex rebus si cuncta creantur
atque in eas rursum res omnia dissoluuntur,
qui magis illa queunt rerum primordia dici
quam contra res illorum retroque putari?
alternis gignuntur enim mutantque colorem
et totam inter se naturam tempore ab omni.
sin ita forte putas ignis terraeque coire
corpus et aerias auras roremque liquoris,
nil in concilio naturam ut mutet eorum,
nulla tibi ex illis poterit res esse creata,
non animans, non exanimo cum corpore, ut arbos.

I quote Bailey's comment (Op. Cit. p. 33): "These two criticisms taken together do in fact exhibit the real weakness of the theory of the 'four elements'. On the one hand it has destroyed the old idea of fundamental unity, for it leaves the world fourfold in character, and the permanence of its new basis is very doubtful: on the other hand its pluralism is not thoroughgoing enough, for it is in reality no easier to explain the world as we know it with four 'elements' than with one. The true solution must at once offer a greater permanence and unity, it must be more Monistic; and it must also afford far greater possibilities of complex combination and consequent variety, it must be an infinitely more genuine pluralism".

Nevertheless the theory, suitably emended to suit each man's basic tenets, had many adherents, probably for the reason given by Sherwood Taylor (Op. cit. p. 5): "Its continuance was due, probably, to the fact that it was vague enough to be stretched to explain, after a fashion, almost any phenomena and, while it could not be proved, it was extremely difficult to disprove".

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CHAPTER EIGHT

ANAXAGORAS

Our interest now shifts from Sicily to Athens, for the first time. In approximately 480 b.c. Anaxagoras came to Athens from Clazomenae in Ionia. He was slightly older than Empedocles, but published his work later. * He eventually left Athens for Lampsacus, but he had in the meantime introduced the Athenians to a love of philosophy that they never subsequently abandoned.

Empedocles' four element theory was a view of matter that, after being accepted with modifications by Plato and Aristotle, was adopted in one form or another (sometimes with a fifth element added, e.g. Aristotle's ether, or sulphur) right down to the Seventeenth Century, and left a considerable mark on English literature (v. p. 3 sup.). It exerted, in fact, more and more lasting influence on posterity than other Greek theories actually nearer to the truth. This was the triumph of one of the two great schools of Western Greek thought. The other school,

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* According to one interpretation of Arist. Met. 984 a 11, D. 59 A 43.

the Pythagorean, based its theory on that principle of mathematically expressible structure that, in spite of its use in the schools of Plato and Aristotle, was practically ignored until Newton and Leibnitz invented a calculus that could express it, but that is now regarded as all-important.

Anaxagoras was a member of the third great school, the Ionian, and the last really great member of it before the (Ionian) city of Athens became the home of philosophy. His cosmology is, at least on the macroscopic scale, in fact closer to that of Anaximenes than was that of Heracleitus, but his theory of matter on the microscopic scale had no real predecessor - nor, apart from Archelaus, any real successor; but it pointed the way towards the atomic theory (also a product of Ionian thought), which many centuries later triumphed over the four element theory when it received a form expressible mathematically.

It is thus possible to see in the thought of each school ideas that have been hailed by some as glorious anticipations of modern science. It cannot be too highly emphasized, however, that they were not real anticipations. The Greeks would not have recognised their ideas in our science. They were actually just as far from the truth as we see it as were the men of what we Indo-Europeans, blind to the greatness of Arabic science, like to refer to as the 'Dark Ages'. In reality, after the Renaissance thinking men embarked on speculations prompted indeed by the newly discovered Classics, but based on their own far greater empirical knowledge, derived from experiment and observation (never the Greeks' strong point), including that of the alchemists and astrologers. Such speculations, carried out by the scientific method that medicine alone among the Greek sciences truly practised, were the true origins of modern science. The Greeks did not 'anticipate' our knowledge: rather, they had certain embryonic ideas of a type capable of growing to maturity when implanted into the modern mind. Moreover they never got beyond mere hypothesis whereas we can claim full knowledge in some fields, and a very high mathematical probability of being right in others.

Empedocles, then, postulated four elements capable of explaining an infinite number of substances: one might almost say that Anaxagoras postulated an infinite number of substances capable of explaining the four elements.

I mean that however truly elementary the four elements may have been to Mediaeval thought we shall find that during the rest of the Greek period, although they are often given prominence in cosmogony, or are regarded as pure substances of which others are compounded, they are not any more regarded as basic and primary. Their properties are regarded as needing explanation. I quoted on p. 215 the dictum of Plato that they are not 'even so low as syllables'.

Anaxagoras had no elements in the Empedoclean sense. The outline of his system is simple enough, but its details are often obscure. It is by no means certain that Anaxagoras himself was aware of all the implications, and it is manifest that commentators of the calibre of Aristotle and Lucretius were in error in their interpretations. Modern commentators are still far from agreement over the precise nature of the fundamental entities and the manner of their combination. Fortunately, since air is not to Anaxagoras one of the fundamental entities, it will not be necessary to enter exhaustively into the controversy concerning the latter. Moreover there is an excellent summary of the views expressed up to 1928 in Appendix I to Bailey's The Greek Atomists and Epicurus.

Since Bailey wrote, further attempts have been made to settle the problem, including those of Cornford, Vlastos and Raven, [*] and I find myself more closely in agreement with Raven than with any of the others.

Let us first consider Anaxagoras' position with respect to his predecessors and contemporaries. He is above all an Ionian, and we shall find that he retains the Ionian infinite store of matter and that his cosmology is clearly a descendent of the Milesians'. He accepts, however, the idea that the senses are not fully trustworthy, Frags. 21 and 21a. He agrees with Empedocles in accepting Parmenides' arguments against generation and destruction, and like him accounts for them by the mixture or separation of permanently existing entities, Frag. 17. He differs from him, however, over the nature and number of these entities.

He agrees with Parmenides that there is a constant amount of matter in the universe (Frag. 5 expresses this in wording that is slightly reminiscent of Parmenides), but not that this amount is limited. The amount is in

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[*] Vlastos in Phil. Review, lix, 1950; Cornford and Raven in Class. Quart., xxiv, 1930, and xlviii (new series iv), 1954 respectively.

fact infinite. Moreover this matter is infinitely divisible:

> ὁμοῦ πάντα χρήματα ἦν, ἄπειρα καὶ πλῆθος καὶ σμικρότητα· καὶ γὰρ τὸ σμικρὸν ἄπειρον ἦν.

Frag. 1.

Yet in spite of this the amount is constant: the wording of Frag. 5 is this time reminiscent of Frag. 3 of Zeno - Raven may be right (Op. Cit.) that it is a direct answer to Zeno and that to Anaxagoras Zeno's Frag. 1 demanded the reply:

> οὔτε γὰρ τοῦ σμικροῦ ἐστι τό γε ἐλάχιστον, ἀλλ' ἔλασσον ἀεί (τὸ γὰρ ἐὸν οὐκ ἔστι τὸ μὴ οὐκ εἶναι) - ἀλλὰ καὶ τοῦ μεγάλου ἀεί ἐστι μεῖζον. καὶ ἴσον ἐστὶ τῷ σμικρῷ πλῆθος, πρὸς ἑαυτὸ δὲ ἕκαστόν ἐστι καὶ μέγα καὶ σμικρόν.

Frag. 3.

You can go on halving a thing as many times as you can double it: there is no limit to divisibility, but this does not, as Zeno thought, destroy the reality of the matter so divided, nor will the division reach a stage, as it would for Empedocles, when your next cut will divide your piece of matter into two different (elemental) types of matter. The problem now is: how many infinitely divisible material entities, and of what sort, are necessary to explain change? Greek philosophy is now interested in physiology, and so he poses this question to himself with especial reference to the processes of nourishment and growth:

> πῶς γὰρ ἂν ἐκ μὴ τριχὸς γένοιτο θρὶξ καὶ σὰρξ ἐκ μὴ σαρκός;
>
> Frag. 10.

Now since all things are infinitely divisible, they cannot be composed of a finite number of Empedoclean type elements. As Aristotle pointed out (cf. pp. 224 - 231 sup.), any theory of elements entails a limit to divisibility. The number of substances in the phenomenal world is infinite: so, too, must be the number of primary entities.

But an infinite number of individual and separate entities, each homogeneous and unchanging, could only explain away an instantaneous universe. As soon as any change occurs the theory will have broken down. Consequently his entities are not homogeneous. Both on the macroscopic scale (when 'all things were together') and on the microscopic all things must contain a portion of everything. The following fragments demonstrate this and make it clear that it applies 'as in the beginning, so too even now'. I omit from Frag. 4 as irrelevant a passage about animals and men and cities.

τούτων δὲ οὕτως ἐχόντων χρὴ δοκεῖν ἐνεῖναι πολλά τε καὶ παντοῖα ἐν πᾶσι τοῖς συγκρινομένοις καὶ σπέρματα πάντων χρημάτων καὶ ἰδέας παντοίας ἔχοντα καὶ χροιὰς καὶ ἡδονάς.

πρὶν δὲ ἀποκριθῆναι ταῦτα πάντων ὁμοῦ ἐόντων οὐδὲ χροιὴ ἔνδηλος ἦν οὐδεμία· ἀπεκώλυε γὰρ ἡ σύμμιξις πάντων χρημάτων, τοῦ τε διεροῦ καὶ τοῦ ξηροῦ καὶ τοῦ θερμοῦ καὶ τοῦ ψυχροῦ καὶ τοῦ λαμπροῦ καὶ τοῦ ζοφεροῦ, καὶ γῆς πολλῆς ἐνεούσης καὶ σπερμάτων ἀπείρων πλῆθος οὐδὲν ἐοικότων ἀλλήλοις. οὐδὲ γὰρ τῶν ἄλλων οὐδὲν ἔοικε τὸ ἕτερον τῷ ἑτέρῳ. τούτων δὲ οὕτως ἐχόντων ἐν τῷ σύμπαντι χρὴ δοκεῖν ἐνεῖναι πάντα χρήματα.

Frag. 4.

καὶ ὅτε δὲ ἴσαι μοῖραί εἰσι τοῦ τε μεγάλου καὶ τοῦ σμικροῦ πλῆθος, καὶ οὕτως ἂν εἴη ἐν παντὶ πάντα· οὐδὲ χωρὶς ἔστιν εἶναι, ἀλλὰ πάντα παντὸς μοῖραν μετέχει. ὅτε τοὐλάχιστον μὴ ἔστιν εἶναι, οὐκ ἂν δύναιτο χωρισθῆναι, οὐδ' ἂν ἐφ' ἑαυτοῦ γενέσθαι, ἀλλ' ὅπωσπερ ἀρχὴν εἶναι καὶ νῦν πάντα ὁμοῦ. ἐν πᾶσι δὲ πολλὰ ἔνεστι καὶ τῶν ἀποκρινομένων ἴσα πλῆθος ἐν τοῖς μείζοσί τε καὶ ἐλάσσοσι.

Frag. 6.

οὐ κεχώρισται ἀλλήλων τὰ ἐν τῷ ἑνὶ κόσμῳ οὐδὲ ἀποκέκοπται πελέκει οὔτε τὸ θερμὸν ἀπὸ τοῦ ψυχροῦ οὔτε τὸ ψυχρὸν ἀπὸ τοῦ θερμοῦ.

Frag. 8.

It is over the precise meaning of 'all things contain a portion of everything' that commentators especially disagree. The two halves of Frag. 4 and the phrase from Frag. 6 quoted at the bottom of p. 259 show that it applies to both the original mixture and every portion that has separated off from it, however small.

Frag. 4 lists among the contents seeds having all sorts of shapes and colours and savours, all unlike each other, and infinite in numbers, and also the hot and the cold (cf. Frag. 8) and the wet and the dry (Anaximander's opposites) and the bright and the dark (Pythagorean) and earth, to which Frag. 1 adds ether and aer (ether meaning 'fire') and Frag. 16 adds water (giving Empedocles' four elements), while Frag. 15 adds the dense and the rare (cf. Anaximenes). When expressed in this way, the list surely appears to be, as Raven also holds it to be, exhaustive in the sense that it includes absolutely everything that anyone appears ever to have thought of as having real material existence.

I cannot therefore agree with Tannery and Burnet who say that the sole contents were the traditional opposites, nor even with Cornford's indefinite number of pairs of opposites, or rather interconnected opposite quality-things, that can never be separated into single opposites (cf. Frag. 8). I must, therefore, agree with Simplicius, Lucretius and Aëtius (D. 59 A 41, 44 and 46), and with Bailey, Cherniss and Raven, that the contents include all the types of matter that there are.

The next point of disagreement is whether these are contained juxtaposed in a mechanical mixture, even though there can be no minimal particles, as Ross and Cherniss and Giussani agree however different their explanations are otherwise, or in a closer union, more like a chemical fusion, as Bailey puts it. I agree with Raven that neither explanation can be correct. As he says, neither a water-and-wine nor a sugar-and-sand illustration is apposite. "The only possible analogy is that which the influence of Zeno clearly suggests, the analogy of the infinite number of points contained in even the shortest geometrical line" (Op. cit. p. 129). But unlike the points, the parts of the mixture, however small, still have some magnitude, and are not all alike. I do not, however, believe that Anaxagoras, if pressed, could have given a completely satisfactory solution to this problem. I think that, like Empedocles, he had not fully worked out the implications of his theory.

Since we are considering the nature of air, to enter any more fully into this controversy would be pointless. The main point is clear: air is not an element, but a mixture of everything; and we may now pass on to the cosmogony in order to see how air is separated out from the original mixture, and what part it has to play.

Fragment 4 described the original mixture - it had no χροιή, it did not look like any particular thing. In other words it was more like the apeiron of Anaximander that had likewise no specific characteristics than, say, the aer of Anaximenes. But Frag. 12 says:

> ἕτερον δὲ οὐδέν ἐστιν ὅμοιον οὐδενί, ἀλλ' ὅτων πλεῖστα ἔνι, ταῦτα ἐνδηλότατα ἓν ἕκαστον ἐστι καὶ ἦν.

Consequently even though the senses could not have picked out any individual thing in the mixture it was vaguely characterized by the fact that it contained more 'ether' (fire) and air than anything else, as Frag. 1 states:

> ..καὶ πάντων ὁμοῦ ἐόντων οὐδὲν ἔνδηλον ἦν ὑπὸ σμικρότητος· πάντα γὰρ ἀήρ τε καὶ αἰθὴρ κατεῖχεν, ἀμφότερα ἄπειρα ἐόντα· ταῦτα γὰρ μέγιστα ἔνεστιν ἐν τοῖς σύμπασι καὶ πλήθει καὶ μεγέθει.

When the cosmogony started it was fire and air that first separated out from the rest which is still described in

Frag. 2 in Milesian terminology as the 'surrounding boundless', the external store:

> καὶ γὰρ ἀήρ τε καὶ αἰθὴρ ἀποκρίνονται ἀπὸ τοῦ πολλοῦ τοῦ περιέχοντος, καὶ τό γε περιέχον ἄπειρον ἐστι τὸ πλῆθος.

This separation that started the cosmogony was caused by 'Mind', Anaxagoras' answer to Parmenides' query about the moving cause. Mind is described in material terms (cf. Empedocles' Love and Strife) but in a way that makes an even stronger impression that Anaxagoras was striving after the description of a non-material entity than we felt in the case of Empedocles. Again it is a case of Greek vocabulary lagging behind thought. I give the relevant fragment, No. 12, in English, because of its length:

> The other things contain a portion of everything, but mind is not limited and controls itself, and is mixed with no other thing, but is alone by itself. For if it were not by itself but were mixed with anything else, it would contain a share of all things if it were mixed with any; for in every thing there is a portion of everything, as I said before (Frag. 11). The things with which it was mixed would prevent it from controlling any thing, as it does in fact through being alone by itself.
>
> It is the rarest and purest of all things, and it has complete cognizance of everything, and has the greatest power. It has control over everything that has life, both the greater and the smaller. Mind also controlled the complete revolution, so that it began

to revolve at the start. The revolution started to revolve from some small beginning, but it now revolves over a larger volume and will do so over an even larger.

Mind also took cognizance of all the things that are mixed together and separated off (ἀποκρινόμενα - separated into masses of individual substances) and split up (διακρινόμενα - split up into component parts). Mind set in order all such things as were going to exist and such as were in existence, things that are not now in existence, and things that do now exist, and such as will exist. It also set in order this revolution in which there now revolve the stars and the sun and the moon and the air and the ether (fire) that are being separated off. The revolution itself caused the separation off. The dense is separated off from the rare, the hot from the cold, the bright from the dark, and the dry from the moist. And many things have many portions; but nothing is absolutely separated off or split apart from anything else except Mind. Mind is completely homogeneous, both the greater and the smaller. Nothing else is like anything else, but each individual thing is and was most manifestly those things of which it has most in it.

Thus the separation off of fire and air that is the first step in the cosmogony was caused by this force called 'Mind' through the agency of a revolution that clearly descends from the Milesian whorl. The description of the expansion of the volume affected by the revolution reminds one of the modern idea of the evolution of the spiral nebulae (the stellar universes) from a small beginning under the twin influences of gravity and revolution, and of the theory of the 'expanding universe'.

Fire and air separated off foremost because they were the 'things of which it has most in it' when the revolution started. The full cosmogony is given in the following fragments, nos. 15 and 16:

> τὸ μὲν πυκνὸν καὶ διερὸν καὶ ψυχρὸν καὶ τὸ ζοφερὸν ἐνθάδε συνεχώρησεν, ἔνθα νῦν <ἡ γῆ>, τὸ δὲ ἀραιὸν καὶ τὸ θερμὸν καὶ τὸ ξηρὸν ἐξεχώρησεν εἰς τὸ πρόσω τοῦ αἰθέρος.

> ἀπὸ τουτέων ἀποκρινομένων συμπήγνυται γῆ· ἐκ μὲν γὰρ τῶν νεφελῶν ὕδωρ ἀποκρίνεται, ἐκ δὲ τοῦ ὕδατος γῆ, ἐκ δὲ τῆς γῆς λίθοι συμπήγνυνται ὑπὸ τοῦ ψυχροῦ, οὗτοι δὲ ἐκχωρέουσι μᾶλλον τοῦ ὕδατος.

Aristotle several times states that αἰθήρ is the name given by Anaxagoras to fire, and he criticizes him for this since the ancients believed the primary body in the uppermost region, called by them αἰθήρ, to be different from fire. * This ether/fire Frag. 15 locates in its usual place at the periphery of the vortex, ** while the centre is the destination of that which is dense etc. (more accurately, which contains more of the dense than the rare, is most manifestly dense etc.). This is still the traditional centripetal vortex in a fluid or gaseous

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* Cf. de Caelo 270 b 24 and 302 b 4, Meteor. 339 b 21.

** The centre is 'here where the earth is now' but was not then, if we read ἡ γῆ; if not, it is 'here where the dense is now', the fact that the earth is here as well being irrelevant - the earth and the dense now share the centre, for the earth has the dense around it and even inside it, in subterranean cavities.

medium (cf. pp. 233-4). Once, however, solids have formed in Frag. 16 the revolution flings 'stones' off and these move outwards more than do liquids, because of the action of centrifugal force which in their case overcomes the centripetal force that prevails in the vortex as a whole.

The parallelism between the motion of the dense to where the earth was not yet and that of the rare 'towards the further part of the ether' might suggest that as the dense was not earth so too the rare was not ether, particularly since it would seem more meaningful to say that the rare went towards the ether than that the ether went towards the ether. If it were not for Aristotle's identification of ether with fire we could, then, perhaps say that the rare was fire and the dense was water-vapour, so that we should (after the formation of the earth) have a consistent system with ether and fire together at the periphery and earth and vapour at the centre, fire and vapour having in Frag. 15 lists of ingredients that correspond to the attributes of Heracleitus' light and dark exhalations.

This or something like this does in fact appear to be the interpretation of Bailey, who takes 'ether' to be 'sky' and 'aer' to be 'mist' (cf. Kranz's translation: 'Dunst'), and appears to take Frag. 15 to refer to fire and water. * (His account is not very clear.)

Apart, however, from the fact that we should expect Frag. 15 still only to be dealing with the aer and ether of Frags. 1 and 2, and that the rare would have to differ from both fire and ether since ether <u>is</u> fire, the system of ether and fire at the periphery and vapour or water and earth at the centre does not agree with the description in Diogenes Laertius II 8 (D. 59 A 1) of the state of the universe after the developments of Frags. 15 and 16

> τῶν δὲ σωμάτων τὰ μὲν βαρέα τὸν κάτω τόπον, <ὡς τὴν γῆν>, τὰ δὲ κοῦφα τὸν ἄνω ἐπισχεῖν, ὡς τὸ πῦρ, ὕδωρ δὲ καὶ ἀέρα τὸν μέσον.

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* In Op. cit. p. 548 he identifies the hot (from the rare list of Frag. 15) with fire and the moist (from the dense list) with water. On p. 546 note 4 he says that 'aer' is the vaporous misty air of Anaximenes and 'ether' the bright clear air of the sky, the element of Empedocles. On p. 41 he appears to take Frag. 15 to be chronologically posterior to Frag. 16. He says that mist and sky separated off first; he proceeds: "Then 'from clouds water is separated off, from water earth, and from earth stones are solidified by the cold'. Gradually these separated elements (sic) began to form themselves into a world". He now quotes Frag. 15 in full, and rounds it off with the phrase "and these formed the heavenly bodies". This seems to imply that he takes the rare etc., sc. fire, to be the substance of the heavenly bodies and not, as in the normal view, the 'stones' of the end of Frag. 16 which he leaves unquoted.

Here Diogenes not only identifies the rare etc. * with fire but also by implication (ex silentio) with ether, an identification confirmed by Theophrastus de Sens. 59 (D. 59 A 70), where the dense is also identified with aer:

> τὸ μὲν μανὸν καὶ λεπτὸν θερμόν, τὸ δὲ πυκνὸν καὶ παχὺ ψυχρόν, ὥσπερ 'Αναξαγόρας διαιρεῖ τὸν ἀέρα καὶ τὸν αἰθέρα.

Thus Diogenes actually describes a state when the dense had parted from fire in Frag. 15 and had undergone the separations of Frag. 16 so as to give layers of air, water, and earth. He is, in fact, saying that Anaxagoras' cosmogony leads to the standard stratification of the universe consistently described by Greek scientists whether they believed, like the Ionians, in a vortex, or, like Aristotle, in absolute weight and lightness, as the cause.

Burnet accepts this identification of the rare and dense with ether/fire and air, and makes Frag. 15 describe a first stage, the separation of the great masses of Frag. 1 as in Frag. 2, and Frag. 16 the next stage, with phases

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* The rare etc. is called by Diogenes 'the light things' - he is using Aristotelian terminology, and he similarly substitutes the vertical for the radial direction although the former is appropriate only to Aristotles' theory of relative weight, not to a vortex. Cf. the second paragraph on this page.

that follow the order of Anaximenes' density increases and produce clouds, water, earth, and stones <u>from</u> <u>air</u>. This interpretation is supported by Hippolytus (Ref. I 8, 2, D. 59 A 42): *

> τὸ μὲν οὖν πυκνὸν καὶ ὑγρὸν καὶ τὸ σκοτεινὸν καὶ ψυχρὸν καὶ πάντα τὰ βαρέα συνελθεῖν ἐπὶ τὸ μέσον, ἐξ ὧν παγέντων τὴν γῆν ὑποστῆναι· τὰ δ' ἀντικείμενα τούτοις, τὸ θερμὸν καὶ τὸ λαμπρὸν καὶ τὸ ξηρὸν καὶ τὸ κοῦφον, εἰς τὸ πρόσω τοῦ αἰθέρος ὁρμῆσαι.

This is clearly a paraphrase of Frag. 15 with a summary of the origin of earth in Frag. 16 inserted after the dense list, showing that Hippolytus took water earth and stones to be derived from the dense etc. He quotes the awkward phrase ἐς τὸ πρόσω τοῦ αἰθέρος, which Burnet rendered 'towards the further part of the aether' and interpreted as meaning 'the outside', ignoring the fact that

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* Here ὑγρόν replaces the less familiar διερόν of Frag. 15, and σκοτεινόν ζοφερόν, while πάντα τὰ βαρέα is added to the dense list (cf. τὰ μὲν βαρέα in D.L.): in the rare list τὸ λαμπρόν is added (since it is opposed to τὸ ζοφερόν in Frags. 4 & 12 Schorn is probably right in reading it in Frag. 15), while τὸ κοῦφον (again cf. D.L.) replaces τὸ ἀραιόν instead of being added to the list. The inserted phrase about earth may perhaps indicate that ἡ γῆ was in Hippolytus' text. The presence of this in Frag. 15 or of the parallel ὡς τὴν γῆν in D.L. is so uncertain that no interpretation should depend upon it. In my interpretation (v. inf. and cf. p. 266 ad fin.) its presence or absence is immaterial.

the phrase must on his interpretation mean that ether went to the further part of the ether. The phrase must, if we accept that the rare etc. is ether/fire, be interpreted differently. *

In Burnet's view, then, Frag. 2 states the fact of the separation from the mixture of Frag. 1 of its two greatest components, fire and air, and Frag. 15 explains it as the separation from one another of some of the many ** ingredients that these components contain, namely of the

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* It could be said that Frag. 2 gives the first separation of ether and air from the mixture, so that there is from the start ether contiguous to the 'surrounding mass' at the periphery of the small revolving volume, and that Frag. 15 gives a later stage when more ether parts from air within the now growing volume and moves towards the ether that is already at the periphery. Alternatively, since this is over-subtle and prejudges the question whether Frag. 15 is a later stage, we might say that the genitive is not partitive but possessive or defining: the further region that belongs to, or, as Aristotle would put it, is the proper place of, ether. Frag. 15 would then assert that the dense went, during or after the separation, 'here where it (either alongside or as the origin of earth according to the reading) is now' and the rare 'towards the more distant ether-region', i.e. each to its proper place. Frag. 15 need not then be later than Frag. 2.

** Fire and air are, of course, still mixtures not elements: Frags. 4 & 6 (p. 260) and 12 (p. 264) make this certain. Cf. Arist. de Cael. 302 a 28sq., where fire and air are said to be mixtures, and de GC 314 a 24sq., where they and water and earth are πανσπερμίαι. After their separation the rare etc. predominated in fire and vice versa.

opposite quality-things, each pair of which Frag. 4 states to have been present in the original mixture. Meanwhile Frag. 12 explains how the revolution started by Mind caused the separation of these pairs, but Frag. 8 reminds us that they are never completely sundered. *

Then Frag. 16 describes the solidification of earth and stones via clouds and water ἀπὸ τουτέων ἀποκρινομένων. What is the antecedent to τουτέων? Burnet says air: in other words he takes the plural to refer to the members of the dense list, as did Hippolytus. ** Simplicius, however, quotes Frag. 16 (in Phys. 179, 3sq., D. 59 B 15 & 16) just after Frag. 15 with connecting comments that refer to both the substances of Frag. 15 (which he calls ταῦτα) as ἀρχοειδῆ and ἁπλούστατα then state that things may 'solidify' or may 'separate off' from them; whereupon he quotes Frag. 16. It appears, therefore, that he took both substances to be the antecedents of τουτέων.

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* For Burnet (cf. p. 261 sup.) the original mixture consisted solely of the traditional opposites - in discussing them, however, he wavers between the notions of opposite qualities and opposite things.

** Burnet reads ἡ γῆ in Frag. 15 and ignores ἐνθάδε in his translation: "...come together where the earth is now". This is connected with his interpretation of Frag. 16, cf. my caveat in note to p. 270 sup..

The earth is, in fact, given as an example of what may separate off from the total contents of Frag. 15 by Simplicius. Kranz's translation of Frag. 16, 'Aus diesen sich abscheidenden Mengen ...', seems to show that he understood it to refer to the two great masses, and I too understand it so. *

I see no difficulty in supposing that the clouds could have separated off from fire as well as air. Fire contains a predominance of the rare etc. over their opposites; it nevertheless also contains portions of those opposites. Similarly air is not absolutely dense etc., although it is so compared with fire. Fire and air are most manifestly fire and air but, like everything else, they contain portions of everything, and in particular of cloud. Consequently from both there could separate off something that would most manifestly be the clouds of Frag. 16. Since they are both stated to be infinite,

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* There is no statement that Frags. 15 and 16 were consecutive. If they were, then the demonstrative is actually separated from the alleged antecedent, the dense etc., by the rare etc. and so should be taken either with the rare etc., which is nonsense, or with all the neuters. If they were not, then it might grammatically have any antecedent that we care to supply, including the total contents of Frag. 15 that Simplicius supplies, or the words 'fire and air'. It could not have the singular 'air'.

however small a percentage of their mass consisted of cloud or earth it would be enough when separated off and massed together to provide all the cloud water earth and stones in the phenomenal universe. *

Moreover the theory that the clouds come only from the dense etc. depends upon the assumption that Anaxagoras' air is the dark misty air of the Ionians. 'The dense and the moist and the cold and the dark' sounds it is true like the Milesian and Pythagorean aer, the Parmenidean night, or the Heracleitan dark exhalation, all of which had been opposed to fire, like, in other words, water vapour rather than the true air that Empedocles called 'ether' and distinguished from vapour; but compared with fire Empedocles' ether and even Anaximenes' invisible aer (denser than fire but rarer than mist) would be dense etc. and since it, like everything else except fire, lacks light, it could legitimately be described as dark. We know ** that Anaxagoras was as familiar with the eclipse

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* This can be so even if the amount of cloud etc. is infinite, for we already see in Frags. 1 & 2 that infinite air and ether separate from the infinite mixture.

** Cf. Hipp. loc. cit. Sec. 9 and Aët. II 29, 6, D. 59 a 77. It is true that Anaxagoras speaks of 'the dark', but this is a concession to his predecessors, cf. p. 261.

explanation that entails the non-corporeality of darkness as was Empedocles, and this alone serves to distinguish his aer from that of the Milesians and Pythagoreans. The latter also confused aer with void, but we know that Anaxagoras 'strained wineskins' and performed the clepsydra experiment, and therefore knew that invisible air is corporeal. * He knew, therefore, of the reality and nature of Empedocles' 'ether', of air in our sense of the word, and of its difference from water vapour. So it would be startling if his air were not descriptively similar to the ether of Empedocles, although not an 'element', and differently named. **

Moreover if the dense of Frag. 15 were vapour,

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* Cf. Arist. Phys. 213 a 22 and Ps. Arist. Probl. 914 b 9, D. 59 A 68, 69, v. p. 249 sup.. It is not clear why he used these experiments, and he may in fact be open to Aristotle's criticism, cf. Cherniss p. 147.

** Having adopted the archaic use of the word αἰθήρ (cf. p. 243) for that which is at the periphery, even though as Aristotle complained he meant by it fire and not a special celestial substance, he would be forced to use the word ἀήρ for air, even though he meant by it the true air called αἰθήρ by Empedocles and not mist. He may have avoided the word πῦρ in order to indicate that he meant something different from the fire of Heracleitus, either because he knew this to be symbolic, or because, like Aristotle, he misunderstood it as a sole element, or because, being a mixture, his fire was more like the dry exhalation than like 'pure' fire.

either it or the clouds of Frag. 16 would be otiose. The stages of Anaximenes were fire - wind - cloud - water - earth - stones, and neither in the account by Simplicius nor in that by Hippolytus (D. 13 A 5 & 7, pp. 50-1 & 65 sup.) does a stage of mist intervene between wind and cloud. Wind, between visible fire and visible cloud, must consist of his invisible form of aer, and must, if we are to press the striking analogy between the two men's cosmologies' phases, be that which corresponds to the dense of Frag. 15, which is between ether/fire and the clouds. If one grants invisibility to Anaxagoras' air (and it is certainly invisible in Frag. 1), one should not, while explaining away the 'dark' of Frag. 15 as on p. 274, take the 'moist' literally to indicate water vapour, for the invisible form of true water vapour is steam, which is hot, but the dense list includes the term 'cold'. Thus the air of Anaxagoras corresponds to, but is not identical with, the invisible aer of Anaximenes (which must have been hot since it is only one degree less rare than fire and rarity correlates with high temperature - p. 56sq. - although he did not always realise this himself).

There remains to be explained the presence of 'the moist'. Now fire is pre-eminently dry, and since the separation of fire and air entails the separation of the dry from the moist (traditional opposites included in the mixture in deference to Anaxagoras' predecessors, v. p. 261), the moist had to be given to air. But just as the air is not as dense as cloud (aer) nor, qua invisible, as dark as thunder-cloud, nor as cold as hail (from frozen cloud), so too it is not as moist as cloud.

Ritter and Preller, indeed, and Burnet, who is too much influenced by the apparent similarity between the cosmologies of Anaximenes and Anaxagoras (although he does not spot the point of p. 276), take the latter's air to be mist, as do Bailey and Diels-Kranz, and thus to be the sole source of the clouds. Raven, however, identifies it with the 'ether' of Empedocles, and so does Cherniss, with the wise caveat (Op. cit. p. 120) that in neither case is atmospheric air per se meant.

Atmospheric air was known by now to be a mixture, * and this invisible air was one of the components of the mixture. For Anaxagoras, moreover, though not for Empedocles, it was itself a mixture. Its properties we may say to have been those given under Empedocles on p. 243,

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* Cf. pp. 172-3 (Heracleitus) and 233, 242-3, 250 (Empedocles).

to which we must add a density greater than that of fire, a lack of the absolute dryness that is characteristic of fire (the influence of Milesian and traditional ideas was so strong that even after Empedocles air never quite broke clear from moistness in Greek thought even when distinguished from vapour proper), and a lack of innate heat and light (which is as true of the invisible as of the black). By contrast Anaxagoras' ether corresponds to the fire which Empedocles confirmed as a real substance (p. 250 sup.). It is the rarest (and lightest) form of matter, possessing innate heat and brightness, and is dry.

It is not quite clear whether the corporeal light of Empedocles (p. 240) is distinct from fire or not. It is probably not; at any rate there is no such distinction for Anaxagoras - light is an ingredient of the mixture that constitutes fire. Aristotle specifically denies that light is fire just before he objects to Empedocles' theory of light travelling (v. p. 240), and in objecting to Empedocles' and Plato's theories of vision in de Sensu 437 b 12sq. he says that hot and dry are not properties of light. Consequently, although he does not name Anaxagoras here, his criticism nevertheless applies to his ether too.

Supplementary note:-

There is a further point in which my interpretation of Anaxagoras' cosmogony differs from that of Burnet and most if not all others. I give it here in the form of this note since it is not strictly relevant to the nature of ether or air themselves.

Most interpretations make the cosmogony proceed by clear-cut stages in time analogous to the stages given by Anaximenes. This is not necessarily correct, for the following reasons.

Frags. 2 and 15 as we have seen apply to the same time, even for Burnet. Just as Frag. 4 explains the contents of the mixture of Frag. 1, so Frag. 15 explains the contents of the mixed substances of Frag. 2. Frag. 16 adds water and earth to the air and fire, and so completes the list of so-called elements, which are also in the mixture as well as the opposites. Frag. 16 has been taken as a later stage, so that earth is posterior to water and both to air and fire. Yet Frag. 4 states in a striking manner that the original mixture contained earth, a fact that has troubled many scholars and led some to turn a simple genitive into an apparently irrelevant genitive absolute. Surely Raven is right in believing that the contents of the mixture include all previous so-called primary entities as a condemnation of their alleged primary character and yet, as I believe, as a concession to the fact they do appear to manifest themselves in the sense world.

Now Frag. 16 may be logically posterior, but I do not believe it to be so chronologically. All its verbs are in the present tense, following the present participle (whereas the verbs of Frag. 15 are aorist). I interpret it thus: "From these (sc. fire <u>and</u> air) while they are being separated off (over a period of time) earth is (during that time) being massed together; for from the clouds (that also arise from both fire and air during the separation) water is being separated off (simultaneously), and from the water earth; and from the earth stones are being massed together by the cold (that is an ingredient of the air that is at the centre alongside the water and the earth and is in contact with them), and these are moving outwards more than is the water (because of the speed of the revolution, cf. Frag. 9 and p. 267)". These stones form the heavenly bodies (v. inf.).

Frag. 12 shows the intimate connexion between Frags. 2, 8, 9, 13, 15, and 16: "Mind set in order everything that was is and will be." (that is the sense, whatever the true reading, cf. textual note in DK) "It also set in order this revolution in which there now revolve the stars and the sun and the moon and the air and the ether (fire) that are being separated off (or: are separating off). The revolution itself caused the separation off. The dense is separated off (present tense, contrasting with the aorist used for the start of the revolution) from the rare, the hot from the cold, the bright from the dark, and the dry from the moist... but nothing is absolutely separated off or split apart from anything else except Mind". Note that instead of 'the revolution itself caused the separation off', the reading of Schorn and DK, the manuscripts read 'this revolution caused...'.

Here both the substances of Frag. 2, fire and air, and the apparent end products of Frag. 16, the heavenly bodies, are included in the same act of revolution ('this' revolution according to the manuscript reading) and separation, an act in which the rare separates from the dense and so on (as in Frag. 15) - which would be strange if opposites, elements, and stars belonged to separate stages. Stars and air and fire are mentioned together here just as the opposites and earth are together in Frag. 4. In none of these fragments is there any mention of chronological differences other than that between the eras before and after the revolution started. For this single act of commencement we have the aorists of Frags. 12 and 13 and 15, all dealing with the motion, but for the separations we have either the present tense (even in Frag. 2!), which is particularly noticeable in Frags. 9 and 16, or the imperfect (continuous) of Frag. 13, or the perfects of state of Frags. 5 and 8, and even in the latter case the perfect is actually negatived, showing a lack of completeness of the separation. The only relevant aorist occurs in Frag. 13, and there only for a reason: "And when mind began to cause motion, it was continually separating itself from all that was in motion, and all this that (at that time) mind set in motion underwent a process of splitting up. While the motion and splitting up continued, the revolution continually caused the splitting up greatly to increase". Here the emphasis is on the commencement and continuation of the motion and of the consequent splitting up of the source material, the mixture, and not on the separation off of the end-products.

Thus there was, is now, and will be, a continual increase in the volume and mass affected by the revolution: the separation off of the products is likewise continual, as the splitting up affects more and more of the mixture. (This is reminiscent of F. Hoyle's theory of 'continuous creation' in our 'expanding universe'.)

I conclude that the various separations and massings together are concurrent over a period that covers past present and future, and not successive and already complete, and that the processes of formation of the different end-products may occur simultaneously. There is, then, no set of successive stages (mixture - opposites - fire and air - water - earth - universe) as Burnet and Raven, and mutatis mutandis Bailey, maintained, nor does cosmology only deal with the 'elements' and physiology with the 'opposites', as Peck claimed.

We have several times recalled that in the list of contents of the mixture Anaxagoras deliberately included all the basic entities of his predecessors. He embraced earlier ideas, refined or corrected them, and either adapted them to or explained them by his new theory (and in doing so condemned by implication their originator's handling of them). He did the same with their processes. One single but complex process produced our universe, but he split its explanation, as he split that of its contents between substances and opposites, in such a way as to give a reconciliation of the theories of his predecessors.

The opposites of Frag. 15 explain the formation of the 'world-masses' of Heracleitus or the 'elements' of Empedocles; and the process of formation of these is also simultaneously that of the formation of the universe, which is consequently stratified as in the traditional account (cf. p. 269), except that the heavens contain not only fire but also visible and invisible solids - and even these are paralleled by the 'earthy bodies' of Anaximenes.

The cosmogony, then, was is and will be just one process, as Heracleitus also claimed (Frag. 30, p. 136 sup.). It starts with a blend of the potentiality for separation of Anaximander's apeiron or Empedocles' sphere and the substantial nature of Anaximenes' aer, reinterpreted as a mixture containing most manifestly fire and true air. It develops by a process of splitting up analogous to Anaximander's or Empedocles' in which there separate off a pair of substances whose opposed ingredients have affinities with the attributes of Heracleitus' exhalations or the light and dark of the Pythagoreans and Parmenides, though they far differ from them, and with the opposites of Anaximander. This separation also simultaneously causes certain parts of the whole to undergo changes parallel to the density increases of Anaximenes and the Way Down of Heracleitus. As in the latter case, however, increased density is an incidental result not a basic process, even though the proximate cause is the same as for Anaximenes, the cold - rather than the solidifying fire of Empedocles.

These changes, which produce a universe apparently made of Empedocles' four elements, result from a separation that is itself not a pure and complete sundering: for simultaneous with it is a regrouping, as with Empedocles, that can be called mixing together (συμμίσγεσθαι, Frag. 17) or, when increased density results, massing together (συμπήγνυσθαι, Frag. 16). These simultaneous processes are summed up in the compound συγκρίνεσθαι (Frag. 4), separation with recomposition, while the recomposition itself is called προσκρίνεσθαι (Frag. 14), being the opposite of the splitting up, διακρίνεσθαι (Frag. 13), that leads to separation off, ἀποκρίνεσθαι (Frag. 2).

The process is, though single, just as much a mixture as are the substances that it affects. Its components proceed concurrently and, as with Heracleitus, there is no point in time when any individual 'opposite' or 'element' is entirely isolated - only to Mind can this occur (Frags. 6, 8, 12 and 13). As with Empedocles, the recompositions may give the appearance of a sham physical law, the attraction of like to like (cf. Hipp. Ref. I 8, 2, D. 59 A 42). The proximate cause of the complex of simultaneous processes is the revolution, as with the Milesians, and the ultimate cause (demanded by Parmenides) is Mind, Anaxagoras' major innovation.

It will be seen from this note that Anaxagoras was at once an eclectic and an innovator. He was willing to incorporate into his very original theory notions found in all types of previous theory, as if to say that one need not totally abandon one's previous convictions in order to accept his own: if one discards certain misconceptions, one will find that the old theory will fit into the new, provided that one accepts two new premises: that the Urstoff is not a single element or a mixture of a few elements or opposites, but a mixture of the infinitely numerous and infinitesimally small seeds of everything (including one's own hitherto favoured entities), and that there is a vortex that has a cause, the new postulate Mind, which includes in its complex method of operating whatever method of change one has previously postulated as the sole method.

The remainder of the cosmological and meteorological thought is less original, and is equally patently the teaching of the Milesians, especially Anaximenes, brought up to date in the light of advances in empirical knowledge. In Athens Anaxagoras was naturally credited with discoveries that had actually been made in Magna Graecia, known to him but not, hitherto, to the common people of Athens, for example the reflected light of the moon and the explanation of eclipses and darkness.

In view of the comparative lack of originality I shall not quote the sources in full, but give a summary, indicating the reference to DK by "A" passage numbers unless otherwise stated, and naming the authorities.

1. a. The earth is flat. 1, D.L.; 42, Hipp.; 87, Exc. Astron.; 88, Simpl..

b. Having come to the centre of the vortex, it there floats on air because of its large surface area and the resistance of the latter, 42, Hipp.; 88, Arist. Simpl.; 89, Arist.; 13 A 20, Arist., there being no void, 42, Hipp.; 68, Arist..

c. The sea and rivers come from moisture that, evaporated by the sun's heat, falls as rain and settles upon the earth, and also from subterranean waters. The salt is left behind by the evaporation. 1, D.L.; 42, Hipp.; 90 Aët. etc.; cf. Arist. Meteor. 349 b 2.

2. a. The sun moon and stars are the 'stones' of Frag. 16, flung off upwards and heated into incandescence by the force of the revolution. 1, D.L.; 42, Hipp.; 12, Plut.; 71, Aët..

b. The sun is referred to as:

μύδρον (red-hot mass, esp. of iron) διάπυρον. 1, D.L.; 2, Harpocr.; 19, Olympiod.; 20a, Schol. Pind. Schol. Eurip.; 72, Aët..

μύλον (millstone) διάπυρον. 19, Joseph..

λίθος or πέτρος. 3, Suid.; 12, Plut.; 20a Schol. Pind.; 35, Plato; 42, Hipp.; 72, Aët.; 73, Xenoph..

c. The moon is a στερέωμα διάπυρον 77, Aët., and made of earth 35, Plato; 42, Hipp.; 77, Achill. Aët., or of stone 42, Hipp..

d. Stars are made of rock. 71, Aët..

e. There are also dark invisible heavenly bodies (as Anaximenes thought) below the moon. 42, Hipp.; 77, Aët.. (The order of height is: bodies, moon, sun, stars.)

f. At first the heavens revolved 'like a cupola' (cf. Anaximenes), but later they received an inclination (cause unexplained). 1, D.L.; 42, Hipp.; 67, Aët..

g. The 'turnings' of the sun and moon in declination are due to air resistance (cf. Anaximenes). 42, Hipp.; 72, Aët..

3. The moon shines by reflected light. Frag. 18; 42, Hipp.; 76, Plato; 77, Aët..

4. Eclipses of the sun are caused by occultation by the moon, and of the moon by its falling into the shadow of the interposed earth or by the dark bodies, while the new moon is dark because it is in conjunction with the sun. 42, Hipp.; 77, Aët, from Posidonius and Theophrastus.

5. The Milky Way is the light (1 and 42 wrongly say reflected light) of stars that are not drowned by sunlight when they are shielded from the sun by the earth. 1, D.L.; 42, Hipp.; 80, Arist. Aët..

6. Comets are planets so close together that they seem to touch. 1, D.L.; 81, Aët, Arist..

7. Shooting stars are like sparks from the ether (1 says aer) that rebound owing to the revolution. 1, D.L.; 42, Hipp.; 82, Aët..

8. Wind is air rarefied by the sun 1, D.L.; 42, Hipp., and when things that are burning up recoil and are thrown back up towards the pole. 42, Hipp.. Frag. 19 does not imply that wind comes from water vapour, cf. Cherniss Op. Cit. p. 128. Like Empedocles Frag. 50 it merely makes a weather-forecasting assertion: wind or rain follows the rainbow.

9. Earthquakes are caused when the upper air falls onto the earth or the air below the earth; for this being moved causes the earth, which rests upon it, to rock. 1, D.L.; 42, Hipp.; 89, Aët.. Alternatively, the ether,

which naturally moves upwards, is caught in hollows below the earth and so shakes it, for though the earth is actually porous its surface is clogged up by rain. 89, Arist., who here rather misrepresents Anaxagoras, by referring the cause to ether (though Seneca in 89 also seems to suggest this) and by giving to it his own idea of natural upward motion, v. Cherniss pp. 207-9.

10. Clouds and snow are explained as by Anaximenes. 85, Aët.. For rain cf. Frag. 19.

11. Thunder and lightning occur when part of the upper ether (fire) descends from above into the clouds. Lightning is the gleam of this fire, and thunder the hissing noise of its quenching in the cloud. 42, Hipp.; 84, Arist. Aët. Seneca. (1, D.L., oversimplifies.)

12. Rainbow (also Mock Suns) is sunlight reflected in clouds. Frag. 19; 86, Aët..

13. Hail comes when a cloud is thrust up into the cold upper atmosphere so that the water freezes. It occurs in summer and in warm countries since the greater heat elevates the cloud further from earth. 85, Aët. Arist. Alex..

14. Night gives clearer audibility than day because the air, heated by the sun in the daytime, makes a hissing noise, but is calmer in the night's coolness. The air, when thus heated, has a vibratory motion, made manifest by the motes in a beam of light, and it is these that make the hissing noise. 74, Ps. Arist. Probl. and Plut..

The most striking difference from the theories of his immediate predecessors is Anaxagoras' assertion that the heavenly bodies are stones flung off by centrifugal force and made incandescent by motion, although the lower ones (travelling in a cooler region) remain dark and invisible, No. 2 sup.. It obviously springs from the idea of Anaximenes about 'earthy bodies' (13 A 7, Hipp. and A 14, Aët.). Ps. Plut. Strom. 3, 13 A 6, incidentally, while wrongly saying that Anaximenes' sun is of earth, attributes its heat similarly to swift motion, while Xenophanes gave the same explanation for his luminous clouds (pp. 124-5 sup.). The reason why Anaxagoras not only returned to this idea of Anaximenes but also applied it to all the heavenly bodies, which Anaximenes did not do, instead of adopting the view of most of his immediate predecessors that the latter are made of fire or of incandescent aer, will have been that the famous Aegospotami meteorite appeared to him as to others (e.g. Diogenes, v. inf.) to confirm the view that he adopted. Of course the story that he predicted the meteorite's fall (cf. 1, D.L.; 6, Philostr.; 11, Pliny etc.; 12, Plut.) must be false.

The explanation of shooting stars (No. 7) is to us surprising, for the Aegospotami meteorite was in fact a large shooting star - shooting stars are in fact solids that are normally dark and invisible but that become incandescent through friction when they enter the earth's atmosphere at speed. They are termed meteors or meteorites according to their size: meteors are small and melt right away, but the occasional larger body survives the heat in part so that the remnant crashes upon the earth as a meteoritic stone. Anaxagoras thought that the stone fell from the sun; but such objects are actually fragments of shattered comets. Comets are bodies composed of a large nuclear head that is a fairly dense mixture of small solid particles and gas and a tail, changeable in shape, that is a similar mixture, but so rarefied and tenuous that it is actually moved by the pressure of light photons from the sun. Anaxagoras' explanation of their elongated shape (No. 6) is quite wrong, and yet it is just meteors and comets that in fact most closely correspond to his definition of heavenly bodies as a whole.

Anaxagoras not only repeats the correct explanation of eclipses, but also correctly accounts for the phases of the moon (or at least for the new moon, No. 4). This shows as we have seen that he knew that darkness is absence of light and not a substance, and this knowledge of how the earth can occult the light of the sun enables him to give a reasonably correct account of the Milky Way.

One of the consequences of Parmenides' denial of the void is that Anaxagoras retains the old Ionian idea that the earth is flat and rests upon the air. The use made of this idea to explain earthquakes is ingenious, but it shows that the Ionians over-estimated the resistance of air - cf. p. 15 sup.: "Gases ... are extremely compressible and elastic, but offer little resistance to a moving body unless compressed considerably". They were right to attempt to explain the degree of resistance by postulating a large flat contact area, but as long as the air beneath the earth could have free passage round the edges of the latter, its weight would cause the earth to displace the air, and it would fall. *

The 'strained wineskins' experiment (like attempting to flatten an inflated balloon) demonstrates the compressibility and elasticity of air and also the strength of its resistance when compressed. But the conditions are different from those of the air beneath the earth. However Aristotle in de Cael. 294 b 13sq., D. 13 A 20, shows how the Ionians tried to circumvent the difficulty. The flat earth acts like a lid (or, as we should now say, like a piston) and the air immediately below it has not

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* There is no absolute up and down in the vortex as there is for Aristotle, only motion to and from the centre. The earth is already rotating at the centre, so that Anaximander and Empedocles were, each in his own fashion, in fact more consistent than Anaximenes and Anaxagoras.

room to get round the edges as above, but is compressed and stays still owing to the air still further below, just as water rests on air in the clepsydra experiment. Aristotle is speaking of Anaximenes, Anaxagoras and Democritus, but the latter point is obviously particularly relevant to Anaxagoras. After he had performed such experiments the theory that the earth floats on air would seem more plausible than it had, for example, to Xenophanes, to whose 'rooted' earth Aristotle had just referred in this context.

In addition to the properties of air discussed on pp. 277-8 we find in Nos. 8 and 13 sup. an explicit statement of a property of air that must have been for a long time known by observation, and that is implied in the Way Up of Heracleitus: hot air rises. Winds may occur when things burn and move up towards the pole, and hail is formed when heat pushes the clouds upwards, we are told.

Nobody who has seen the smoke of a fire or the steam from a cauldron could fail to be aware of the principle, but we now have it made the explanation of currents of air that are not visible, in contrast to smoke and vapour. The reason for the rise of hot air is that it is expanded by heat so that it is more rarefied and has less weight per unit volume than the surrounding cooler air. It is consequently displaced upwards by that heavier air. Anaxagoras was therefore on the right track in his alternative explanation of wind: air rarefied by the sun. The observation that such a rising air current may lift up a cloud is correct, in spite of Aristotle's lack of agreement with Anaxagoras over the cause of hail. There is usually a rising column of air below a cumulus cloud, for example, as Daedalus may have discovered.

Quite remarkable is No. 14, the connexion of the observation of motes that oscillate in a sunbeam with the observation that audibility improves at night, leading to the correct conclusion that heat causes irregular shimmering movements in the air, which may be audible or may adversely affect the transmission of sound. This is an unusually good example of 'scientific method ' for a Pre-Socratic philosopher.

To sum up, until the time of Empedocles air was either the primary substance itself or one of a limited number of primary substances, so that it would have been meaningless to enquire of what it is made. Anaxagoras denied that it was an element, and so he had to answer this enquiry. His answer was that it was made of all the things that there are, of 'portions' of everything. Its presence was recognised by the fact that in what was most manifestly air there was more air than there was of all other things combined: but what this predominating thing is was still not really explained. (It subsumed certain of his predecessors' 'opposites', but in a new and rather obscure way.)

Later thinkers abandoned the idea of a thing containing portions of everything, and explained the properties of air by describing the type or types of primary entity of which it is composed, just as we explain them by the type of molecule or atom of which it is composed. The list of the properties of air known in the time of Empedocles and Anaxagoras, the first half of the fifth century, is practically as complete as can be ascertained without the use of modern laboratory methods and apparatus. In future we shall expect to discover not further properties of air, but advances in the theory of its composition and of the reasons for its possessing those properties. We shall, however, meet with some theories that are less satisfactory than those of Empedocles and Anaxagoras, and especially with theories in which air is still regarded as a form of water vapour.

The theory of Anaxagoras was at least as consistent and rational as any that could be arrived at on Ionian principles. The infinite store of matter is no longer conceived of as 'breathed in' by the world as if the latter were alive. Motion is not now an intrinsic property of matter, but is provided with an efficient cause. The cosmogony is entirely materialistic, and strife and justice no longer rule. Its Ionian origin is manifest, but the acquaintance of its author with Pythagorean discoveries and mathematical theories, with the elements of Empedocles, and with the logic of Parmenides and Zeno, has completely transformed it. Concepts unknown to the Milesians are included, for example recomposition (the sham physical law of the attraction of like to like) and infinite divisibility.

Yet it is a difficult theory (witness the widely diverging modern reconstructions) and one that failed to win lasting recognition. The microscopic aspect is not satisfactory; to explain the infinite variety of phenomenal substances by an infinite variety of primary substances is not very fruitful, while infinite divisibility leads to insuperable difficulties.

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CHAPTER NINE

IONIAN MONISM IN DECLINE.

Infinite divisibility, important though it be to mathematics, is unfruitful when applied to physical theories of the constitution of matter, and Anaxagoras had few followers (apart from Archelaus, v. inf.). There is, so to speak, nothing for the physicist to get hold of - no minimal unit, no basic entity. Real progress was henceforward made by members of other schools of thought, who believed that matter was composed of fundamental indivisibles of some kind.

Before passing on to these, however, we must first consider the final decay of Ionian monism. Aristophanes, in the Clouds passim, and Euripides, e.g. Troades 884sq. and in some fragments, refer to theories now current in contemporary Athens that base the universe on aer or ether and even make it a god. Athens was not yet the leader of Greek speculation that it became under Plato and Aristotle, but was already full of the ideas not only of Anaxagoras, but also of men like Hippo, Idaeus, Diogenes and Archelaus. These were not original thinkers, but just eclectics, men of the second rank, vainly trying to fuse ideas from any source into a workable Ionian system.

The abler among them still maintained the monistic hypothesis and tried to mediate between one or the other of the Milesians and Anaxagoras, while those of less ability frankly gave up the struggle and tried to build an Ionian edifice upon the foundation of a pluralism derived from Magna Graecia. In the mid fifth century the Pythagorean communities were being scattered, and it is not always easy to decide whether one of these minor philosophers is a refugee Pythagorean or a man trained in the purely Ionian tradition, a tradition that in the main goes back to Anaximenes.

Hippo is an obscure figure. His name may even have been Hipponax, and his origin is variously given as Samos, Metapontum, Rhegium and Croton. His date must be later than that of Empedocles, for he criticized one of the latter's theories (v. inf.). He held that the basic substance was moisture, from which fire originated, thus giving for the purpose of cosmogony two principles, the hot and the cold, cf. Hipp. Ref. I 16, D. 38 A 3:

῞Ι. δὲ <ὁ> ῾Ρηγῖνος ἀρχὰς ἔφη ψυχρὸν τὸ ὕδωρ καὶ θερμὸν τὸ πῦρ. γεννώμενον δὲ τὸ πῦρ ὑπὸ ὕδατος κατα-

> νικῆσαι τὴν τοῦ γεννήσαντος δύναμιν συστῆσαί τε τὸν κόσμον. τὴν δὲ ψυχὴν ποτὲ μὲν ἐγκέφαλον λέγει, ποτὲ δὲ ὕδωρ· καὶ γὰρ τὸ σπέρμα εἶναι τὸ φαινόμενον ἡμῖν ἐξ ὑγροῦ, ἐξ οὗ φησι ψυχὴν γίνεσθαι.

Alexander, 26, 21, D. 38 A 6 (commenting on Arist. Met. 984 a 3, A 7, where Hippo is stated to have been mentally inferior to Thales) says:

> Ἵππωνα ἱστοροῦσιν ἀρχὴν ἁπλῶς τὸ ὑγρὸν ἀδιορίστως ὑποθέσθαι οὐ διασαφήσαντα πότερον ὕδωρ ὡς Θαλῆς ἢ ἀὴρ ὡς Ἀναξιμένης καὶ Διογένης.

There really is a doubt about the meaning of 'moisture' here, which we must try to resolve. The other ancient commentators too readily jumped to conclusions. * Simplicius (Phys. 23, 22, A 4) names Hippo along with Thales as having posited ὕδωρ as the principle, and (D. 11 A 13) repeats the connexion between moisture (and its derivative heat) and life and semen. Now this connexion is mentioned by Aristotle in Met. 983 b 17sq., D. 11 A 12, but he gives it as Thales' own reason for choosing water as the principle. In view of the Milesians' interest in τὰ μετέωρα, e.g. the evaporation cycle, in contrast to the

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* Sextus, Pyrrh. Hyp. III 30 and IX 361, D. 38 A 5, gives both water and fire (its derivative) as his principles; Ioann. Diac., A 6, even gives earth! Philoponus, de An. 88, 23, A 8, like Hippolytus and Simplicius, names ὕδωρ rather than τὸ ὑγρόν.

physiological interest introduced by Alcmaeon, it is likely that this reason was actually given by Hippo rather than by Thales, and read into Thales by Aristotle since no true account of Thales' own reasons had survived.

Aëtius, IV 3, 9, A 10, says that Hippo postulated that the soul is from water, and Aristotle, de An. 405 b 1 says:

> τῶν δὲ φορτικωτέρων καὶ ὕδωρ τινὲς ἀπεφήναντο (τ. ε. τὴν ἀρχήν) καθάπερ Ἵππων· πεισθῆναι δ' ἐοίκασιν ἐκ τῆς γονῆς ὅτι πάντων ὑγρά· καὶ γὰρ ἐλέγχει τοὺς αἷμα φάσκοντας τὴν ψυχήν, ὅτι ἡ γονὴ οὐχ αἷμα· ταύτην δ' εἶναι τὴν πρώτην ψυχήν.

Hippo appears to be attacking Empedocles here (cf. p. 295). At b 24 (A 10) Aristotle goes on to say that those who posit two contrary principles, e.g. the hot and the cold, equate the soul with one of these, and those who equate it with the cold give an etymological connexion between ψυχή and κατάψυξις (here, the coolness of the breath). Philoponus, ad loc. 92, 2, A 10, states that this refers to Hippo. Menon, Anon. Lond. 11, 22, A 11, says that Hippo connected moisture with perception, life and health. Disease comes when excess of heat or cold causes the moisture within us to change its state. This change may be one of rarefaction or condensation.

The connexion with breath and life in these passages and the mention of condensation and rarefaction put one in mind of Anaximenes, and when one remembers that semen appears to be frothy (v. inf.) rather than truly liquid, one is, I feel, led to conclude that Hippo probably postulated as his principle moisture, water vapour, rather than water as such - something like the mist of the later Milesians rather than the water of Thales. He may in fact have been correcting Thales in the light of subsequent advances: this is more likely than that he should in spite of his awareness of the latter have gone blindly back to Thales' original assumption.

He himself almost certainly employed the words τὸ ὑγρόν, as indeed Alexander states (loc. cit. p. 296) and Menon's use of the later word ὑγρότης implies; and the ὕδωρ of the other commentators is probably due to their being misled by the way in which Aristotle too readily makes him merely an inferior imitator of Thales. He may possibly have avoided the word ἀήρ for this moist misty substance either because he was formerly a Pythagorean (cf. Iamblichus' catalogue, D. 38 A 1) and associated that word with void or breath and not with sensibly moist water vapour or because the work of Empedocles had rendered that word temporarily uncertain in meaning (cf. p. 275 note 2).

Hippo's interests seem to have been predominantly physiological, and we have no information concerning his cosmogony beyond the bald statement of Hippolytus quoted on p. 295. Neither his physiological work nor his sole extant fragment are relevant, and we may leave him.

Ion of Chios was a poet with an interest in philosophy. He was born about 490 b.c. and spent much time in Athens. He wrote at least one cosmological work in prose, and his theory was that everything went by threes, including the elements, which were, he claimed, fire air and earth (Isoc. XV 268 and Philop. de GC 207, 18, D. 36 A 6). In his theory of triads he shows the influence of the Pythagorean triad: beginning middle and end.

Ion was one ahead of his compatriot Oenopides, a younger contemporary of Anaxagoras, who was an astronomer and geometrician. He preferred to postulate only two elements, fire and air, like some of the early Pythagoreans and Parmenides (Sext. Pyrrh. Hyp. III 30, D. 41 A 5). He is credited with having discovered (or plagiarized from Pythagoras) the obliquity of the ecliptic. We have no details of his generation of the world from fire and air.

Of Idaeus of Himera we again know very little. His only mention in the commentators is in Sext. IX 360 (D. 63), where he is listed along with Anaximenes, Diogenes, and Archelaus, as a believer in aer as the sole element. Yet Zeller-Nestle and, hesitantly, Diels attribute to him, totally without evidence, the theory of an intermediate element (τὸ μεταξύ), with which I shall be dealing in connexion with Diogenes.

This Diogenes was a man of greater ability than these others, and was the last major figure in the Ionian school before it turned from monism to the atomic theory. He was, according to Diogenes Laertius, a contemporary of Anaxagoras, by which is probably meant a younger contemporary. He came from Apollonia, by which the Phrygian Apollonia (cf. Ael. V.H. II 31, D. 64 A 3 - where he is named along with Hippo as an atheist) is almost certainly meant, not the Cretan city. He must have come to Athens at some time, for his views are clearly parodied in the Clouds of Aristophanes (e.g. 225sq., 264sq., et passim) and by Euripides (e.g. Troades 884sq.). Simplicius saw a copy of one of his books, the On Nature, and also refers to accounts by Theophrastus, Nicholaus of Damascus, and Porphyry; Aristotle and Aëtius also tell us much of him.

The brief account of Diogenes Laertius (ix 57, D. 64 A 1) includes the following:

> στοιχεῖον εἶναι τὸν ἀέρα, κόσμους ἀπείρους καὶ κενὸν ἄπειρον· τόν τε ἀέρα πυκνούμενον καὶ ἀραιούμενον γεννητικὸν εἶναι τῶν κόσμων· οὐδὲν ἐκ τοῦ μὴ ὄντος γίνεσθαι οὐδὲ εἰς τὸ μὴ ὂν φθείρεσθαι...

Here we obviously have the tradition of Anaximenes with an addition made to satisfy the Eleatics. However grafts of later ideas were made upon the original stock, as Simplicius says in Phys. 25, 1, A 5:

> καὶ Δ. δὲ ὁ 'Απολλωνιάτης, σχεδὸν νεώτατος γεγονὼς τῶν περὶ ταῦτα σχολασάντων, τὰ μὲν πλεῖστα συμπεφορημένως γέγραφε τὰ μὲν κατὰ 'Αναξαγόραν, τὰ δὲ κατὰ Λεύκιππον λέγων· τὴν δὲ τοῦ παντὸς φύσιν ἀέρα καὶ οὗτός φησιν ἄπειρον εἶναι καὶ ἀίδιον, ἐξ οὗ πυκνουμένου καὶ μανουμένου καὶ μεταβάλλοντος τοῖς πάθεσι τὴν τῶν ἄλλων γίνεσθαι μορφήν. καὶ ταῦτα μὲν Θεόφραστος ἱστορεῖ περὶ τοῦ Διογένους, καὶ τὸ εἰς ἐμὲ ἐλθὸν σύγγραμμα Περὶ Φύσεως ἐπιγεγραμμένον ἀέρα σαφῶς λέγει τὸ ἐξ οὗ πάντα γίνεται τὰ ἄλλα. Νικόλαος μέντοι τοῦτον ἱστορεῖ μεταξὺ πυρὸς καὶ ἀέρος τὸ στοιχεῖον τίθεσθαι. καὶ οὗτοι δὲ τὸ εὐπαθὲς καὶ εὐαλλοίωτον τοῦ ἀέρος εἰς μεταβολὴν ἐπιτηδείως ἔχειν ἐνόμισαν· διὸ τὴν γῆν δυσκίνητον καὶ δυσμετάβλητον οὖσαν οὐ πάνυ τι ἠξίωσαν ἀρχὴν ὑποθέσθαι· καὶ οὕτως μὲν οἱ μίαν λέγοντες τὴν ἀρχὴν διῃρέθησαν.

That ἀήρ was his principle is clear from Frags. 4 and 5, and I shall postpone discussion of the statement of Nicolaus until I have dealt with them. That it was his principle is also stated by Aristotle (e.g. Met. 984 a 5, de An. 405 a 21), Ps. Plutarch (D. 64 A 6), Aëtius (A 7), and Sextus (D. 63). It was the substance of soul (Frag. 4, Arist. loc. cit. and Aët., D. 64 A 20) and it was referred to as a god (Frag. 5, if DK's text be sound, and passages in A 8).

Diogenes' reasons for disagreeing with the pluralists, particularly Empedocles, and adhering to monism are given in Frag. 2 (which is summarised with approval by Aristotle in de GC 332 b 12, A 7):

> ἐμοὶ δὲ δοκεῖ τὸ μὲν ξύμπαν εἰπεῖν πάντα τὰ ὄντα ἀπὸ τοῦ αὐτοῦ ἑτεροιοῦσθαι καὶ τὸ αὐτὸ εἶναι. καὶ τοῦτο εὔδηλον· εἰ γὰρ τὰ ἐν τῷδε τῷ κόσμῳ ἐόντα νῦν, γῆ καὶ ὕδωρ καὶ ἀὴρ καὶ πῦρ καὶ τὰ ἄλλα ὅσα φαίνεται ἐν τῷδε τῷ κόσμῳ ἐόντα, εἰ τούτων τι ἦν ἕτερον τοῦ ἑτέρου, ἕτερον ὂν τῇ ἰδίᾳ φύσει, καὶ μὴ τὸ αὐτὸ ἐὸν μετέπιπτε πολλαχῶς καὶ ἑτεροιοῦτο, οὐδαμῇ οὔτε μίσγεσθαι ἀλλήλοις ἠδύνατο, οὔτε ὠφέλησις τῷ ἑτέρῳ <γενέσθαι ἀπὸ τοῦ ἑτέρου> οὔτε βλάβη, οὐδ' ἂν οὔτε φυτὸν ἐκ τῆς γῆς φῦναι οὔτε ζῷον οὔτε ἄλλο γενέσθαι οὐδέν, εἰ μὴ οὕτω συνίστατο ὥστε ταὐτὸ εἶναι. ἀλλὰ πάντα ταῦτα ἐκ τοῦ αὐτοῦ ἑτεροιούμενα ἄλλοτε ἀλλοῖα γίνεται καὶ εἰς τὸ αὐτὸ ἀναχωρεῖ.

Simplicius, ad loc. Phys. 151, 28, D. 64 B 2-8, comments that at first sight he took this to mean that Diogenes' principle was something apart from the four so-called elements, but that after Frag. 3, which states that the principle contains νόησις (cf. the νοῦς of Anaxagoras; but while the latter and Empedocles distinguished causes and elements Diogenes combined the two concepts), Frag. 4 makes it clear that living creatures come from this principle, which is aer, and get their soul and intelligence from it. Frag. 5, he adds, makes this clear.

Frags. 4 and 5 show in fact that Diogenes' reason for the choice of aer for his principle was similar to that of Anaximenes (v. p. 50 sup.), while Frag. 5 shows that this aer, although a material element, has some affinities with Anaxagoras' νοῦς (and cf. the Heracleitan fire). These fragments read thus in the text of DK:

4. ἔτι δὲ πρὸς τούτοις καὶ τάδε μεγάλα σημεῖα. ἄνθρωποι γὰρ καὶ τὰ ἄλλα ζῷα ἀναπνέοντα ζώει τῷ ἀέρι. καὶ τοῦτο αὐτοῖς καὶ ψυχή ἐστι καὶ νόησις, ὡς δεδηλώσεται ἐν τῇδε τῇ συγγραφῇ ἐμφανῶς, καὶ ἐὰν τοῦτο ἀπαλλαχθῇ, ἀποθνῄσκει καὶ ἡ νόησις ἐπιλείπει.

5. καί μοι δοκεῖ τὸ τὴν νόησιν ἔχον εἶναι ὁ ἀὴρ καλούμενος ὑπὸ τῶν ἀνθρώπων, καὶ ὑπὸ τούτου πάντας καὶ κυβερνᾶσθαι καὶ πάντων κρατεῖν· αὐτὸ γάρ μοι τοῦτο θεὸς δοκεῖ εἶναι καὶ ἐπὶ πᾶν ἀφῖχθαι καὶ πάντα διατιθέναι καὶ ἐν παντὶ ἐνεῖναι. καὶ ἔστιν οὐδὲ ἓν ὅ τι μὴ μετέχει τούτου· μετέχει δὲ οὐδὲ ἓν ὁμοίως τὸ ἕτερον τῷ ἑτέρῳ, ἀλλὰ πολλοὶ τρόποι καὶ αὐτοῦ τοῦ ἀέρος καὶ τῆς νοήσιός εἰσιν· ἔστι γὰρ πολύτροπος, καὶ θερμότερος καὶ ψυχρότερος καὶ ξηρότερος καὶ ὑγρότερος καὶ στασιμώτερος καὶ ὀξυτέρην κίνησιν ἔχων, καὶ ἄλλαι πολλαὶ

ἑτεροιώσιες ἔνεισι καὶ ἡδονῆς καὶ χροιῆς ἄπειροι. καὶ πάντων τῶν ζῴων δὲ ἡ ψυχὴ τὸ αὐτό ἐστιν, ἀὴρ θερμότερος μὲν τοῦ ἔξω ἐν ᾧ ἐσμεν, τοῦ μέντοι παρὰ τῷ ἡλίῳ πολλὸν ψυχρότερος. ὅμοιον δὲ τοῦτο τὸ θερμὸν οὐδενὸς τῶν ζῴων ἐστίν (ἐπεὶ οὐδὲ τῶν ἀνθρώπων ἀλλήλοις), ἀλλὰ διαφέρει μέγα μὲν οὔ, ἀλλ' ὥστε παραπλήσια εἶναι.

οὐ μέντοι ἀτρεκέως γε ὅμοιον οὐδὲν οἷόν τε γενεσθαι τῶν ἑτεροιουμένων ἕτερον τῷ ἑτέρῳ, πρὶν τὸ αὐτὸ γένηται. ἅτε οὖν πολυτρόπου ἐούσης τῆς ἑτεροιώσιος πολύτροπα καὶ τὰ ζῷα καὶ πολλὰ καὶ οὔτε ἰδέαν ἀλλήλοις ἐοικότα οὔτε δίαιταν οὔτε νόησιν ὑπὸ τοῦ πλήθεος τῶν ἑτεροιώσεων. ὅμως δὲ πάντα τῷ αὐτῷ καὶ ζῇ καὶ ὁρᾷ καὶ ἀκούει, καὶ τὴν ἄλλην νόησιν ἔχει ἀπὸ τοῦ αὐτοῦ πάντα.

Simplicius continues (Phys. 153, 13, B 6) that Diogenes showed that semen is πνευματῶδες (cf. p. 298 sup.) and that intelligence comes when the aer occupies the whole of the body along with the blood via the veins (Frag. 6), and concludes that his principle was 'that which men call aer'. (In spite of his first impression that it was not one of the so-called elements.) He then comments that it was strange to say that other things come from changes in aer and yet that aer is eternal (which is stated in Frags. 7 and 8).

We are, as we have already seen, bound to agree with Simplicius that aer is the principle. What, then, of the statement of Nicolaus that it was μεταξὺ πυρὸς καὶ ἀέρος? Simplicius repeats the statement in Phys. 151, 20, A 4:

> ἐπειδὴ δὲ ἡ μὲν τῶν πλειόνων ἱστορία Διογένην τὸν Ἀπολλωνιάτην ὁμοίως Ἀναξιμένει τὸν ἀέρα τίθεσθαι τὸ πρῶτον στοιχεῖόν φησι, Νικόλαος δὲ ἐν τῇ Περὶ Θεῶν πραγματείᾳ τοῦτον ἱστορεῖ τὸ μεταξὺ πυρὸς καὶ ἀέρος τὴν ἀρχὴν ἀποφήνασθαι.

This passage occurs shortly after a full discussion of the point at issue in Phys. 149, 5, D. 63, which is a comment on Arist. Phys. 187 a 12 (quoted as passage no. 3 on p. 32 sup., cf. p. 39). I give this discussion in translation because of its length:

> For all postulate that this One is something corporeal, but some made it one of the three elements, e.g. Thales and Hippo water, Anaximenes and Diogenes aer, Heracleitus and Hippasus fire ... , while others made it something other than the three, which is denser than fire and rarer than aer, or, as Aristotle says elsewhere, denser than aer and rarer than water. Now Alexander thinks that Anaximander postulated as the principle the other kind of body apart from the elements, but Porphyry says that as Aristotle divides those who make the substrate body in an undefined sense from those who make it either one of the three elements or something else that is between fire and aer, Anaximander was the one who said that the substrate was body, apeiron, in an undefined sense, not defining its form as either fire or water or aer, while he (Porphyry) himself, like Nicolaus of Damascus, attributed the intermediate to Diogenes of Apollonia. But it seems more natural to me according to the text not to understand it as body being divided from the elements and the intermediate, but as body being rather divided up into the three and the intermediate. For Aristotle says: "... the substrate body, either one of the three

> or something else that is denser than fire and rarer than aer", and he added concerning all the aforesaid in common that such men 'generate the rest by rarefaction and condensation', and yet Anaximander, as Aristotle says, does not generate them in this way, but by separation out from the apeiron.

We must surely agree with Simplicius rather than with either Alexander or Porphyry.

In addition to the passage under review, Phys. 187 a 12, other passages of Aristotle also mention an intermediate between fire and aer, namely de GC 328 b 35 and 332 a 21 and Met. 988 a 30. An intermediate between aer and water occurs elsewhere, as Simplicius says, namely at Phys. 203 a 18 and 205 a 27, de Cael. 303 b 12, de GC 332 a 21, and Met. 989 a 13, while one between fire and water occurs at Phys. 189 b 1.

Burnet, E.G.P. p. 55 note 4, says: "This variation shows at once that he is not speaking historically. If any one ever held the doctrine of τὸ μεταξύ, he must have known which 'elements' he meant". Burnet's conclusion, in spite of the distinction between the rarefiers and the separators pointed out by Simplicius, is that although the word 'elements' is an anachronism Aristotle does indeed mean Anaximander when he refers to the intermediate, but he is careless in stating which pair it was between.

Joachim also (Op. cit. p. 224-5) takes the view just stated and quotes Burnet with approval. Both he and Burnet are convinced by the word περιέχειν, which occurs in de Caelo 303 b 12 and de GC 332 a 25, for they take it to be an expression characteristic of Anaximander - but we have seen that it is a word widely used by or about many of the Pre-Socratics.

Ross, note on Phys. 187 a 12, rejects the attribution of the intermediate to Anaximander because of the point about separation made by Simplicius, and says that the view in question is probably later, mediating between Heracleitus and Anaximenes, Thales and Anaximenes, or Heracleitus and Thales. The theory is, because of the rarefaction, in the tradition of Anaximenes. It is not the view of Diogenes, for his principle is definitely aer. There is no evidence for Zeller's conjecture about Idaeus. We must therefore, says Ross, refer the belief to some member or members of the school of Anaximenes, and account for Aristotle's variation by assuming (as, of course, do Burnet and Joachim) that the view was implied rather than openly stated.

Guthrie, note to de Caelo 303 b 12 in the Loeb edition, agrees with this. I agree also. To put the view later than Heracleitus, when all three so-called elements have been suggested but have failed to satisfy, rather than immediately after Thales has suggested water but before Anaximenes and Heracleitus have thought of suggesting aer and fire (so that there is no pre-conceived pair for Anaximander to go in between), seems to me to present far less of an anachronism than that which Burnet is expressly prepared to accept.

I would add that although the variation sounds like either carelessness on Aristotle's part or inference by him from what was not explicit, it need not have been so. There is one passage, de GC 332 a 21, in which he mentions thinkers in the plural and specifies the intermediates between two of the pairs, fire and aer, and aer and water - which reads more like attempted precision than carelessness. One might therefore as plausibly say that after the time of Heracleitus there may have been a number of members of the school of Anaximenes, all 'rarefiers' and not 'separators', who postulated different points along the scale fire - water (ultra-gas - liquid) as the basic state of matter. The essence of this theory is that the states of matter form a continuum of increasing density or rarity, but one state is to be chosen as primary.

Different choices of primary state would place the 'principle' at different intermediate stages either between fire and aer or at aer or between aer and water, and all choices would be intermediate between fire and water. Aristotle's statements need not then be careless although they may well have been inferential.

This explanation particularly frees Aristotle from censure in the case of the intermediate between fire and water (Phys. 189 b 1). As a summary of the theories of several Ionians with different choices it is a less unsatisfactory phrase than it would be if it were what it could literally be taken to be, a circumlocution for aer.

In this connexion Cherniss notes * that Simplicius in his comment on de Cael. 303 b 12 names Anaximander as believing in that between aer and water, and ** that he also names him at Phys 458, 23, commenting on Arist. Phys. 203 a 18. Cherniss, like Ross and Guthrie, takes the Phys. 187 a 12 passage as decisive against Anaximander. He points out *** that in his note on the fire and water

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* Op. cit. p. 12 n. 52.

** Op. cit. p. 17 n. 70.

*** Op. cit. p. 54 n. 215.

passage Simplicius refers the intermediate concerned to Diogenes. Cherniss says that the phrase could indeed include aer, which Simplicius knew to be the principle of Diogenes, although Aristotle in fact meant something in contrast to any of the four so-called elements, as his very next sentence showed. Cherniss then proceeds:

> It would be possible to consider it a reference to Anaximander's apeiron; but the identification of Simplicius which was that of Nicolaus (cf. Simpl. Phys. 25, 8-9) may have found support in such phrases of Diogenes as ὁ ἀὴρ καλούμενος ὑπὸ τῶν ἀνθρώπων (Frag. 5, 1-2) which could be made to imply that Diogenes considered his principle to be not ordinary air but something to which the term ἀήρ was extended, though wrongly, by men, perhaps a purer, less dense state of the principle than that found in the atmosphere of the earth. Warmth varies directly with rarity for him; and the purest air, in his sense of principle, would be that state of density and warmth midway between water and fire. Air in this state is the soul, which is warmer (and rarer) than the atmospheric air, colder (and denser) than the air about the sun where the element is on the point of passing from air to fire (cf. Frag. 5, 12-13). Diogenes, then, made the principle not air in a general sense, but that air which was midway between water (or vapor) and fire, at the point where it was in fact the soul. (In this manifestation it may vary in warmth but only very slightly - Frag. 5, 14-16.) But whether Aristotle was aware of this and means Diogenes here is uncertain. At Met. 984 a 5sq. he says Diogenes made air the principle.

Whatever we may think of the relevance of the passage of Aristotle or the comment of Simplicius, Cherniss has given an excellent description of the aer of Diogenes, one with which I entirely agree.

As with Empedocles and Anaxagoras, we are dealing with a purer form of air than that actually found in the atmosphere. Much of what has just been said is also applicable to the aer of Anaximenes. The continuity of the tradition from the Milesians to this latest of the Ionian monists can also be seen in the phrase from Frag. 5:

> καὶ ὑπὸ τούτου πάντας καὶ κυβερνᾶσθαι καὶ πάντων κρατεῖν· αὐτὸ γάρ μοι τοῦτο θεὸς δοκεῖ εἶναι.

κυβερνᾶν appears to be an Anaximandrian word (cf. D. 12 A 15), used also by Heracleitus and Parmenides, while its near synonym κρατεῖν occurs in one of Diogenes Laertius' apophthegms of Thales and was used in a similar sense by Heracleitus, Empedocles and Anaxagoras. Both words were later similarly used by the Stoic Cleanthes.

Moreover Diogenes' use of the word θεός is probably similar to the Milesians', implying eternity (cf. Frags. 7 and 8, where the words ἀΐδιον and ἀθάνατον recall Frags. 2 and 3 of Anaximander); although it is even more similar to Alcmaeon's use (cf. p. 113), for if the text of Diels be accepted Frag. 5 asserts that aer is a god because it controls everything and is immanent in everything, in other words that it is in some literal sense divine. The Milesians were atheists in our sense of the word - they did not recognise any divinity at all: Diogenes and others whom the ancients accused of being atheists, e.g. Hippo and Anaxagoras, recognised the divinity of some sort of principle or cause in some fashion, but refused, for their science, to make any use of traditional conceptions of the divinity of the Olympians. Their real crime was that they substituted a physical entity for the Olympians, saying that what men call 'Zeus' is just aer or ether. To them the material principle was 'active' - it could initiate change, just as to Alcmaeon divinity was associated with eternity of motion, a characteristic of soul and of the purest bodies in the region of ether.

Diogenes' cosmogony is, like Anaxagoras', of the Ionian type, but with the same important exception: the heavenly bodies are no longer glowing masses of aer or fire or collections of the bright exhalation - they are solids. They are not, however, simply lumps of rock or metal made incandescent by motion like those of Anaxagoras. The dark invisible stars in which Diogenes also believed are indeed of rock, and these may fall as meteorites; but the luminous bodies are given a rather more complicated explanation. The relevant passages, from Aëtius, in D. 64 A 12-14, follow in this order: II 13, 5: II 20, 10:

II 23, 4: II 25, 10.

Διογένης κισηροειδῆ τὰ ἄστρα, διαπνοὰς δὲ αὐτὰ νομίζει τοῦ κόσμου. εἶναι δὲ διάπυρα. συμπεριφέρεσθαι δὲ τοῖς φανεροῖς ἄστροις ἀφανεῖς λίθους καὶ παρ' αὐτὸ τοῦτ' ἀνωνύμους· πίπτοντας δὲ πολλάκις ἐπὶ τῆς γῆς σβέννυσθαι καθάπερ τὸν ἐν Αἰγὸς ποταμοῖς πυροειδῶς κατενεχθέντα ἀστέρα πέτρινον.

Διογένης κισηροειδῆ τὸν ἥλιον, εἰς ὃν ἀπὸ τοῦ αἰθέρος ἀκτῖνες ἐναποστηρίζονται.

Διογένης ὑπὸ τοῦ ἀντιπίπτοντος τῇ θερμότητι ψυχροῦ σβέννυσθαι τὸν ἥλιον.

Διογένης κισηροειδὲς ἄναμμα τὴν σελήνην.

The earth is still the central solid of an Ionian vortex, and like that of Anaxagoras (and Anaximenes) it floats on the aer (cf. Schol. in Basil. Marc. 58, D. 64 A 16a), a view parodied in Eurip., Troad. 884-8 and in Aristoph., Clouds 264:

ὦ γῆς ὄχημα κἀπὶ γῆς ἔχων ἕδραν
ὅστις ποτ' εἶ σύ, δυστόπαστος εἰδέναι,
Ζεύς, εἴτ' ἀνάγκη φύσεος εἴτε νοῦς βροτῶν,
προσηυξάμην σε· πάντα γὰρ δι' ἀψόφου
βαίνων κελεύθου κατὰ δίκην τὰ θνήτ' ἄγεις.

ὦ δέσποτ' ἄναξ, ἀμέτρητ' Ἀήρ, ὃς ἔχεις τὴν γῆν μετέωρον...

Diogenes Laertius' summary (continued from p. 301 sup.) reads:

τὴν γῆν στρογγύλην, ἠρεισμένην ἐν τῷ μέσῳ, τὴν σύστασιν εἰληφυῖαν κατὰ τὴν ἐκ τοῦ θερμοῦ περιφορὰν καὶ πῆξιν ὑπὸ τοῦ ψυχροῦ.

From this we see that the earth was solidified by the cold as with Anaximenes. Empedocles' solidification by heat finds no favour with Diogenes any more than with Anaxagoras. The brief description of the cosmogony in Ps. Plutarch Strom. 12 (D. 64 A 6) shows the operation of the vortex according to the rarefaction and condensation theory more clearly than we learned it from Anaximenes, and at the same time reminds one of the commentaries on Frag. 15 of Anaxagoras, except that here (wrongly as it so happens) the author states that the lightest matter formed the sun:

> κοσμοποιεῖ δὲ οὕτως· ὅτι τοῦ παντὸς κινουμένου καὶ ᾗ μὲν ἀραιοῦ ᾗ δὲ πυκνοῦ γινομένου, ὅπου συνεκύρησεν τὸ πυκνὸν συστροφῇ <τὴν γῆν> ποιῆσαι καὶ οὕτως τὰ λοιπὰ κατὰ τὸν αὐτὸν λόγον, τὰ <δὲ> κουφότατα τὴν ἄνω τάξιν λαβόντα τὸν ἥλιον ἀποτελέσαι.

It is only to this extent, that the light of the sun is due to the rays from the ether, sc. very rarefied incandescent aer, that are 'fixed in' (Aët. II 20, 10, sup.) the pumice-like, sc. porous, solid sun, that Ps. Plutarch was correct in the assertion about the sun.

I quoted as passage no. 10 on p. 34 part of the difficult context the first two sections of Book II of Aristotle's Meteorologica, and discussed its relevance concerning the theory of solstices to Anaximander on p. 45 and to Anaximenes on p. 67. I also quoted as passage no. 10a the commentary of Alexander, derived from Theophrastus, which states that the theory concerned was that of Anaximander and Diogenes. Whether or not it has been correctly interpreted by Theophrastus as far as solstices are concerned, the whole context does appear to give a reasonably authentic picture of the cosmogonical process of Diogenes.

In addition to passage 10, there is at Meteor. 355 a 21 (D. 64 A 9) this similar passage:

> τὸ δ' αὐτὸ συμβαίνει καὶ τούτοις ἄλογον καὶ τοῖς φάσκουσι τὸ πρῶτον ὑγρᾶς οὔσης καὶ τῆς γῆς, καὶ τοῦ κόσμου τοῦ περὶ τὴν γῆν ὑπὸ τοῦ ἡλίου θερμαινομένου, ἀέρα γενέσθαι καὶ τὸν ὅλον οὐρανὸν αὐξηθῆναι, καὶ τοῦτον πνεύματά τε παρέχεσθαι καὶ τὰς τροπὰς αὐτοῦ ποιεῖν.

From this and passages 10 and 10a (of which a fuller version appears at D. 64 A 17) we see that when the vortex commenced to revolve (or a vortex - for Aëtius says that Diogenes believed in an infinity of universes), the progressive condensation, which proceeded in the order described by Anaximenes, first gave rise at the centre of the vortex to the moist, viz. to denser aer than that at the periphery - just as Anaxagoras' solid earth was preceded (logically) at the centre by the dense. Subsequently continuing condensation produced solid earth, surrounded by a region that was still moist. *

By this time the sun had formed - we are not told how the pumice-like solid had reached the upper region, but may guess that Anaxagoras' explanation applied - and was emitting the implanted rays of ether. Its heat therefore caused evaporation (rarefaction) of this moist region. Part was evaporated so as to produce the next rarer stage, the atmosphere, while part remained to form the seas. This subsequent rarefaction produced more material in much the same state as the original rare matter that occupied the peripheral region, and so 'the whole heaven was increased'. The winds were also due to the same cause. The sea is salt because the sweet has evaporated.

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* The word used by Aristotle for 'region' in the passage quoted is κόσμος. This use of the word supports my interpretation of the same word in the footnote to passages nos. 1 and 1a of Anaximander, p. 31, whom I do not believe to have postulated an infinity of universes.

It is noteworthy that Diogenes is backward in his astronomy compared with Anaxagoras in that he makes the moon shine with its own light (D. 64 A 14) and the sun be quenched by the cold (A 13). As for his meteorology, we only have two short notices (A 16), both of which give traditional explanations of thunder and lightning, with the addition that if wind rather than fire falls onto cloud we hear thunder without lightning being visible.

Finally we may note that in Alex., Quaest. II 23, D. 64 A 33, we see Diogenes' equivalent to the theory of Empedocles concerning magnetism (v. p. 242). The lodestone, being rarer than iron, draws into itself the moisture from the iron (for all ductiles naturally give off and absorb moisture), and the iron is swept along by the speed of motion of that moisture. This is clearly a plagiarizing of the basic idea and a rephrasing in Ionian terms, with the substitution of the Ionian concept of rarity for the Western concept of pores.

The Hippocratic de Flatibus 3 (D. 64 C 2) contains material derived from Diogenes that amplifies what we know of his theories a little, and incidentally draws a verbal distinction between πνεῦμα, breath within the body, and ἀήρ, atmospheric air. The air is, though invisible, yet apparent to the reason because of its power. Wind, air in motion, can uproot trees, raise waves on the sea, and wreck ships. In winter the atmosphere, the whole air-filled interval between the earth and the heaven, is dense and cold; in summer it is soft and calm. The heavenly bodies move through air 'for the pneuma is nourishment for the fire, and fire deprived of aer could not live'. This is presumably because aer when rarefied turns into fire, but for aer read oxygen and, unwittingly, this theory that air nourishes fire anticipates modern combustion theory - by coincidence, of course, for the reason is wrong. Even the sea, the passage continues, contains air, or else fish could not survive (correct). The earth is the base for air, and air supports the earth, nor is there anything empty of air. (Cf. Frag. 5, line 5.)

This system of Diogenes is obviously Ionian theory brought up to date by one acquainted with the work of Anaxagoras, but yet refusing to abandon the traditional monistic hypothesis as he had. Far more clearly thought out than its ancestor, the system of Anaximenes, it yet retains certain childish features, and although it might have been worthy of great acclaim had it been proposed a century or so earlier it is in its age, from the physical point of view merely an awful example of science in decay. It is a reactionary system produced in an age of progress. The surprising thing is that its author is the same man as he who wrote the impressive account of the veins in the human body, preserved in Frag. 6.

Diogenes' contemporary Archelaus deserves consideration, if there is any truth in the story that he was the teacher of Socrates. He was himself a pupil of Anaxagoras; and Eusebius (P.E. 504, 3) says that he took over the school at Lampsacus from him. He was probably an Athenian by birth, the first native Athenian natural philosopher (though some say that he was a Milesian and the first to bring Ionian physics to Athens *). Since he did not follow Anaxagoras slavishly, Simplicius, in Phys. 27, 23, D. 60 A 5, comments:

> ... ἐν μὲν τῇ γενέσει τοῦ κόσμου καὶ τοῖς ἄλλοις πειρᾶταί τι φέρειν ἴδιον, τὰς ἀρχὰς δὲ τὰς αὐτὰς ἀποδίδωσιν ὥσπερ Ἀναξαγόρας. οὗτοι μὲν οὖν ἀπείρους τῷ πλήθει καὶ ἀνομογενεῖς τὰς ἀρχὰς λέγουσι τὰς ὁμοιομερείας τιθέντες ἀρχάς.

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* See Hipp. Ref. i 9, 1, D. 60 A 4; Simpl. Phys. 27, 23, A 5; Sext. adv. Math. vii 14, A 6 and ix 360, A 7; Epiph. adv. Haer. iii 2, 9, A 9; and contrast D.L. II 16, A 1 and Suidas, A 2.

Although he agreed with Anaxagoras' original mixture of seeds of everything, Archelaus went further than Anaxagoras, who derived from it two important but not basic substances, air and ether. Archelaus picked out the hot and the cold and made of them efficient as well as material causes, the hot being in motion and the cold at rest, according to Hipp. Ref. I 9, 1sq., D. 60 A 4, and Herm. Irris. 11, A 8. 'Mind' was therefore, says Hippolytus, a mixture of some kind.

Moreover he made aer an active principle in somewhat the same way as Diogenes, although it was derivative, according to Sextus adv. Math. IX 360 and Aëtius I 3, 6, both in A 7. According to Hippolytus and D.L. II 17, A 1, aer, like earth, is derivative from water, though Aëtius says that fire and water are derived from aer by rarefaction and condensation. In any case aer is a derivative of the mixture.

These notices are confusing, but already we see in Archelaus the typical eclectic. He added on to the theory of Anaxagoras the most lasting of the traditional Ionian views, the opposition of the hot and the cold, and also that of the rare and the dense if we may trust Aëtius. The adoption of the hot and the cold as causes, even though they are derivative, may have been borrowed from Hippo, for whom at least one of the pair is derivative, while the emphasis on aer points to Diogenes.

It is not clear in what way the actions of the hot and the cold, of aer, and of Mind as causes differ; but aer appears to be in some way parallel to Mind, and the latter may have been a mixture of the hot and the cold as Hippolytus thought, though a distinction is drawn by Aëtius, if we compare I 7, 14, A 12, with II 4, 5, A 14:

> Ἀρχέλαος ἀέρα καὶ νοῦν τὸν θεόν, οὐ μέντοι κοσμοποιὸν τὸν νοῦν.
>
> Ἀ. ὑπὸ θερμοῦ καὶ ἐμψυχίας συστῆναι τὸν κόσμον.

Here the hot and the cold perform an operation specifically denied to Mind. Yet Clem. Protrept. 5, 66, A 11, says that Archelaus and Anaxagoras both set Mind over the infinite, and August. de Civ. Dei VIII 2, A 10, says that the relation of Mind to the seeds was the same for both men.

The account of Hippolytus mentions aer and the hot and the cold in connexion with the generation of the physical universe, Mind and the hot and the cold in connexion with that of living creatures. Aët. IV 3, 2. A 17, says that the soul is airy, while Philop. de An. 71, 17, A 18, says that Mind is the cause of motion and that to cause motion is a function of soul. This is a comment on Arist. de An. 404 a 25, where the air-soul of Diogenes 'and some others', which both has knowledge and causes motion, is being discussed; and Philoponus specifies Archelaus.

These passages seem to suggest that aer and Mind are two aspects of, even two names for, the same thing, which in common parlance is called 'soul', a rational cause that for Archelaus either is a blend of the hot and the cold or else operates through these when they have been separated out from the mixture. Archelaus learned one name from Anaxagoras and the other from Diogenes, and may possibly have called his cause 'aer' when dealing with inanimates and 'Mind' when dealing with animates. I am in agreement with Burnet (E.G.P. p. 360) that the replacement of Mind as the generator of the universe by something more physical and less rational was probably due to the fact that Leucippus' advocacy of a totally irrational cause, Necessity, had rendered a rational cause unnecessary.

In view of the lack of clarity over causes it is not surprising that as with Hippo (v. p. 296) our sources differ: some make aer primary, others derivative from water under the action of fire. It may be that Aëtius was correct after all in making him derive fire and water from aer. We saw on p. 310 a distinction in the case of Diogenes between elementary aer and the ordinary impure aer of the atmosphere, an impurity already recognised by Heracleitus, Empedocles and Anaxagoras. * Archelaus may have similarly thought of a primary aer over and above the impure aer derived from water. This primary aer must, since we are told that Archelaus agreed with his teacher over the constituents of the original mixture, have been a mixture from whose many components the hot and the cold could have separated in the manner described by Anaxagoras and referred to by Hippolytus (loc. cit.).

Now the hot and fire are alike, and indeed the hot was one of the constituents of Anaxagoras' ether/fire, while his water included the cold among its constituents. Moreover we saw on pp. 295-6 that Hippo's principles, water and its derivative, fire, were identified with the cold and the hot. It is not unreasonable, then, to suppose that Archelaus made a similar identification.

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* See p. 277 and the references given there.

If, now, we say that from the original mixture an active principle known as 'aer' or 'Mind' separated out two derivative principles (which in fact in its aspect 'aer' it separated out from itself - which may be the reason for their possessing the power to act as principles), and through them generated the universe, the hot, as fire, acting on the cold, as water, to produce impure atmospheric aer and solid earth, we obtain a coherent theory from all the confused authorities except one. Epiphanius, adv. Haer. III 2, 9, D. 60 A 9, says that Archelaus' principle was earth. (We may recall that Ioannes gave earth as Hippo's principle.)

I suggest that the explanation for this lies in the fact that Archelaus said that living creatures at first sprang from the earth when it was warmed and the hot and the cold mixed to form slime and that only later did they commence to reproduce their own kind. The statement will then be on a par with the statements of D. 21 A 36 referred to on p. 122 that Xenophanes made earth his element, and with his Frags. 27, 29 and 33.

This tradition of creatures springing from earth mud or moisture, of spontaneous generation preceding reproduction, is an old one, represented in mythology by the

Sparti (Sown Men) and by the Mother Goddess Earth herself. Philosophically it goes back to Anaximander (whose φλοιοι surrounding the first creatures represent the same idea as the 'wombs rooted in earth' of the Atomists and Lucretius). From Xenophanes it proceeds through Parmenides and Zeno, if the commentators are to be trusted, Empedocles, Anaxagoras, Hippo, and Diogenes, to Archelaus, and from him to the Atomists and Plato. *

From the hot and the cold Archelaus derived the universe in a typically Ionian manner, and the account of Hippolytus (Ref. I 9, D. 60 A 4), which I shall only summarise because of its length, contains both vocabulary and ideas reminiscent of Anaxagoras.

After stating the separation of the hot, which is in motion, from the cold, which is at rest, Hippolytus says that the water, on being 'melted', flowed to the centre and there because of the heat aer and earth were generated. The aer rose and the earth settled below, remaining at rest at the centre since it was, so to speak,

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* References: Anaximander, D. 12 A 30; Parmenides, 28 A 51; Zeno, 29 A 1; Empedocles, 31 A 72, 75 & 76, B 62; Anaxagoras, 59 A 1, 42, 62 & 67, B 4; Hippo, 38 A 6; Democritus, 68 A 139, B 5; Lucretius, V 783sq.; Plato, Aristophanes' speech in the Symposium and the Politicus myth.

'no part of the whole'. The aer produced by the heat 'took charge of the whole', and from its original combustion came the heavenly bodies. The heaven was inclined and so the sun lit the earth and made the aer transparent and the earth dry. The earth was at first like a lake with a ridge round the rim. Proof of this is that the sun does not everywhere rise and set at the same time. Hippolytus concludes with the generation of living creatures that we have already discussed.

The brief report of Diogenes Laertius (loc. cit.) confirms this account, and adds this interesting point:

πρῶτος δὲ εἶπε φωνῆς γένεσιν τὴν τοῦ ἀέρος πλῆξιν.

The cosmogony described in these accounts is clear enough and its derivation from those of Anaxagoras and the Ionians is plain. We can add only a few details: the passages in D. 60 A 15-16a tell us that Archelaus' account of the nature of the stars, the cause of thunder, and that of earthquakes, was similar to that of his teacher. He illustrated the account of thunder by the noise made when a hot stone is plunged into cold water.

Burnet well says (E.G.P. p. 360): "The cosmology of Archelaus, like that of Diogenes, has all the characteristics of the age to which it belonged - an age of reaction, eclecticism, and investigation of detail". We can sum up the whole history of Ionian thought so far by saying that the basic idea throughout has been evolution from some infinite, originally amorphous, store of matter, the apeiron of Anaximander, whose physical description, if it is given one, is due to the presence in everyday experience of the amorphous and chaotic substance called 'mist' or 'cloud'. This visibly undergoes transformations and changes of state, one of which is the apparent change into invisible atmospheric air. As a result some form of air or some analogous entity was usually considered to be primary (or at worst especially important) and to be also the substance of the soul and even of the gods.

This gaseous substance, as we should now refer to it, seems to those who do not know that the atmosphere is a mixture to have several forms - all characterized by motion so that either no cause for motion was deemed necessary or the substance was thought to contain within its own nature the principle of motion - and different members of the school chose different forms as primary. Forms corresponding to the names fire, air, and moisture (which are actually three entirely different and unrelated things) were normally chosen, but occasionally something that is intermediate between them was postulated. Between fire and invisible air lies ether (in its original sense, not in that used by Empedocles or by Anaxagoras), which is the clear bright upper air or sky, 'blue fire' as Burnet calls it (Note to Plato's Phaedo 109 b 8), and between air and moisture lies aer in the original sense of mist.

Evolution from this original substance produced, by means of a vortex, our universe, the detailed description of which was continually amended as observation progressed, but whose character remained much the same, according to the picture of Anaximenes rather than that of Anaximander. The history of the school, then, is one of continual advance in physical knowledge, especially astronomical knowledge, until a stage is reached in which the now outworn original thesis can no longer support the system. When this fact was at last reluctantly recognised, Ionia devised the atomic theory to replace it.

It would appear that at this time in Athens there was considerable public interest in philosophy. Not only is the Periclean Age the age of sophistry, but also, thanks to Anaxagoras and Archelaus, the age in which the man in the street first became acquainted with the various theories of the east and the west. Aristophanes and

Euripides would not have made their allusions before an audience uninterested and uninformed, and passages of Plato such as Phaedo 96 A sq. and 108 C sq., which refer to Pre-Socratic theories as if well known, attest the continuation of this interest. It is not surprising, then, that so popular a subject should have engaged the minds of men of the second rank such as the eclectics whom we have just been considering, but they made no really useful contribution to the Greeks' knowledge of the nature of air.

.oOo.

CHAPTER TEN

LATER PYTHAGOREANISM AND PLATO

The traditional Ionian monism having died a natural death, Empedocles and Anaxagoras having failed to convince with their versions of pluralism, and the Eleatic school being aphysical, the Fifth Century closes with two major attempts to give a satisfactory physical system, those of the later Pythagorean and later Ionian (atomic) schools. Since these existed concurrently and both had a long life and lasting influence, it will be confusing if we adhere to the method of discussion in chronological order. I propose therefore to examine first the Pythagorean theory together with its derivative, the Timaeus of Plato, and then the atomic theory. The former concentrates mainly on form and mathematical structure, the latter on matter and motion.

In both cases although we still have only fragments of the work of the men themselves we have a voluminous amount of comment in comparison with that concerning the earlier thinkers. These men were of the same generation as either Socrates or Plato, and members of both schools were active contemporaries of Aristotle. Consequently they are not treated by Plato or Aristotle as 'primitives', men whose work was half forgotten even in their day, but as serious opponents whose theories are still alive and familiar.

Since Plato and, particularly, Aristotle tend to be repetitive, and to be prolix in discussion, and since the doxographers furnish a great deal of matter that simply repeats or complements what they have written, considerations of space will henceforward forbid a continuation of the method of fairly complete quotation of, or reference to, the authorities. This applies particularly to the case of Plato himself, for not only do the ipsissima dicta exist, but they are also easily accessible since there is only one dialogue, the Timaeus, with which I am really concerned. I shall therefore quote or refer to only passages of special interest or difficulty and such as may stand as individual examples chosen from many that contain the same thought.

The two schools concerned, and Plato and Aristotle themselves, have received far more scholarly attention than the earlier thinkers with whom we have dealt, and I shall necessarily be for the most part summarising that which is already known in a form relevant to my discussion of gases rather than stating anything new. Where I am dealing with any point about which scholars are in complete or nearly complete agreement I shall content myself with dogmatic assertion, omitting even to give references in cases where they would be obvious or well known.

First, then, we must examine the developments in Pythagoreanism after the Eleatic attack had shown that the theory outlined in Chap. 4 was untenable. It will be recalled from pp. 81sq. that Raven believes that there was little change after the attack of Parmenides apart from the abandonment of the equation of unity with limit and the counter-attack that extra-cosmic void could exist (for breathing in) even outside Parmenides' sphere. Melissus indeed postulated a spatially infinite One and reiterated emphatically the denial of the void (Frags. 3, 5, and 7, cf. Arist. de GC 325 a 14), and his reason may have been such a counter-attack.

It will also be recalled that Cornford and Cherniss on the other hand both posit a form of 'number-atomism' for this era. Cornford claimed that until Zeno's attack geometrical magnitudes and sensible bodies were confused, but that the void and the breathing in, and his 'fiery pyramid', were abandoned immediately after Parmenides.

Raven postulated a major recasting after Zeno that led to a totally distinct third stage in which geometrical solids and sensible bodies were still identified and matter was infinitely divisible not atomic, being in effect space (the unlimited) limited by points without extension and lines and surfaces that gave it its form. I claim that this is far too close an approach to the Receptacle of Plato and to the informed matter of Aristotle, too abstract an idea for the pre-Platonic era.

Cornford, by contrast, believed that this stage was one of clarification only. In it mathematical and corporeal solids were eventually distinguished. He admitted that the association of four of the regular solids with the four elements may have been made before Plato by these Pythagoreans (as Burnet claimed and Raven agrees). Until this was effected they continued to believe in a thorough-going number-atomism like that evoked for this stage too by Cherniss.

Before embarking on a detailed discussion I shall summarise my own view of the development of Pythagorean theory. I agree with Cornford that Parmenides destroyed the early theory and that Zeno faced a number-atomism of the type that he and Cherniss postulate. I share the belief that Zeno's attack did not cause the commencement of a totally distinct third stage; but I claim that there was such a third stage nevertheless. For the number-atomists came face to face not only with Zeno but also with his contemporary Empedocles. My third stage, then, consists of a final realisation that void and breath (aer or pneuma) are distinct and of a gradual assimilation (as maintained by Burnet, E.G.P. p. 292) of the idea that four substances are essentially primary on the macroscopic scale. Simultaneously geometrical researches revealed the existence of certain regular solids (although their construction was not in all cases fully understood), and these were identified with the 'elements'.

There was also a fourth, post-Platonic, stage in which the Pythagoreans adopted the 'fluxion' theory of numerical generation that gave the ultimate answer to Zeno, who had, so to speak, been temporarily appeased by the segregation of arithmetical number, geometrical magnitude, and sensible body, that forms the main part of the 'clarification' of Cornford's third stage. The third stage ended at the point where Plato borrowed widely from Pythagoreanism in the Timaeus, and our estimate of the state of Pythagoreanism then will depend, as will be seen, upon our estimate of the extent of this borrowing and of the degree of Platonic originality.

In detail, then, we may first clear Zeno out of the way. His arguments against the Pythagoreans were mainly mathematical, and since their subject matter concerns above all divisibility and motion their discussion is not relevant to a dissertation on gases except in that void was again denied and that their nature enables the advocates of number-atomism to deduce its form in the absence of positive evidence (v. inf.).

The main positive consequence of Zeno's attack, apart from the clarification referred to on p. 334, was the adoption of the 'fluxion' or 'dynamic' theory of numerical generation in which the point 'flows into' a line, the line into a square surface, and the square into a cubic solid. This replaced the point-line-triangle-and-pyramid theory. Numerical generation was eventually realised to be logical rather than temporal, and geometrical solids to be continuous while matter, sensible solids, are discrete. These realisations were probably concurrent with the 'fluxion' substitution, and the latter was probably finally effected in the 4th. century, even though some members of the school may have made it earlier, for the process was known to Plato and Aristotle but it is to the earlier process that Speusippus Frag. 4, following Philolaus, refers (D. 44 A 13).

Of far more importance physically were: firstly the attack on the void and on traditional theories of 'becoming' by Parmenides, and secondly the proof of the existence of corporeal air by Empedocles. Between them these two events completely destroyed the original theory. Generation by breathing in had already been attacked by Xenophanes, and was rendered untenable by Parmenides and Melissus, and the identification (or confusion) of void and aer was vitiated (or clarified) by Empedocles' clepsydra. Moreover generation by breathing in aer was no longer satisfactory when aer had to be considered, thanks again to Empedocles, to be on a par with fire water and earth. For all these reasons I agree with Cornford that by the time of Zeno's attack the Pythagoreans had replaced their original theory by number-atomism, and with Burnet that sooner or later the four 'elements' had to be assimilated for prestige reasons. I refer the reader to Cornford (Op. cit. pp. 58sq.) for his reconstruction of the number-atomism, which I have summarised on pp. 82 - 84 sup..

There is little positive evidence for this number-atomism and so we cannot deduce anything much about aer from it. The denumeration procedure of Eurytus as outlined on p. 84 may well have been that of hypothetically counting the point-atoms in an object, in which case it would be evidence of a sort, but it may equally well have been that of merely indicating the number of points in the (three-dimensional) outline of an object, whether considered as non-extended limits as by Raven or as points with magnitude as by Cherniss. Aristotle's description suits the latter interpretation better; Alexander's could fit either (D. 45, 3).

Ecphantus of Syracuse, of unknown date but referred to between Xenophanes and Hippo by Hippolytus (Ref. I 15, D. 51, 1) may possibly have been one of these number-atomists, but he may equally possibly have heard of the work of Leucippus and have tried to adapt atomism to Pythagoreanism. At any rate Hippolytus and Aëtius (I 3, 19 and II 3, 3, D. 51, 2 and 4) both state that he believed in 'indivisible bodies' or 'atoms'; but whereas Aëtius says: "He was the first to show that the Pythagorean monads were corporeal." he also says that he made the void a principle as well: this could be an inference made by

Aëtius, for Cornford claims that number-atomism did not postulate a void as did Leucippus, or at least that nothing in Zeno shows that they did. If it is not inference but fact, and if Cornford is correct, we should have to say that Ecphantus was not a number-atomist. If it is inference, or if Raven is right in thinking that the Pythagoreans defended the void against Parmenides, he may have been one. The account of Hippolytus, however, if it has not been contaminated, clearly includes ideas due to Leucippus and Democritus but differing in detail. The phenomena are due to three παραλλαγαί of the indivisible bodies, μέγεθος σχῆμα δύναμις, not σχῆμα θέσις τάξις, and the cause of motion is not βάρος or πληγή, the two causes which the doxographers rightly or wrongly attribute to the atomists, but a divine power which he called 'mind' and 'soul'. Moreover Aëtius (II 1, 2, D. 51, 3) says that he posited just one universe. (He is also noteworthy as having stated that the earth is not stationary at the centre of the universe, but revolves round its own axis.)

All this sounds very much like deliberate correction of the atomists, but it is hard to say whether it is a case of Ecphantus adopting atomism with reservations or of a Pythagorean number-atomist's reply to the new theory, intended to show where the latter was wrong. On the whole, especially in view of the statement of Aëtius quoted on p. 337, I am inclined to take the latter view.

This, then, is all the positive evidence one could claim to have for number-atomism, apart from any inferences that one may draw from Aristotle's comparisons of Pythagoreanism with atomism proper.

A new stage in the development ensued when the Pythagoreans had to face in addition to the Eleatic attack the fact that Empedocles' four elements were gaining so wide an ear and did indeed seem to represent something so basic in the universe that they had to be taken into account or explained away. The Pythagoreans were forced to consider afresh the problems of the constitution of matter and the apparent mutual transformations of the so-called elements.

Things must still be numbers, they would ponder, but the precise connexion between things and numbers must now be differently expressed from the old unit-point and aer/void idea or from number-atomism, which takes no real account of the basic differences between substances apart from the difference in the numbers of atoms that they may contain. Different substances may have different proportions of atoms, different λόγοι μίξεως, but if the atoms are all identical unit-points it is less easy to see how qualitative differences may arise than it is in the case of different proportions of Empedocles' non-identical elements.

Even Ecphantus, who admitted differences in size and shape in his atoms according to Hippolytus' account, was constrained to add differences in δύναμις in order to explain the objects of sense. This idea of 'powers' is a Pythagorean concept * that also appears in the Way of Opinion of the renegade Pythagorean Parmenides **, in the medical writers ***, and in Plato's Timaeus (e.g. 33 A and 52 E). These 'powers' are in fact the active aspect of the traditional opposites, the hot and the cold etc., and may well have been drawn up in a table like the Table of Opposites (cf. Cornford Op. cit. p. 47). Plato gives such powers to the four elements as well as the special

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* This is another reason why I incline to the view that Ecphantus was indeed a Pythagorean number-atomist.

** Parmenides, Frag. 9. Cf. p. 193 sup..

*** The term is attributed to the Pythagorean Alcmaeon in connexion with 'isonomia' in Aët. V 30, 1, D. 24 B 4.

shapes that he makes the Demiurge impose upon them - the 'powers' are theirs by nature and not so imposed.

This mention of elemental shapes leads me to that which I believe to have been the Pythagoreans' new solution to the problems that we are considering. In spite of the appearance in the summary of Alexander Polyhistor (D.L. viii 24-33, D. 58 B 1a, v. p. 107 sup.) of some very early ideas and of the use of some anachronistic Platonic terms it is probable that its main contents are relevant to the period under review (as Cornford, pp. 3, 13, 16 and 22, and Raven, pp. 159sq., agree). The summary is very long and covers much ground, and for convenience I quote Cornford's translation of Sec. 25, missing out the first two phrases as irrelevant and probably anachronistic:

> From the One and the Indefinite Two came numbers; and from numbers, points; from points, lines; from lines. plane figures; from plane figures, solid figures; from solid figures, sensible bodies. The elements of these are four: fire, water, earth, air; these change and are wholly transformed, and out of them comes to be a cosmos ... .

Ignoring the (Platonic) indefinite dyad since we are only interested in physics, we may start our examination at the step from numbers to points. (The Pythagoreans who made the new advance that we are about to consider were trained as number-atomists, so that these points will have been indivisible magnitudes.)

The successive steps from the One to the four elements and the cosmos are given in more detail but in the same order and in similar terms in Sextus Empiricus' account of Pythagoreanism in adv. Math. x 276-283 (v. the translation of Cornford, op. cit. p. 16). He states that the plane and solid figures concerned are the triangle and the pyramid and that the 'fluxion' theory was later than this, and also that the mathematical points have no extension so that the line is length without breadth between two points. Whether we agree with Cornford that this does not apply to sensible bodies and their component points or with Raven that it does (v. inf.), these two statements between them prove that the theory concerned was held later than Zeno and earlier than Speusippus. The conclusion of the account contains this sentence, which may be compared with Alexander's summary:

> In this way, with numbers taking the lead the solid bodies are produced; and from these finally sensible bodies also: earth, water, air, fire, and in general the cosmos.

With these two similar passages we may compare again the order of the list of Pythagorean Tetractyes given by Theo of Smyrna (v. Raven pp. 155 and 158-9 where the relevant parts of the Greek text, 93, 19sqq., are quoted). The tetractyes concern respectively:

1. The numbers 1 - 4.
2. (Theo's addition to the original list relevant to the Timaeus and not to our theory.)
3. Numbers and the point, line, plane, and solid.
4. Numbers and the 'elements': fire, air, water, earth.
5. Fire, air, water, earth, and the pyramid, octahedron, icosahedron, and cube.
6. Numbers and the growth of living creatures from the seed to the three-dimensional complete body.

The remaining five tetractyes are irrelevant here. Apart from the intrusive second, those I have referred to follow the same sequence of steps up to the four elements as the accounts of Alexander and Sextus.

As far as geometrical solid figures we are on the familiar ground of the generation of the tetrahedron; but we must now decide whether the points did have magnitude or not. This decision will affect our interpretation of the next step, from solid figures to sensible bodies.

Although Raven's arguments (e.g. p. 107) for the interpretation of the line at this time as length without breadth between two limiting points without magnitude and for analogous interpretations of the plane and the solid are very strong, and in fact convincing, I still cannot accept his conclusion that they apply to sensible as well as to geometrical solids and their components. He claims on p. 149: "The difference between geometrical solid and sensible body was a difference of degree rather than of kind. The nature of a sensible body was held to lie in its limiting surfaces; and so, in this respect at least, it was thought to differ from a geometrical solid only because it was less regular and more complicated. ... the geometrical solid too ..., like the sensible object, must be embodied in matter". As I have already said, his interpretation of body is too Platonic, and the last phrase even reads suspiciously like Aristotle's informed matter or enmattered form.

I grant that geometrical magnitude eventually, after Zeno's attack had had time to penetrate, became regarded as continuous and infinitely divisible as Raven argues and as Cornford admitted (Op. cit. p. 59). But I agree with the latter that the result of Zeno's attack was not the complete reinterpretation of figures and bodies alike, but the eventual distinguishing of these, which had been confused before, the continuous geometrical figures being regarded as the result of only logical generation, not actual generation in time, and sensible bodies as discrete and reducible to the indivisible magnitudes of which they were composed. If their unit-points had no magnitude, they would be 'nothing', and so would the bodies themselves.

The step from solid figures to sensible bodies, then, that Raven considered to be no real transition was no real transition in Cornford's earlier stages either (when the geometrical solid was also discrete), but it is now a step over a major obstacle, as Aristotle saw. (In Met. 989 b 29sqq. D. 58 A 22, among other points, he asked how mathematical figures could acquire motion and weight.) To cross this obstacle we need a bridge, a bridge between geometrical figures and the four Empedoclean elements, in fact, since these now have to be taken into account. It is the same obstacle as that which Parmenides had to bridge between his Way of Truth and his Way of Opinion, cf. pp. 190sq..

At this point Raven demands no bridge, of course, but he nevertheless requires a 'subsidiary explanation' that will 'account for the palpable differences, other than those of size and shape, that exist between one body and another' to replace the earlier explanation of qualitative differences that he postulates, the varying proportions of Limit and the Unlimited in the λόγος μίξεως (Raven, p. 150).

The 'subsidiary explanation' advanced by Raven is the same as that which I advance as the necessary 'bridge', and is of the same kind as that which Burnet advanced to account for the four elements for prestige reasons and as that which Plato employed in the Timaeus. It appears in the fifth tetractys of Theo (p. 343 sup.): it is the ascription to each of the four so-called elements of the form of one of the regular solids of geometry.

If these solid figures were in this context regarded not as continuous geometrical magnitudes but as discrete sensible solids composed of the appropriate number of unit-points with magnitude arranged in shapes similar to those of the corresponding mathematical figures, our obstacle has been bridged.

Plato's bridge differed in purpose, although not in kind, from that which I postulate and the 'subsidiary explanation' of Raven; for Plato's figures are there to provide only the element of limit or form, which is intelligible, and to explain the mechanism of change, while he had to have recourse to the 'powers' (p. 340) for the purpose of providing causes for our sensations (v. Cornford, Op. cit. p. 15). Yet it is for just that purpose, to explain the 'palpable differences', that Raven, for whom the Pythagorean solids, both geometrical and sensible, already have, as well as space for matter, limits for form and essence, believes the ascription of the figures to the elements to be serviceable to the Pythagoreans.

I reiterate that Raven's interpretation of body smacks too much of Plato's form and receptacle, and now add a further objection to his theory: he has used the ascription for a purpose for which Plato found it inadequate. It is far more serviceable to the Pythagoreans as providing a necessary link between (logically generated) geometrical figures and discrete sensibles that can also succeed where number-atomism per se had failed - in accounting for the four elements, as Burnet says. It was indeed used to explain qualitative differences too: but not, as we shall see, v. p. 354 inf., in the manner suggested by Raven (p. 157), who reverts for this explanation, once he has obtained his four elements, to the idea of a λόγος μίξεως concerning them - a proportion that worked in the same way as that of Empedocles.

The ascription to the four elements of the regular solid figures appears, as we saw, in Theo's fifth tetractys:

> ἡ μὲν γὰρ πυραμὶς σχῆμα πυρός, τὸ δὲ ὀκτάεδρον ἀέρος, τὸ δὲ εἰκοσάεδρον ὕδατος, κύβος δὲ γῆς.

Speusippus is said by Theolog. Arith. 82, 10sq. (D. 44 A 13) to have included in a book on Pythagorean numbers mostly based on Philolaus an account περί τε τῶν πέντε σχημάτων, ἃ τοῖς κοσμικοῖς ἀποδίδοται στοιχείοις. (We shall examine shortly the question what is meant by the fifth figure.) Aëtius (II 6, 5, D. 44 A 15, from Theophrastus) confers the whole theory on Pythagoras himself with the comment that in this Plato 'pythagorizes':

> Πυθαγόρας πέντε σχημάτων ὄντων στερεῶν, ἅπερ καλεῖται καὶ μαθηματικά, ἐκ μὲν τοῦ κύβου φησὶ γεγονέναι τὴν γῆν, ἐκ δὲ τῆς πυραμίδος τὸ πῦρ, ἐκ δὲ τοῦ ὀκταέδρου τὸν ἀέρα, ἐκ δὲ τοῦ εἰκοσαέδρου τὸ ὕδωρ, ἐκ δὲ τοῦ δωδεκαέδρου τὴν τοῦ παντὸς σφαῖραν.

The attribution of a theory involving the Empedoclean elements to Pythagoras is obviously absurd, and Burnet (p. 292 n. 2) says that Achilles in his extract from the same source says οἱ Πυθαγόρειοι.

Cornford stated in Plato's Cosmology, p. 210, that so far as we know no earlier thinker had anticipated Plato's assignment of these figures to the elements, but later changed his mind and admitted in Plato and Parmenides, p. 15 n. 2, 'it is not impossible'. Raven accepts the assignment as we have seen, while Burnet believed that the elements were indeed built up from some of the geometrical figures, but not in just the way described here. Others have thought that Plato was definitely the originator of the theory.

Of course, on the supposition that the Timaeus is nothing more than an exposition with hardly any original additions of the doctrine of a Pythagorean predecessor (with whom Plato did not necessarily agree) the point does not arise: however even if we refuse to accept this, to me, absurd view, I see no reason why we should not attribute at least the germ of the theory to the late fifth century Pythagoreans and say that they allocated the figures to the elements in the way stated by Theo even though they did not fully understand the mathematical analysis of the figures themselves. My reasons for this conclusion are given in the following note:

Raven (p. 150sq.) refers to two main grounds on which the attribution of this theory to Philolaus or to any other Pre-Socratic has been disputed. The first is that the scholia on Euclid xiii 1, Vol. 5 p. 654, 1 Heiberg, quoted as conclusive by Burnet, p. 284 n. 1, say that only three of the figures were τῶν Πυθαγορείων, the cube, pyramid, and dodecahedron, while the octahedron and the icosahedron were Θεαιτήτου. The genitives here are interpreted by those of this persuasion as meaning 'the discovery of'. This view is supported by the words of Suidas s.v. Theaetetus: πρῶτος δὲ τὰ πέντε καλούμενα στερεὰ ἔγραψε. Raven's answer to this is complete: "But whatever its meaning (sc. ἔγραψε) it cannot mean 'discovered the existence of'; for in any case it is universally admitted that three of the regular solids were known at a considerably earlier date. It is most likely that Theaetetus first completed the theoretical construction of the figures; and that, as Cornford says (P. and P., p. 15, n. 2), is an entirely different matter either from the knowledge of their existence or from their association with the elements".

In passing we may note that the dodecahedron is associated with Hippasus. Iamblichus more than once (v. D. 18 A 4) says that the reason for his death was the revelation of this figure. D.L. viii 79sq., D. 47 A 1, if the manuscript reading be right, says that Archytas first ' discovered the cube, as Plato says in the Republic'. Diels doubtfully refers this to Rep. 528 B where Plato says that 'the dimension of cubes and of everything that has depth' ... 'does not appear to have been investigated yet'. There is no mention of Archytas here. It may be that what Diogenes is referring to here is the solution of the problem of the duplication of the cube. The third of the figures concerned, the pyramid or tetrahedron, was of course familiar to the school from early times.

The second ground is that since Aëtius' list of figures is the same as that in the Timaeus it is evident that the former is derived from the latter. Raven points out that this is an ambivalent argument that could equally support the opposite contention, which I agree with Raven to be actually the case.

Yet another argument is offered by Burnet. He took the Rep. 528 B passage translated above to refer to the delay in discovering the octahedron and icosahedron. But Shorey in his note ad loc. in the Loeb edition says: "This is not to be pressed. Plato means only that the progress of solid geometry is unsatisfactory", and says that he may or may not be referring to the duplication of the cube.

The only other possibly negative evidence that I know of is the statement of Aristotle in Met. 990 a 14 that the Pythagoreans said nothing about fire or earth or the rest since, he supposes, they have nothing original to say about sensibles. I agree with Raven that the existence of Pythagorean astronomical theories proves that they did talk about sensibles and about fire and the rest, and I would add that the statements of Alexander, Sextus, and Theo that we are discussing rule Aristotle out of court.

There appears at first sight to exist one piece of positive evidence that our theory was held by the Pythagoreans of the generation of Philolaus. Frag. 12 attributed to Philolaus reads: καὶ τὰ μὲν τᾶς σφαίρας σώματα πέντε ἐντί, τὰ ἐν τᾷ σφαίρᾳ πῦρ <καὶ> ὕδωρ καὶ γᾶ καὶ ἀήρ, καὶ ὁ τᾶς σφαίρας ὁλκας†, πέμπτον. Burnet and Raven, unlike Diels (v. inf.), confidently assert that this fragment refers to the five regular solids. Burnet, because he believes that Philolaus knew of only three of these, takes it to be one more proof that the so-called fragments of Philolaus are spurious. Cherniss (p. 386) agrees with this, and so does Rey (Maturite p. 9). Raven says that irrespective of the question of the genuineness of the fragment all the above arguments prove that Philolaus could have held such a view. Since the fragment is, as I believe, probably spurious, and since its text is in any case doubtful, one had better say that it proves nothing either way.

If Philolaus himself or his contemporaries did, as the above note shows to be at least possible and as I believe to have been the case, hold the view in question, what factor does the dodecahedron represent that some sources mention, since the elements are but four? It is most probable that it was associated with the sphere of the heavens. It is the figure that fits most closely into the sphere in which all the figures can be inscribed, and a spherical ball can in fact be made of twelve pieces of flexible material sewn together in the fashion of a dodecahedron. This is said to be the shape of the earth in the Phaedo myth (110 B) - the 'earth' here refers to the whole ideal world not just to this planet. In the Timaeus (55 C) too the dodecahedron is associated with the universe. As the 'hull of the sphere' (Philolaus Frag. 12) the dodecahedron has affinities with the ὑποζώματα of the Republic (616 C), and we may compare the use of the word τρόπις in connexion with the sphere of the whole in Aët. II 4, 15, D. 44 A 17. In the passage quoted on p. 348 Aëtius states that the sphere of the whole is from the dodecahedron.

This seems straighforward enough, but Diels emphatically refers Frag. 12 not to the solid figures at all but to a five element theory. The 'hull of the sphere' would then have to represent a fifth element. Aëtius II 6, 2 says that Pythagoras made the universe ἀπὸ πυρὸς καὶ τοῦ πέμπτου στοιχείου. Raven (pp. 154-5) admits that though the above interpretation is the more plausible this one is possible. There is no doubt that the fifth element was not an invention of Aristotle. It appears in Epinomis 981 C in the form of ether, and if not by Plato at least this work was by a member of the

Academy. Plut. de E Delph. xi attributes the theory to Plato, with the dodecahedron representing heaven, light, or ether, or 'the fifth substance, the only body to which circular motion is natural ...'. Cornford in Plato's Cosmology p. 220-1 gives other similar references including some derived from Xenocrates. We even find that the fifth element is attributed to Occelus of Leucania, a Pythagorean whom several authorities state to have been plagiarized by Aristotle in the de GC and one, Syrianus, when commenting on Aristotle's complaint that the Pythagoreans do not say anything about the objects of sense, says to have been the source of the Timaeus as well. It is Sextus (adv. Math. x 316, D. 48, 3a) who says that Occelus anticipated Aristotle's fifth element. Olympiodorus (D. 42, 5) associates Pythagoras (cf. Aëtius sup.) with Hippocrates of Chios in the belief that heavenly bodies are made of a fifth element.

What are we to make of this? It is likely that at the end of his life Plato believed in a fifth element and possible that certain late Pythagoreans did too. It is certain that in the Timaeus the dodecahedron is not to be associated with it, but with the sphere of the universe. It is possible that the Pythagoreans other than any who may have adopted both a fifth element and the ascription of solid figures to the elements - and such men must have been few since there is no proof that the school took either step - ascribed four of the figures to the Empedoclean elements and the fifth to the universe as did Plato; but it is equally possible that they only employed four of the figures, as in Theo's tetractys, and that the appearance of the dodecahedron in some of the passages referred to is an anachronism due to confusion with Plato.

I conclude, then that the Pythagoreans of Philolaus' generation proceeded along the path subsequently followed by the Timaeus at least as far as the association of four of the figures with the elements, even though they did not know the theoretical construction of more than three of them (while Theaetetus worked out that of the other two), and even though they did not necessarily use them to explain qualitative differences and change in precisely the same way as Plato did. I shall try to show that they may have given a relatively crude explanation that might yet have served as a hint towards Plato's more refined explanation, rather than have given an explanation along lines suggested by Empedocles as Raven seems to think (cf. p. 347 sup.).

Burnet (E.G.P. p. 293), accepting that they knew and used only the first three figures and employed one of them - the dodecahedron - for the sphere of the whole, believed that they only made the equations of fire with the tetrahedron and earth with the cube. Following this hint Plato, according to this view, will then after the 'discovery' of Theaetetus have added the figures of air and water in such a way that this pair could be transmuted into fire and vice versa while earth cannot be transmuted at all (cf. Timaeus 54 C).

On this assumption Burnet maintains for our period too a Pythagorean dualism, with fire still serving as one element as it was for Hippasus, but with earth as the other and not air as it was in the Way of Opinion of Parmenides, which Burnet believes to have been purely Pythagorean - air in the Pythagoreans' early sense will have lost favour because of Empedocles' demonstration of its true nature. Burnet claims that it was the existence of this fifth century dualism of fire and air that misled Aristotle into his misinterpretation of Parmenides' Night as earth (cf. p. 195 sup.). Cherniss demonstrated the fallacy in this last point, and although the whole idea is ingenious it is untenable, as I now hope to show, and must be rejected along with Taylor's hypothesis that Plato in the Timaeus is teaching a fifth century Pythagoreanism that has amalgamated with Empedoclean biology.

Alexander Polyhistor's summary (v. p. 341 sup.) definitely attests to the fact that all four elements alike μεταβάλλειν καὶ τρέπεσθαι δι' ὅλων, and makes no exception in the case of earth. The naming of the four most basic substances 'elements' in our sources, and possibly even by the Pythagoreans themselves, is obviously due to Empedocles; but in the latter's view they can never be transmuted or transformed - each is as permanent as Parmenides' One. Zeller claimed that the idea of the mutual transformation of all four is a Stoic contamination, but Delatte and Wellmann showed that it is a Heracleitan idea (v. Cornford P. & P., p. 13, and Raven, p. 161), and I agree. Moreover Anaxagoras evidently believed in their mutual transformations (Frag. 16) and so did Anaximenes and Diogenes. Although members of different schools explained the mechanism of transformation differently, none of them specifically excluded earth, while all of them, like these Pythagoreans, believed the four 'elements' not to be in fact elemental. I believe in fact that these Pythagoreans accepted from Empedocles the idea that these four substances were physically - viz. on the macroscopic scale - the most fundamental, and from Heracleitus (or from Ionian thought in general) the idea that all four could undergo mutual transformation, and that they then put forward a theory intended to explain these ideas by postulating for the four substances four regular solid forms that could be transformed into each other. If one or, in the case of the tetrahedron and cube, more of the figures were broken up into the component unit-points with magnitude, lines, and planes, these could then be reformed into one or more of the other figures.

This theory preserves the idea 'things are numbers', for the figures consist of a number of unit-points, and also gives a meaning to the λόγος μίξεως: this could refer to numerical ratios between the figures concerned, e.g. the octahedra of air have 6 points and the icosahedra of water 12, so that 1 particle of water could break down and reform into 2 of air and so on. Similar ratios could exist between the numbers of lines in the figures, but to Pythagoreans trained in number-atomism the breakdown into points seems the more natural. We shall see how Plato employed the numbers of surfaces similarly. I believe this use of surfaces to have been Plato's amendment.

Raven admits (p. 162) that this regular solid theory permits transformations, but cautiously says that the Pythagoreans may have been aware of this and content with it (as Aristotle was not) but that the doctrine of transformation may equally possibly have been inserted into the Pythagorean framework by some little-known eclectic. Raven's interpretation of matter as space bounded by limiting points without magnitude does not, of course, bear with the idea of breakdown into points as well as does the rather more atomic interpretation that I suggest.

I maintain that the Pythagoreans were not just (as Raven says) 'content with' the possibility of transformations, but deliberately used them to explain qualitative change. I also maintain that criticisms by Aristotle such as those in Met. 1028 b 16 and 1090 b 5 that the Pythagoreans thought of surface and line and point as being real entities, and more so than body and the solid, could well have been apposite to just such a theory as that which I have suggested.

If a complete breakdown into points, or even only as far as lines, were postulated, the difficulty that three of the figures have faces based on the equilateral triangle while those of the cube are based on the square would not be a difficulty at all, and earth could take part in the transformations. There is no need to reject the evidence of Alexander Polyhistor because of the distinction drawn by Plato in the Timaeus or because Burnet, like Taylor, believed that Plato is giving the views of a Pythagorean predecessor with whom he himself does not in fact at all times agree.

If my interpretation is correct, then, air was, in the form of an octahedron, one of four primary substances whose structure explained how 'things are numbers' and 'the universe is a harmony'. It was capable of being transformed into fire or water or earth by the mathematical rearrangement of its component parts, which were in my view indivisible magnitudes spiritually descended from number-atoms.

Whereas in early days fire may have been in the sense discussed on pp. 96 and 104-5 the primary substance (at least to Hippasus and his followers) while aer played the part of a void separating the units of fire, air (I no longer spell it 'aer') and fire are now both equally members of a series of bodies that are composed of specific structures, and these structures explain their chemical behaviour. I refer the reader back to what was said on pp. 110-1 concerning the debt owed by science to the Pythagorean emphasis on quantitative and structural analysis.

Having discovered as far as we can the nature and structure of air in later Pythagorean theory, we ought now to proceed to examine its properties and behaviour in our normal manner by examining the cosmology and meteorology. Unfortunately information is almost totally lacking for the reasons given on pp. 75 and 106 and also because one can hardly expect confirmation of this sort from the authorities for a theory which we have failed to find detailed in those authorities and have had to infer for ourselves. Our best source for this period should be Philolaus; but in view of the spurious nature of some if not all of the fragments attributed to him he must be used with caution, and even from him we can learn little that is germane.

Concerning the cosmological views of other great figures, such as Eurytus and Archytas, we know little or nothing. There is one matter of sublunary interest that is raised by a theory held according to Theo (v. D. 47 A 19a) by Eudoxus and Archytas. Frag. 1 of Archytas argues at length with several pieces of observational or experimental evidence a thesis also argued in slightly less clear fashion bv Aristotle in de An. 420 a 30: the thesis that velocity and pitch are connected in sound. According to Archytas high pitch is produced when the blow (struck or breathed) that originates the sound is quick and strong, low pitch when it is slow and weak, and the stronger sound carries further and faster because the air gives way to it more. Aristotle puts it from the hearer's point of view: high pitch penetrates (like a stab) a long way in a short time and vice versa. Both these views appear to indicate that the velocity of the transmission of sound through air as a medium varies with pitch (though Aristotle hedges a little over this); but modern theory is that the velocity of transmission is constant, but the frequency varies with pitch. The frequency is determined by the number of 'blows' per second in the (vibrating) source of sound, in other words by the velocity of the movement of the source. Archytas' viewpoint is therefore nearer to the truth than is Aristotle's. Considering the lack of modern measuring instruments it is a very creditable performance of the Pythagoreans to have come so close to the truth.

This thesis has, however, taught us nothing fresh about air itself, only about what happens when it is used as a medium. Incidentally it will be recalled that it was in connexion with an earlier Pythagorean, Alcmaeon (v. p. 204), that we first met this capacity of air for transmitting sound. It was natural that a school two of whose major practical interests were medicine and music should consistently interest itself in the theory of sound and hearing.

The little information that we can gather about astronomical matters is hardly more helpful to our purpose than the theory of sound has been. We have already discussed on p. 100 the cosmogony attributed to Philolaus and seen it to employ air in a more or less Ionian manner. We have also seen on p. 102 that Philolaus is credited with the belief that the purpose of respiration is to cool the body by drawing in air; and we have seen how Cornford showed the connexion between the cosmogony and the physiology. So far air seems in practice to have had Ionian properties.

To this we must add a connexion with Empedocles. Aëtius (II 20, 12, D. 44 A 19) ascribes to Philolaus a development of Empedocles' 'double sun' theory (cf. p. 239 sup.). The actual heavenly body is a glass-like mirror that reflects to us the light and heat of the cosmic fire that is in the heaven (whatever that fire may be). That fire represents a prior sun, the glass-like body a second, and the reflected beam that we actually see is, so to say, yet a third sun. The famous Pythagorean theory of a Central Fire round which the earth revolved was also probably a development of the Empedoclean extrapolation from the correct explanation of lunar light, and in fact Burnet (p. 298) claimed that the cosmic fire of the Aëtius passage referred to this Central Fire, 'the heaven' being a reference to the sublunar region. I make no claim to decide the question whether or not Philolaus believed in the Central Fire, but whatever his belief I do not think that Aëtius was referring to that theory here but to a separate Pythagorean 'treble sun' theory. We know that more than one astronomical theory was current in the school, and we also know that the Pythagoreans paid attention to the views of Empedocles.

Another obscure passage of Aëtius (II 5, 3, D. 44 A 18), dealing with the destruction and nourishment of the universe, mentions 'exhalations' which reminds us of the influence of Heracleitus on the school.

It remains to state that whatever the status of the earth, whether it was a particularly important planet or the actual central body of the universe, the one thing that none of the Pythagoreans of the era believed about it was that it was a flat body floating on air as was believed by Anaxagoras and his fellow Ionians.

From these scanty notices it is probably safe to conclude that in concentrating mainly on positional astronomy the Pythagoreans were content to take over what seemed best in Ionian or Empedoclean astrophysics. Consequently on the macroscopic scale, since they had certainly accepted Empedocles' and Anaxagoras' demonstrations of the error of their ways in their former interpretation of aer, they will presumably have now thought that the properties and behaviour of air were as described by those thinkers and the contemporary Ionians.

To conclude, the Pythagoreans' particles of air and the others, in spite of their capacity for mutual transformation, have some affinities with the atoms of Leucippus, and so do the units, the indivisible magnitudes, from which they are generated. If Plato had not intervened and, as we shall see, deliberately reformed the theory in such a way as to oppose it to atomism, I think it very probable that not only Leucippus but the Pythagoreans too, men of the cast of Ecphantus and of the little-known

Xuthus, would have arrived at an atomic theory. (Xuthus is said to have been a Pythagorean, and to have been associated with an argument in favour of the void, but whether he argued thus before or after the work of Leucippus is not known.) The details of such a theory would have differed, for there would have been a greater emphasis on structural regularity and change would have been explained in a way capable of giving rise to numerical formulae.

The direction of development would have been away from the idea that mathematical objects, points etc., can be the elements of the bodily and in a diametrically opposite way from that taken by Plato on the question of the existence of the void. Whatever we may think of the bridge between geometrical solid and sensible body that I have suggested to have been built during the period just reviewed, Aristotle's attitude, which can be summed up as 'things that consist of their points or figures are not solid enough', seems justified. But what would he have thought of our own non-material sub-atomic basic entities, our particle-wavicles?

Had the Pythagoreans been able to proceed undisturbed by the Timaeus, and had this dialogue not had such a great influence on European thought, it is possible that atomic theory would have been established permanently by the Greeks - even though it would still have had to wait at least nearly as long as it did before assuming its modern form. Instead the enthusiastic experimenters of the early alchemical age were forced by the deadening influence of Neoplatonism into the mystical nonsense that characterized the 'science' of the Middle Ages.

It is in this connexion (as in a very few others) that I can find some sympathy with the view often expressed during the past few decades by historians of science who are not professional classical scholars that Plato was a disaster of the first magnitude for the history of science. Some classical scholars have felt this too, but the recent trend in criticism seems to be in the direction of absolving Plato from much of the blame he has been apportioned for discouraging the use of 'scientific method'.

.oOo.

Section ii.

In Plato's Timaeus we shall find little of value for physical science though much of interest for mathematics and scientific method. Plato strongly advocated the theoretical sciences, e.g. pure mathematics and astronomy, and harmonics; but, regarding the phenomenal world as less worthy of study, he tended rather to discourage the observational and experimental methods of empirical science. *

The only real world for Plato was the world of Ideas, of which our world is an imperfect copy whose contents at best resemble or participate in the eternal and immutable Ideas. These are the only possible objects of true knowledge; the things of the sense world are apparently always changing and subject to becoming and perishing, so that they can only be objects of opinion. Plato accepted from the Heracleitans and Cratylus the idea of flux, but restricted it, as he restricted the relevance of the relativistic dictum of Protagoras, to the sense world. We cannot, as several Pre-Socratics had said, trust the senses: therefore physics can be no more than

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* They were not completely discouraged. Aristotle must have acquired from the Academy the interest in the method of classification shown in his biology.

a 'likely story', so that there cannot be any profit in concentrating too much on the establishment of a consistent system of physics and cosmology.

The Timaeus gives therefore not a scientific cosmology but a myth of creation by a demiurge. This can not be interpreted point by point by the substitution of scientific terms for allegorical names as can be done with the poem of Empedocles. The creation is presented as a sequence of past events, but this does not necessarily correspond to any order in time in which Plato considered the events to have actually occurred. It is a logical sequence arrived at by successively abstracting different elements from the universe and considering them on their own. Internal evidence from the dialogue shows that the events cannot have happened in time in the given order.

Belief with Cornford * that the demiurge is a symbol for a real element in the world as it exists, the element of reason and order, and that the creation story

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* There has been much discussion of the meaning and purpose of Plato's demiurge and of the relation of the latter to Plato's general religious views. The fullest discussions in English are by Taylor, Archer-Hind, and Cornford; and since I find myself in substantial agreement with Cornford (Plato's Cosmology), I do not propose to discuss the matter in detail.

is not to be taken literally does not alter the fact that this introduction into philosophy of the idea of deliberate creation by a rational creator was a new factor that considerably influenced later thinkers, who did take the idea literally.

The dialogue is one of Plato's later works, and Timaeus of Locri, the Western philosopher and statesman, may (forgeries of works bearing his name notwithstanding) have been invented by Plato as a mouthpiece for the dogmatic statement of a doctrine that I believe to have been Plato's own, much of it original in spite of the obviously Pythagorean origin of parts of it and in spite of the arguments of Taylor and Burnet. It is a development of a Pythagorean theory (in what sense I have tried to show in the last section) but it also contains elememts derived from the Eleatics, Empedocles, and others, and an occasional direct denial of a Pythagorean view. It differs in important respects from the type of Pythagorean theory just discussed in spite of the over-all similarity, and however unoriginal the parts may be, the integrated whole has an original cast of its own.

Of the three main sections of the dialogue, τὰ διὰ Νοῦ δεδημιουργημένα (29D - 47E), τὰ δι' 'Ανάγκης γιγνόμενα, (47E - 69A), and the combination of these in the human being (69A - end), the first, possibly the most important for Plato, is the least scientific, the second will be our main concern, and the third belongs to the history of medicine and psychology.

To commence, then, the demiurge is good, and he desired that all things should as far as possible resemble himself. Consequently (30A):

> The god took over all that is visible - not at rest, but in discordant and unordered motion - and brought it from disorder into order, since he judged that order was in every way the better. *

To accomplish this he fashioned the world as a living creature with a body that contains soul and reason. In doing so he copied the eternal model that is in the world of the Ideas. The copy, like the model, is unique: only one universe exists (31A).

The body of the world, qua bodily, must be visible and tangible. The former implies the existence in it of fire, the latter of earth. Being three-dimensional it needs, according to Platonic mathematics, two means to connect the extremes fire and earth; and this is the raison

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* I shall cite Cornford's translation rather than the Greek text since the latter is easily obtainable.

d' etre of air and water. Fire : air :: air : water :: water : earth. * Here Plato uses an argument derived from the perfection that he saw in the geometrical proportion to prove the necessity for the existence of just those four substances that Empedocles had regarded as 'given'. (All Greek cosmogonies start from something 'given', e.g. the apeiron, aer, the 'mixture', eternal motion, and Plato's own 'all that is visible' of 30A.)

Plato rejects the Ionian and Pythagorean infinite external store of matter (32Csq.). The universe is unique, all-inclusive and everlasting, which it could not be if it were exposed to the attacks from outside of 'hot things and cold and all things that have strong powers'. ** It is spherical, and is described in terms strongly reminiscent of Xenophanes and Parmenides; while there is a specific denial of the growth and 'breathing in' postulated by Anaximenes and the early Pythagoreans. The whole

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* Cornford (P's Cos. p. 51) plausibly argued that the proportion meant is that of the total volumes of the four, the greatest being that of fire. Empedocles' doctrine that the four are equal in quantity was thought not to provide enough matter for the present universe.

** Such 'attacks' would make the body of the world sick - an allusion to Melissus' argument (Frag. 7) that the One cannot suffer pain. For the 'powers' v. p. 340.

outlook of this passage (32C - 34A) is Eleatic, and opposed to the ideas of Ionia, the Pythagoreans, and the atomists and others who had admitted the possibility of the plurality or destructibility of worlds. Plato has agreed with Parmenides and Empedocles against the very Pythagoreans whom Taylor would have us believe him to be quoting.

Two differences from the Eleatic sphere are admitted, however: it has parts and it has uniform rotatory motion (cf. Laws 897C). This is for Plato as for Aristotle that mode of motion that above all belongs to reason and intelligence. Motion implies soul in Plato's philosophy (cf. Alcmaeon, p. 113 sup., and Phaedrus 245C with Timaeus 34 A-B and 40A-B), and so the next part of the dialogue describes the soul of the world. Here Plato departs from science completely, although a great deal of the argument is couched in mathematical or astronomical language. *

After the world-soul has been constituted it is fitted to the body of the world and its connexion with time

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* The soul-stuff (compounded of Being, Same and Other) is divided up into intervals whose choice depends upon the mathematical principles underlying musical harmony. We can see the influence of Pythagoreanism here. Out of the result of this process a system of circles is constructed, and these serve to explain in detail the motions of the heavenly bodies, motions of which they are the causes.

is explained. Time is inseparable from the periodic motions of the heavenly bodies, being in fact produced by them. (38E)

There are four regions in the world, each with its own inhabitants: heaven and the gods, air and the birds, water and the fish, earth and the animals. Each region corresponds to one of the 'elements', and so the divine beings of the heavenly region, viz. the stars, are for the most part made of fire. (They also contain some earth, for solidity, and air and water as means (cf. 31B), but fire predominates. Cf. Epin. 981D.) The stars are gods, the only living beings created by the demiurge himself, and that disposes of the <u>science</u> of astronomy. For this context the earth counts as one of the heavenly bodies. The latter are spherical in shape and their built-in souls are the cause of their motions, which include both circular motion through space (except for the earth) and axial rotation (40A-C).

The remainder of the section concerning the works of reason, up to 47E, concerns the creation of the three non-divine types of living creatures, particularly man, and their souls, and is irrelevant to our purpose. With the proof (on non-scientific grounds) of the necessity for four elements, or rather four basic substances, the statement of the composition of the stars, and the account of planetary motions as the sole contributions to physical science of the work of reason it is with relief that the scientifically minded will turn to what comes about of necessity (47Esq.).

The demiurge was a symbol for one element in the universe: chaos is the symbol for the other. It is that which was 'given', to use a geometer's term, when the demiurge started his 'construction' (cf. p. 371). It corresponds to the unexplained infinite store and eternal motion of the Ionians (and replaces them) and to the tenuous mass of hydrogen of modern theories of nebular and stellar evolution, which is subject to random motions, cf. p. 55. The demiurge was described in 30A as taking over all that was visible, which was in disorderly motion. He had to operate on a chaos that limited the extent to which he was able to give to his created world the properties that he desired it to have. He could only make the world as good as possible, not perfect. He was confronted with the Errant Cause, namely Necessity. It will be worth-while to quote the opening of this section nearly in full (48A).

> For the generation of this universe was a mixed result of the combination of Necessity and Reason. Reason overruled Necessity by persuading her to guide the greatest part of the things that become towards what is best; in that way and on that principle this universe was fashioned in the beginning by the victory of reasonable persuasion over Necessity. If, then, we are really to tell how it came into being on this principle, we must bring in also the Errant Cause - in what manner its nature is to cause motion. ...
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> We must, in fact, consider in itself the nature of fire and water, air and earth, before the generation of the Heaven, and their condition before the Heaven was. For to this day no one has explained their generation, but we speak as if men knew what fire and each of the others is, positing them as original principles, elements (as it were, letters) of the universe; whereas one who has ever so little intelligence should not rank them in this analogy even so low as syllables. ... We are not now to speak of the 'arche' or 'archae' - or whatever name men choose to employ - of all things. ... But holding fast to what I said at the outset - the worth of a probable account - I will try to give an explanation of all these matters in detail, no less probable than another, but more so, starting from the beginning in the same manner as before.

We have seen (pp. 215-6) the importance of part of this passage for the theory of what is an element, and we may note how the fresh starting point is marked by Plato's again emphasizing that his theory is only a 'probable account'.

We must, it seems, reject the Pre-Socratic idea of what an element is: above all we must not think of an element as embodying a cause of motion within itself - that is a characteristic of soul alone. Before Plato can deal with the so-called elements he has to discuss chaos, the work of Necessity that is to be overruled by Reason. Necessity was not to the Greeks of Plato's day, as it is to us, a name for an inexorable natural law or for the connexion of cause and effect, in other words for order in the universe; it was rather the random irrational and disordered element in the universe. It was, when it bore this meaning, linked in Greek minds with the notions of chance and spontaneity, and did not imply for Plato either determinism or purpose. *

Necessity is the 'Errant Cause'. The data upon which the demiurge had to operate possessed of themselves certain 'powers': they acted in certain ways and moved in certain directions of their own nature - blindly, and not through the direction of purpose. That is why the cause is 'errant'. The name 'Necessity' sums up the seemingly chaotic and disorderly behaviour of the data

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* I follow Cornford's interpretation (Plato's Cosmol. pp. 162-177). Some scholars do not accept the association of Necessity with the random. Taylor and Archer-Hind would have had it that with fuller knowledge than we actually possess we should be able to account for necessity and explain away its results rationally. This may have been Democritus' conception of Chance, but it was not Plato's conception of Necessity.

before Reason controlled them. In other words, since we are to discount the description of a time-sequence as myth, 'Necessity' sums up the other factor in the universe besides reason or purpose, namely the natural powers and motions of the four so-called elements and the characteristics of another concept now introduced for the first time, namely the Receptacle or the Nurse of Becoming of 49A. *

The four so-called elements are not in fact real permanent immutable substances in the sense in which the elements of Empedocles were so described or the traditional opposites so regarded. Water <u>seems</u> (this word is emphasized for reasons that appear later) to change into earth by condensation or compacting, or into air by rarefaction or dispersal. In fact there <u>appears</u> to be a complete cyclical transmutation of the 'elements', which Plato describes (49B-C) in the order of Heracleitus' Ways up and Down and in terms meant to recall critically both the rarefaction and condensation of Anaximenes and Diogenes and the separation and mixing of Empedocles and

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* The names given to the Receptacle include the following: ἡ δεχομένη, ἡ δεξαμένη, τὸ δεχόμενον, μήτρα. τιθήνη, ἕδρα, ὑποδοχή, ἐκμαγεῖον.

Anaxagoras. Each 'element' is actually τὸ τοιοῦτον, a 'quality' that recurs in recognisably the same form as the cycles run their course, and the only τοῦτο is that <u>in</u> which all four such qualities come to be and from which they pass away (49D-E).

In direct opposition to Ionia Plato holds that there is change of quality without the existence of any permanent material substrate or ὑποκειμένον, to use Aristotle's term. That which is permanent is that in which those qualities or powers appear, the Receptacle. This is not 'bare matter': it is not that ἐξ οὗ things are made, but that ἐν ᾧ ἐγγιγνόμενα φαντάζεται. 31B (v. p. 370 sup.) made it clear that τὸ σωματοειδές, being visible and tangible, consists of fire and earth and their means; but though constituents of the corporeal these are not, as components of the 'data', in any sense particulate. In the sequential mythical phraseology, they have not yet been given their shapes by the demiurge (cf. Cornford, p. 180-1). Claghorn (Aristotle's Criticism of Plato's 'Timaeus', Chap. II) has shown that there are several points of similarity between the Receptacle and the πρώτη ὕλη of Aristotle, but these must not blind us to the vital difference, the entirely non-material nature of the former.

The Receptacle is compared with a sculptor's lump of gold: it is a matrix for receiving imposed qualities (50A-C). But gold is corporeal and has qualities of its own, and this is not so with the Receptacle. A better comparison is to liken it to the mother, the model (the Idea) to the father, and the resultant sense-object to the child (50D). In current Greek thought the father was the begetter while the mother only provided room for the embryo and acted as nurse. [x]

Just as the mother does not mould the characteristics of the child, so too the Receptacle has no qualities of its own that it could impose on the things that it receives into itself. It is 'invisible and characterless' and an object not of the senses but only, in some 'bastard' way, of rational thought (51A, 52B). The qualities that fleetingly appear in it, so that when it has been made, for example, fiery we call it 'fire', are copies of the Ideas of fire and the rest (51B-E). The copies are always in motion and fleeting, while the Receptacle is Space (χώρα), everlasting and indestructible. Space, then,

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[x] Cf. Aeschylus, Eumenides 660sq., and Aristotle, de Gen. An. 763 b 30 (re Anaxagoras) et alibi.

unlike time, was not a result of the demiurge's creative activity, but was one of the data with which he had to deal. It is to be regarded as 'place' and not as 'void', for Plato followed the Eleatic and not the Pythagorean view of the existence of the latter. Space is where things are, at least potentially.

Having made this clear, Plato then describes the state of affairs before the creation commenced - in other words, gives his picture of the universe as it would be if the element of order were abstracted. The demiurge was faced with three data: Being, Space, and Becoming. The description (52Dsq.) runs as follows:

> Now the nurse of Becoming, being made watery and fiery and receiving the characters of earth and air, and qualified by all the other affections that go with these, had every sort of diverse appearance to the sight; but because it was filled with powers that were neither alike nor evenly balanced, there was no equipoise in any region of it; but it was everywhere swayed unevenly and shaken by these things, and by its motion shook them in turn. And they, being thus moved, were perpetually being separated and carried in different directions ... and it separated the most unlike kinds farthest apart from one another, and thrust the most alike closest together; whereby the different kinds came to have different regions, even before the ordered whole consisting of them came to be. Before that, all these kinds were without proportion or measure. Fire, water, earth, and air possessed indeed some vestiges of their own nature, but were altogether in such a condition as we should expect from anything when deity is absent from it. Such being their nature at the time when the ordering of the universe was taken

> in hand, the god then began by giving them a distinct configuration by means of shapes and numbers. That the god framed them with the greatest possible perfection, which they had not before, must be taken, above all, as a principle we constantly assert.

Just where we begin to hope for some science in the account of the actual nature of air and the others we are brought up against an intrusive ethical principle. The account of creation will be seen to be based on theoretical principles of formal excellence, even though facts patent to even elementary observation will prove to have been ignored. The subservience of science to ethics or religion is a well known phenomenon (best exemplified by the vicissitudes of the heliocentric hypothesis in the history of astronomy).

The passage just quoted describes the primaeval chaos, ruled by Necessity or the Errant Cause. As the random element Necessity has points of affinity with the concept of entropy in modern thermodynamics. To illustrate this in non-mathematical terms, consider a gas. Different parts of this may originally be at different temperatures (which means that the molecules have different velocities of motion) and be moving relatively to each other (swirling about). Initially, in other words, its molecules may have velocities of motion and kinetic energies of any magnitudes and directed in any directions whatsoever. The gas will, however, according to the laws of thermodynamics, rapidly approach a state where the distribution of velocities energies and directions is, statistically, perfectly definite, and independent of the initial motions. This state is that of thermodynamic equilibrium. In this every part of the gas is at the same temperature and of uniform density. The velocities and energies have averaged out and as many molecules are moving in one direction as in that directly opposite to it. The state is one of the greatest possible disorder. The entropy, which is then at a maximum, is simply the measure of the degree of disorder.

The difference between the state of maximum entropy and the state of Plato's errant chaos is that the former resembles the state of the sphere of Empedocles when Love is in complete charge while the latter resembles that sphere when Strife is in charge.

The reason for the difference is that in a state where 'there was no equipoise in any region of it; but it was everywhere swayed unevenly' the operation of the laws of thermodynamics would actually impose an 'equipoise' and bring the mass to equilibrium, whereas the Necessity of Plato, because Plato was ignorant of these laws, relied on the sham law of the attraction of like to like, and imposed instead a state of maximum order, or would have done so had not the demiurge intervened, through a process recalling that of Frag. 15 of Anaxagoras that would lead to the state of Empedocles' sphere of strife.

Plato's excuse might be that Empedocles' elements were all equal in quantity but there was a lack of quantitative balance between his own that might be said to have upset the equilibrium. Apart from that excuse, he has completely reversed the true state of affairs. The laws of thermodynamics assert that a state of imbalance will in the absence of any external cause develop of necessity into a state of equilibrium and complete mixture, whereas Plato infers that it will develop 'of necessity' into a state of complete separation. To use Eddington's phrase, Plato has reversed 'Time's arrow'. * Anaxagoras is innocent of this charge. He has, it is true, changed the state of affairs from equilibrium (Frag. 1) and mixture through the state of Frag. 15 that resembles the present passage of Plato to the ultimate state of maximum order of Empedocles' strife-sphere, but he has not brought this

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* Eddington: The Nature of the Physical World, Chap. IV.

about 'of necessity'. It is for just this purpose that he invoked what I called above 'an external cause', viz. Mind. Mind produced order out of chaos, a chaos that like Anaximander's and Anaximenes' shows similarity with our modern conception of the primaeval state of the universe (cf. p. 55 sup.).

Modern ideas on the relation between chance and causality, order and chaos, time and entropy, nature and determinism, are very clearly discussed in non-mathematical language in the book of Eddington referred to in the last footnote, and this book merits careful study by any historian of Greek science.

Plato abandoned the Milesian idea that material 'elements' can themselves be causes of change and motion, and disagreed too with Empedocles and Anaxagoras, whose 'causes' were still described in more or less material and certainly physical terms. The 'elements' are connected with the irrational, and they derive at least the ordered part of their motions from the fact that they, as parts of the body of the world, are pervaded by soul, a non-material cause of motion, and the only one.

Note: If we interpret Plato's chaos literally, we are presented with natural motions of the elemental 'powers' even before the demiurge endowed the body of the world with soul. This appears to involve an inconsistency with the principle that soul is the sole cause of motion (Phaedrus 245C, cf. p. 372). See Cornford (Cos. p. 203sq.) for a discussion of the implications of this. To that discussion I would add firstly that 34Asq. hints that we must not take the time-sequence literally, secondly that even in making the world-soul the demiurge was operating on 'data' not creating ex nihilo so that the irrational element in that soul posited by Cornford may be due to one of the components out of which soul is compounded, and thirdly that it is eternal circular motion that is particularly characteristic of the divine, so that in performing his abstraction Plato would appear to have had at any rate some justification for associating rectilinear motions with the random element by including them among the 'powers' of the 'elements'.

Having dealt with the random element inseparable from the four basic substances in his description of chaos, Plato is now free to proceed in 53C - 55D to construct the Ideal shapes of the 'most perfect' bodies, viz. of the regular figures copies of which will be imposed on those substances in order to provide them with their element of rationality. Plato's theory is, as Cornford says (p. 210-211), a deliberate correction of Democritus, whose atoms could have any chance shape, by relating shape to reason and perfection. In outline the scheme is simple enough, and we have seen reason to attribute the simplest form of the theory to the Pythagoreans - but only the simplest form. Theaetetus was definitely the first to complete the mathematical analysis of the regular solid figures, and Plato the first to work out the full details of the physical processes of generation and change.

The figures are here constructed from the 'best' triangles, namely the half equilateral for three of the figures and the half square for the cube, and not from full equilaterals and squares as might have been expected. The reason will appear later. This method excludes the dodecahedron (which has pentagonal faces); but there are only to be four 'elements', and the intransigent figure can be made of flexible material and turned into the sphere of the whole (v. pp. 351-3 sup.). The figures form the only aspect of the 'elements' that is due to the demiurge, to reason.

In 55Dsq. the figures are assigned to the 'elements'. Both figures and 'elements' are, I repeat, only copies of their Ideas. Earth is the cube, 'the most immobile and plastic', and the most stable, since it has square faces to act as a base. Water is the icosahedron, the least mobile and largest of the remainder. Fire is the pyramid or tetrahedron, the most mobile, smallest, sharpest, and lightest. Air is the octahedron, intermediate in all respects. (In this context largeness and smallness are relative to a given size of basic triangle.)

The bodies formed by the imposition of copies of the ideal figures upon the hitherto amorphous substances whose 'vestiges' obtained their characters from the 'powers' that were part of their nature as they appeared in the receptacle (v. p. 380) are individually invisibly small and can only be seen in aggregates. Their numbers, motions, and powers, the god 'adjusted in due proportion, when he had brought them in every detail to the most exact perfection permitted by Necessity willingly complying with Persuasion' (56C).

We have seen that the proportions (relative amounts) and powers (qualities) and motions (rectilinear) were 'data' belonging to Necessity, but at least the demiurge did the best that he could with them. Again this is ethics not science, and it was also ethics that decided the choice of basic triangles that is responsible for the statement that earth cannot enter into the process of transformation by breakdown and recombination of the figures. (We are reminded at 54B that at 49B-C it was stated that earth <u>appears</u> to undergo transformations, v. p. 377.)

The cube of earth is formed from the 'best' of all kinds of triangles, the half square, while the other shapes are formed from the next best. This is a quite arbitrary denial both of the evidence of observation (which Plato has admitted to be against him) and of the common Ionian idea of complete transformations. Plato recurs to the point in 56D:

> Earth, when it meets with fire and is dissolved by its sharpness, would drift about - whether, when dissolved, it be enveloped in fire itself or in a mass of air or of water - until its own parts somewhere encounter one another, are fitted together, and again become earth; for they can never pass into any other kind.
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> But when water is divided into parts by fire, or again by air, it is possible for one particle of fire and two of air to arise by combination; and the fragments of air, from a single particle that is dissolved, can become two particles of fire.

For Plato the breakdown proceeds only as far as triangles. These are the only things to which Plato would give the name 'elements'. This serves Aristotle as the starting point for a strong criticism of this part of Plato's theory. I quote Guthrie's translation of de Caelo 306 a 2sqq. from the Loeb edition:

> But if the process is one of analysis into surfaces, there is the absurdity of not allowing <u>all</u> the elements to be generated from each other. ... <u>But</u> for one element alone to have no part in the change is neither logical nor apparent to sense. ... These philosophers find themselves, in a discussion about phenomena, making statements with which the phenomena conflict. This is because they have a wrong conception of primary principles, and try to bring everything into line with hard-and-fast theories...

After a little more in the same vein, Aristotle criticizes in detail several of the points in the theory with which we shall soon be dealing; but some if not all his arguments are valid not so much against Plato as against any Platonists who may have taken a rather Pythagorean view and thought of simply triangles and emptiness, ignoring the Receptacle and solidity, or expressed sensible quality as simply a function of shape and size, ignoring the 'powers', in the Democritean manner. * To the criticism quoted on p. 388, however, I have nothing to add but complete agreement.

The details of the process of transformation by resolution into elementary triangles and recombination are somewhat obscure owing to the compressed nature of the account in the Timaeus: Cornford (Cos. pp. 224 - 257) has put forward an explanation that I find entirely satisfactory, and I propose to accept that explanation without further argument.

The essential nature of the process is straightforward. The particles of an element are broken down into their elementary constituents, the half equilateral or

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* Claghorn, Op. cit. pp. 31-7 discusses these criticisms at length.

right-angled isosceles triangles, which are then adrift in space until they recombine into solid figures, the latter again into cubes, the former into any of the other three figures.

Here lies a major difference between Plato and the Pythagorean theory that I postulated. I claimed (p. 357) that the Pythagoreans' breakdown proceeded through planes and lines right down to points, or at least as far as lines. Such a resolution permits complete transformations, as I pointed out. Plato asserts definitely in 53D that it is the triangles (planes) that are the 'first beginning of fire and of the other bodies' according to the 'likely account'.

He admits, however, that 'principles yet more remote than these are known to Heaven'. 53B contains a hint as to the nature of these: "The god then began by giving them a distinct configuration by means of shapes and numbers". This recalls the Pythagorean procedure. Credibly enough Cornford refers the hint to indivisible lines. He quotes (p. 212) the paper in C.Q. xxx p. 125 of Miss A.T. Nichol, who, after referring to the synthesis from indivisible lines through indivisible surfaces and indivisible solids to sensible solids of Laws 894A, wrote: "The

Timaeus is a myth of the physical world, and therefore has no need to go further back than the surface, the stage where in descending from the ἀρχή the third dimension becomes possible; for without the third dimension there is no sensation".

Plato's choice of triangles as the elementary entities was therefore quite arbitrary - as arbitrary as the isolation of earth that results from it. If taken literally the theory of planes, which, as Aristotle points out in de Caelo 299 a 2sq., clearly should admit a further analysis into lines and points (cf. de GC 315 b 31 et al.), is open to all the objections, especially those about weight, that Aristotle raised throughout his physical treatises, in connexion with the generation from mathematical objects, against the Pythagoreans. It is also open to the further objection (de Caelo 299 b 24sq.) that surfaces may be piled flat on top of each other, and the Timaeus does not allow for this. (The result would either be a prism or nothing at all according to whether the surfaces are built up in the number-atomist manner or as Raven believes.)

It is to be noted that in 54Dsq. we learn that the equilateral triangles that compose the planes of three of the figures are made up of six not of two half equilaterals, while the cubic square surfaces are from four not from two half squares. For this apparently arbitrary departure from what was to be expected we shall find an explanation later.

Meanwhile we learn how the transformations take place (56Dsq. quoted in part on p. 388). Fire can resolve earth into its triangles. In other words, on the macroscopic scale, heat will break down solid bodies, but they are not then transmuted. On cooling they revert to the same solid state. The remainder of the transformations are treated in an order that (apart from the isolation of fire) recalls the Ways Up and Down of Heracleitus and the successive rarefactions and condensations of Anaximenes. In the first case the tetrahedra of fire, being shaped for sharpness and mobility, can break up the figures of air and water. The 20 faces of the water icosahedron can reform into 2 octahedra of air plus 1 tetrahedron of fire. Macroscopically fire boils water giving vapour, which our senses perceive turning into air, or the sun can evaporate water. In each case the resultant air is warmer than the neighbouring air because of the presence of the fire particle. In modern terminology one molecule of water under the action of heat disintegrates into two molecules of air with the liberation of one equivalent of heat energy. The reaction is, we say, exothermic.

If the application of heat continues, the two octahedra resulting from the first reaction may then be split into a total of four tetrahedra. It must be remembered in interpreting this that, as I pointed out on p. 250, the Greek concept 'fire' was a misconception. Fire, as flame, is incandescent gas not a separate substance, and as heat per se it is pure energy - completely non-corporeal. In fact matter and energy are convertible, the death of one being the birth of the other, as Heracleitus might have put it. Consequently in putting this part of Plato's process into modern terms one may either say that the two molecules of air are converted into heat energy or say that they become incandescent - which involves no actual transmutation; one must not say that which Plato really meant, that two molecules of air turn into four molecules of another substance called 'fire'.

On the way down (56E) a large mass of the bulkier particles (even earth) is conceived of as enveloping the particles of a much smaller mass of fire. All is in motion and strife since fire is struggling to get up to its own proper region. Fire loses the unequal contest. Its tetrahedra are shattered, and the resultant triangles are reformed into the octahedra of air in the proportion of two of fire to one of air. Water is produced similarly from air in the proportion of five particles of air (which may have come from ten of fire) to two of water. Macroscopically the process is presumably the formation of mist and cloud and of dew and rain.

Neither the upward nor the downward process need stop until the limit, fire or water, is reached; but beyond that limit no further change is possible. The active 'power' of an element can only act upon what is different from itself. The hot cannot disintegrate the hot.

It should be noticed that numerical ratios exist only between the surfaces concerned in the figures transformed, not between the relative volumes. The volume changes are not in integral ratios, a point that will assume importance later.

We may note that Aristotle complained of the 'suspension of triangles in space' (de Caelo 306 a 21) and Simplicius (de Caelo 647, 9, quoted by Guthrie ad loc. in the Loeb edition) makes a similar complaint (unjustified in the case he cites - four triangles left 'suspended' when water turns into air). We must not, however, take Plato literally over these suspended triangles, as Cornford warns (p. 229), any more than we should ask him what is inside the figures, or if they are hollow. All that he could say would be that they are full of 'powers', the powers that are characteristic of the body of the world, and that enable the figures to move against each other and break each other up. We may be able to account for the suspended triangles later (v. p. 406). In any case, all is only a 'likely account'.

We learn in 57C - 58C why the world, as a result of the intervention of the demiurge, is not like either of the spheres of Empedocles. Firstly, while the random motions in the chaos had sorted apart the main masses of the elements into their separate regions, these transformations interfered with the sorting process. Some of the particles that were in their proper region became transformed and then had to seek a new 'proper region'. Even so, the sorting might eventually become complete, leading to Plato's version of thermodynamic equilibrium, the four separate masses, were it not for a second factor. Homogeneity, the state of our thermodynamic equilibrium when entropy is at a maximum and there is the utmost randomness of motion, entailed for Plato as for Parmenides not motion but a state of absolute rest. Heterogeneity leads to motion, and that heterogeneity is present since the world contains not simply four types of substance associated with four regular figures, but an endless diversity of substances, because each regular figure, as we now learn for the first time, occurs in several sizes, so that the number of possible compounds is far greater than Empedocles' theory would allow.

Not only are the sizes and amounts of the elements unbalanced, their powers are also unbalanced. As a result, the sorting process is again impeded. Even this, however, does not complete the list of reasons for the lack of complete sorting.

The universe has been moulded by the demiurge as a rotating spherical plenum. Its spherical shape limits the available space, and its closed rotatory movement permits no vacant intervals, no internal void, to be formed as would be formed if the particles were free to fly off at a tangent or in a spiral (Cornford p. 244). Being confined in a closed sphere the elements have not complete freedom of motion - they are packed together as closely as possible. Aristotle argued (de Caelo 306 b 3) that the geometrical figures cannot be packed so as not to leave any interstitial void, but Plato says that the less bulky particles are thrust into the interstices between the larger ones. Consequently as each particle tries to move towards its proper region through the attraction of like to like the smaller, pressed into the larger by the 'condensation' process, will shatter the larger.

It is not only the condition of the rotating sphere that causes the thrusting together of the particles and the consequent shattering. We saw that the relative volumes in the transformations are not proportional. This means that as two tetrahedra combine into an octahedron the total volume is increased because one octahedron takes up more room than two tetrahedra with sides of the same length. Consequently the 'condensation' that forms the way down is in a sense an expansion. But it is not the same sort of expansion as that in rarefaction, which, although Anaximenes did not realise it, really involves particles of constant volume that increase their distance from each other. Plato's expansion is one where the particles remain as close as possible to each other but increase their volume. The result is greater density, and, if there is inadequate room, a shattering of the smaller particles between the newly formed large ones. It is an expansion corresponding on the macroscopic scale to the greater volume of the ice formed than of the water that formed it, rather than to the expansion of matter when heated. On the whole it is density rather than over-all volume that is increased, and this explains why Plato did not need to postulate void to fill his interstices.

We may note how the traditional Ionian theories, whose literal interpretation was rejected at 49B-C, are explained away by this theory of condensation with simultaneous and compensating expansion in which the ways up and down presumably balance, as they did for Heracleitus, so that condensation with expansion here is countered by rarefaction with contraction there, and the total volume is constant.

As a result of this close packing and restricted movement and the consequent shattering, together with the already mentioned continual changes of direction of motion consequent upon the transformations and the attraction of like to like, the heterogeneity and imbalance that are the conditions for motion are always maintained, and so inhibit the uniform operation of the Platonic version of entropy that would, according to his belief, culminate in a state of absolute rest in which the universe would resemble the sphere of strife of Empedocles.

In the course of this explanation a very important point was mentioned en passant (57D, v. p. 396): the triangular surfaces out of which the four figures are constructed are not all of the same size. Cornford (Op. cit. p. 234) explains this by means of another point mentioned on p. 392 (54D): the equilateral triangles actually used by the demiurge contain 6 basic triangles, not 2, and the squares 4, not 2. In Cornford's view, which I accept, Plato was making the demiurge construct an average or typical equilateral or square. Smaller than average surfaces could be constructed out of just 2 basic triangles, and larger ones by the use of more triangles still.

The consequence of this is (58C) that there are a number of different types of each so-called element. To put it another way, for Plato, as really for most of the Pre-Socratics even though they did not always realise it, the names 'fire air water and earth' really refer not to individual substances but rather to states of matter: igneous (no true modern equivalent), airy (gaseous), moist (liquid), and earthy (solid).

A further consequence is, as already stated, the possibility of a greater diversity of compounds than that provided by the theory of Empedocles. There will not be merely compounds of just four elements, which would be few unless one were willing to postulate formulae having ridiculously high numbers of each component, but rather compounds of any number of different species of each element.

Every particle of, for example, air consists of the 'powers' of air (which account for most of its sensible qualities, but v. inf.) upon which reason has imposed the form of an octahedron (which accounts for its chemical behaviour, its transformations), which is in turn pervaded by soul (which accounts for its kinetic or potential energy). But, owing to the variety in size of the basic figures, there are various kinds of each 'element' (58C-D):

> Next we must observe that there are several varieties of fire: flame; that effluence from flame which does not burn but gives light to the eyes; and what is left of fire in glowing embers when flame is quenched. And so with air: there is the brightest and clearest kind called 'ether', and the most turbid called 'murk' and 'gloom', and other nameless kinds, whose formation is accounted for by the inequality of the triangles.

The use of the three terms in inverted commas, for which the Greek is αἰθήρ, ὀμίχλη, and σκότος, is a deliberate reference to terminology and concepts that we have frequently met in the Pre-Socratics.

The last phrase of the quotation is obscure. It may mean that the varieties of an element differ in that each variety is composed of particles of uniform size, which differs from the size of those of any other variety, or in that within each variety there are particles of different sizes.

In the case of fire, three varieties are named here. Flame is, I repeat, a substance: gas heated to incandescence, emitting electromagnetic radiation some of which is visible as light and some of which is invisible (infra-red) but perceptible as heat. The second variety is described also in passages concerned with vision (45Bsq., and 67Csq.). To Plato it is the substance of the 'visual ray': to us it is 'light' itself - an electromagnetic radiation that is not material since it is a wave-form, and yet particulate since it occurs in photons, and is also subject to gravitational attraction. Of course the sub-atomic particles from which we construct matter are themselves non-material in analogous ways, so close is the connexion between matter and energy. The important point about light for Plato is that it does not give rise to the sensation of heat. The third variety of fire is the glow from embers. This again is to us radiation - light plus infra-red.

The type of fire that comes as an effluence from bodies to join the visual ray is subdivided in 67Csq.: particles of the same size as those of the ray itself are 'transparent'; larger ones, which contract the ray, are black colour; smaller ones, which dilate it, are white colour; another variety, more piercing, is bright colour; and an intermediate variety is red colour.

The two types of air mentioned in the passage quoted obviously correspond to the ancient distinction between ether and aer. The former will consist of the smallest and most mobile octahedra, the latter of larger and more sluggish ones. Intermediate kinds are here termed nameless.

The passage on odours, 66D-67A, is not quite consistent with this. It contains the following sentences:

> The veins of smell have a structure too narrow for earth and water and too wide for fire and air; hence no one has ever perceived any odour in any of these bodies; odours arise from substances in process of being liquefied or decomposed or dissolved or evaporated. They occur in the intermediate stage when water is changing into air or air into water. All odours are vapour or mist, mist being that which is on the way from air to water, vapour what is on the way from water to air; consequently, all odours are finer than water, grosser than air. Their nature is plainly seen when a man forcibly inhales the air through something that obstructs the passage of the breath: then no odour filters through with it; nothing comes but the air robbed of all scent.

From this passage, in which Plato, who elsewhere in the dialogue has gone against the evidence of the senses, surprisingly adduces observational evidence of the filterability of odours, we learn that although we have previously been told that water and air particles exist in several sizes, no particle of either, nor of any other element or compound of elements, is of the right size to penetrate the passages connected with smell - passages similar to those postulated by Alcmaeon. Moreover we were told in 58D that ὁμίχλη, with σκότος is a kind of air. Here we are told that ὁμίχλη and καπνός, which Cornford here translates 'mist' and 'vapour' respectively, are not varieties of air, but intermediate between air and water. They are finer than water and grosser than air.

That no ordinary regular figure will fit into the 'veins of smell' is astonishing, while this is the first mention in the dialogue of intermediates. Cornford hazards the guess that the self-correction in this passage is intended to introduce the idea of recombination into irregular, transitional, solids as an intermediate stage in the transformation from one regular solid to another, irregular solids that could use up the surfaces 'suspended in space' of which Aristotle and Simplicius complained (cf. p. 395, and Cornford, Op. cit. p. 273-4).

This is a plausible suggestion. But granted that Plato wanted to include a section on intermediate figures, why did he choose to put it in the section on odours, and in such a way as to conflict both with common sense and his own previous statements? I do not think that Cornford has sufficiently answered this.

I suggest that Plato realised that in the account in 58D he had not given an adequate account of air. He had stated that that which the Ionians classed as 'murk' or 'gloom', sc. as forms of 'aer', was in fact a kind of air. But Plato knew that Empedocles had distinguished between true air and water vapour, and had explained darkness as shadow. He knew, in other words, that 'murk', i.e. mist or vapour, does not consist of elementary air at all, and that the Milesian 'aer' was really more akin to water than to true air, although not having the physical form normal to the liquid state.

Consequently, he inserted a self-correction at 66E instead of expanding 58D. The latter passage, by reason of its general vagueness and imprecision, gives me the impression of having been written casually as a connecting link between two passages that held greater interest for Plato: the earlier was the long account of motion and heterogeneity that casually introduced the different sizes of triangle and the idea (shortly to be discussed) of a thrust; the later was the account of the different types of water and earth that makes use of those two new ideas. A longer discussion of the nature of air would have broken the continuity of thought at this link.

In 66E, therefore, Plato places καπνὸς καὶ ὁμίχλη more accurately as τὸ μεταξύ air and water, as in a sense he might have put αἰθήρ as τὸ μεταξύ air and fire (cf. pp. 305-310). Mists and vapours, then, of which the former 'is on the way from air to water' and the latter 'is on the way from water to air', are in the same position as Heracleitan exhalations that are on the downward or upward path. (This may have been the reason why in 66E Plato couples ὁμίχλη not with σκότος but with the Heracleitan term καπνός, if indeed it is Heracleitan - v. p. 170.)

But whereas the Ionians and Heracleitus could in their various ways explain the existence of intermediates without difficulty, because their processes of transformation were continuous, Plato has to explain away something between an octahedron and an icosahedron.

Archer-Hind suggested that the explanation was by means of intermediate irregular polyhedra. Cornford adopted this explanation, showing how figures of 10, 12, 14, 16, or 18 faces could be constructed. He added the suggestion that the construction of these would absorb the surplus 'suspended' triangles. Such figures would, by their instability and inevitable constant flux, serve to explain the amorphous and fleeting nature of mists and odours.

All this, then, explains why a self-correction was necessary and why the section on odours was appropriate for it. It still fails to explain why Plato claimed here that regular figures or their compounds could not fit into the nasal passages. It may be that Plato had in mind some peculiarity of the mechanism of smell discussed by the Sicilian school of medicine, with whose opinions he was familiar. Had they perhaps discovered by dissection peculiarities in the shape of the passages through the nasal bone or the sinuses?

Let us turn to firmer ground by considering the passage on the various types of water and earth and their compounds (58D - 61C). Our subject is gases, not liquids and solids, so that some of the details are irrelevant, but there is still much of interest to us.

We mentioned on p. 399 that the names of the four so-called elements have in the history of Greek science the connotation of states of matter rather than of particular substances known to the man in the street under those names. We have seen how the principle of Hippo was probably not the water that we drink; and we had to distinguish between the air of the atmosphere and the pure aer of Empedocles, Anaxagoras and Diogenes.

We now find that the terms 'water' and 'earth' for Plato have not the connotation of drinkable fluid or soil. But whereas his predecessors' 'water' was always in some sense liquid, Plato's use of the term has a wider application. It applies (58D) not only to matter that is actually in the liquid state, but also to matter that is potentially so, viz. to fusible substances, and in particular to metals. 'Earth' by contrast refers to non-fusible solids such as stone and earthenware and to water-soluble solids such as salt and soda. The latter Plato considered to be 'only half-solid' (60D). Yet other solids, which are non-metallic but fusible, such as glass and wax, are compounds of water and earth.

'Water', then, subsumes not only natural liquids but also substances that may become liquid when heat is applied but revert to the solid state on cooling. There is sense in this. It is only an accident, due to the fact that the temperature of our planet rises only to a certain degree, that metals appear in nature as solids. On the moon or on the inner planets whose temperatures are higher some or even all of the metals are naturally in the liquid state, and even on Earth the metal mercury (quicksilver) is so.

In order to understand Plato's physical chemistry we must remember that, since there is no void, the interstices between the large figures of water or earth are occupied by the smaller figures of air and, especially, fire.

True liquids are mobile because their figures are of the smaller grades, although not all of the same grade. Fusibles, on the other hand, have larger grades of icosahedron, and in each substance the figures are all of the same grade, so that they are firm and stable. But fire can get into the interstices and break down the figures into those of smaller grades. Consequently the figures become smaller and of varying grades, the condition for fluidity. Meanwhile particles of fire also get in between the particles of the surrounding air and force them apart. The air consequently expands, and having no void to move into, since the world is a plenum, it exerts a 'thrust' on the fusible substance. This thrust causes the latter, now in the condition for fluidity, actually to flow. The whole of this process is called 'melting'.

From this important passage (58E) we learn two things of interest. Firstly, larger grades can be broken down into smaller grades of the same shape (and vice versa as 59A shows), in other words transformations can occur between the different types of the same 'element'. Secondly, air when heated expands. This occurs in the neighbourhood of fire that is heating a body: it also occurs when a body is cooling, for that body is then losing heat by radiation, in other words by expelling tetrahedra into the surrounding air. In this case, too, a 'thrust' consequently develops; and this serves to contract a cooling fusible into the solid state (59A).

Water proper has of necessity fire within it to fill up its interstices, and this fire assists the slightly unstable shape of its bases in giving it its mobility. There may be some air in the interstices also. If, now, the fire, and the air if any, are expelled the water cools, and a thrust of the same type from the surrounding air forces its icosahedra to transmute to the larger grade so as to fill up the interstices left by the departing fire. This is how water 'freezes' into hail or snow, ice or frost.

The cubes of earth do not all lie flat against each other. They lie at all angles and leave quite large interstices in which icosahedra will fit. If such a mixture of earth and water is disturbed, the water may be broken up and transmuted to air. The latter will try to go up to its proper region, and will consequently give a thrust to the surrounding air that is already a plenum. As a result there is a downward pressure on the earth, and this forces the cubes so close together that icosahedra can no longer get between them. This is how stones are formed and why they are insoluble. If the cubes are small and uniform in size we get transparent stones, if not, opaque ones. If the loss of water is hastened by the application of heat, we get pottery from clay. If the water loss and compression are not complete, we get soluble solids like salt and soda. (60B - 60E.)

The 'thrust' that occurs when a body moves into the air that surrounds it because that air is a plenum is of great importance to Plato. It is used not only to explain changes of physical state, but also to explain respiration (along with Empedocles' principle of transpiration through 'pores'), the action of medical cupping instruments, the process of swallowing, and the movement of projectiles (79A - 80A). In these latter cases it is a 'circular thrust' that is involved. If a body moves into air it is not moving into empty space, but is displacing air. The displaced air in turn displaces that near to it, and so on, until the air is all thrust round and enters the place out of which the body moved. "All this goes on simultaneously, as when a wheel is driven round, because there is no vacancy" (70B). The Greeks, ignorant of forces that can act at a distance, of the nature of acceleration, and of Newton's law that once set in motion a body will continue to move with constant velocity unless some external force acts upon it, had always been troubled by the motion of projectiles, and Plato's solution is that the air continuously thrusts itself against the projectile.

Plato completes his account of physical chemistry by explaining why things like glass and wax are melted by fire but not dissolved in water.

Earth in its normal state is not dissolved by fire or air because the interstices between the cubes are so large that the small tetrahedra and octahedra can pass right through. Icosahedra, on the other hand, have to force their way through, and in doing so may break down the particles of the earth and so dissolve it. If the earth is compressed, however, air and water cannot get into the interstices at all, and only fire can then dissolve it. Similarly compressed water can only be broken down by fire, but normal water can be dispersed by air's getting into its interstices and transmuted by fire's attacking its actual figures. Compressed air is only subject to transmutation by fire, while normal air can be 'dissolved' by fire (i.e. have the grades of its figures altered).

Things like glass and wax are compounds of earth and water (the latter containing more water). Water cannot dissolve them, for it cannot get into the interstices since these are already occupied by the water that is part of the compound. They can be melted, however, for fire particles can get between the particles of the compounded water and drive them apart. This completes our account of physical chemistry (61C).

The four 'elements' have been seen to be not elements at all, but geometrical forms constructed in space, pervaded by soul, and possessed of powers and motions. It is now necessary for Plato to show how such 'elements' can give rise to observed qualities. We know that the powers should give the elements their qualities, but Plato here ascribes the latter to the figures and their properties. Presumably the powers make the figures exercise their properties.

The sensation of heat is due to the swiftness, sharpness, and smallness of the tetrahedra of fire (61E). Cold is due the the attempt of icosahedra to fit into interstices in the skin left by the departure of fire and air. They cause an unnatural contraction, and this, together with the body's attempts to expand back to its natural state, leads to the vibration that we call by the name 'shivering'.

Hardness is due to a thing's having particles with a large base, like the square of earth, or to the resistance consequent upon density, and softness to the reverse of this. Roughness and smoothness are similarly explained. Weight is merely relative. In a spherical universe there is no absolute up or down. Each element has its own region where the main mass of it is located. The attraction of like to like causes a smaller mass to move towards a larger. Heaviness is felt when a thing tries to move 'down' towards the main mass of its kind, and vice versa. What is 'heavy' in one region is 'light' in another. The amount of the heaviness or lightness is a function of the size of the thing. The smaller of two masses of the same element tends to move towards its parent mass more weakly. This account substitutes for our 'gravity' (itself a sham according to the theory of relativity) the attraction of like to like. There is no absolute lightness or weight, and the origin of our sensation of the latter is the resistance that we feel when we try to restrain a thing from reaching the region proper to it or to remove it from that region.

After discussing these general sense qualities, Plato considers the mechanism of particular senses from the point of view of their connexion with the structure of the elemental figures (65Bsq.). We have already looked at the relevant points in the passages on sight and smell. Plato's theory of sound is strongly reminiscent of that of Archytas (v. p. 361) and nothing more need be said except that in 80A the 'circular thrust' is connected with the transmission of sound. The theory of taste contains nothing that is relevant here.

We find that this discussion of sensible qualities deals with the shapes, permanent physical properties of the 'elements'. Yet the doctrine of the Theaetetus (in 156Asq.) is that sensible qualities are not permanently possessed by objects. The objects have only the power of acting and being acted upon, and so have the sense organs. It is when the object and the organ undergo mutual 'affection' that the object 'becomes' the possessor of such and such a sensible quality. The birth of a perception always coincides with the birth of the quality perceived. How then can Plato in the Timaeus ascribe these evanescent qualities to the shapes, which are permanent? If the theories of both the Timaeus and the Theaetetus are Plato's own, as I believe them to be, there appears to be inconsistency here (cf. Cornford, Op. cit. pp. 259sq.).

It should have been enough, in order to provide objects with the ability always to produce the same sensation whenever an act or perception takes place, to ascribe to objects their 'powers'. It seems that in the Timaeus Plato was emulating the atomists, who ascribed sense qualities to the functions of shape. To compete with this, perhaps, Plato decided to give an explanation by means of shape, in spite of the fact that one would rather have expected him to concern himself with the 'motions and powers' that preceded even the demiurge. These would, however, be too permanent to fit in with the instantaneity of perception, whereas, believing in the Heracleitan flux, Plato could argue that even the shapes, permanent though they seem to be in comparison with the act of perception, were in fact fleeting, since the processes of transformations along the ways up and down are going on all the time.

The description of the physics of sense perception concludes the section on the works of Necessity. The remainder of the dialogue deals with the coöperation of reason and necessity; and, consisting as it does of Plato's medical and psychological theories, it may be postponed to the appendix on those subjects. What is relevant to physics has already been referred to above.

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CHAPTER ELEVEN

THE ATOMIC THEORY

From the theory of the Timaeus we turn to another that has in some respects great similarity to it, but that in other respects contrasts sharply with it. We have already seen that Plato was in some sense consciously setting himself up as a rival to the atomic theory.

The atomic theory was first conceived by Leucippus, who, once a shadowy figure in whom some ancients and moderns even disbelieved, has become clearer through the work of Diels, Burnet, Bailey, and others. It is now possible to trace a number of points in which his successor Democritus differed from him. These two, the former of Miletus and the latter of Abdera, probably flourished about 430 and 420 b.c. respectively (or Leucippus perhaps a little earlier). Between them they established the main tenets of atomism.

Democritus was followed in turn by Nessas, Metrodorus of Chios, Diogenes of Smyrna, Anaxarchus, Pyrrho, Nausiphanes, and Epicurus; but of these we shall only be concerned with the last, for the others were either more interested in Democritus' moral philosophy, or men who as far as we know made no important improvements on the atomic theory, merely passing it on with slight amendments of details.

The differences between the theory as Democritus handed it on and the original theory of Leucippus were mainly of two kinds: the amplification of, or the addition of extra arguments in favour of, points raised by Leucippus, and the correction of details where Leucippus seemed to have erred. (These corrections were not always subsequently accepted by Epicurus.) The corrections were usually slight, and for the most part had no bearing on the nature of air. It will, then, be sufficient simply to deal with what we may call 'Pre-Platonic Atomism', without treating Leucippus and Democritus separately. There is a difference of tone between them, that between any pair related as daring innovator and confident consolidator, particularly as Leucippus seems in character to be a typical Ionian 'physicist' - he is indeed a Milesian - while Democritus more resembles Aristotle in his encyclopaedic interests. This difference does not at all affect the theory itself, only its expression. I shall mention any relevant points in which we can say with confidence that their opinions differed, and that will suffice. It is no part of my purpose to expound the mature theory of Epicurus or of Lucretius, since my interest lies in the Pre-Socratics.

There will, however, be occasions in which the fragmentary nature of our sources would leave a gap in our understanding if we did not fill it by considering the later atomists, or where it is of special interest to follow the development of an idea that is only embryonic in the Pre-Socratic era. It will also be of interest to examine a few cases where Epicurus had to decide between alternative proposals of Leucippus and Democritus.

Epicurus did indeed greatly advance the theory as a whole, but his main achievement in the realm of physics was not the putting forward of essentially new ideas, but rather the giving for the often merely dogmatic statements of his predecessors more or less cogent proofs, or demonstrations depending on observation.

We have prolific sources for early atomism thanks to the interest in it displayed by Aristotle and his commentator Simplicius, and by Theophrastus, and for atomism in general through the writings of Epicurus and Lucretius, and even the comments of Cicero.

The best introduction to Greek atomism has already been written by Aristotle in the form of two passages that compare it with its forerunners. The first passage is Phys. 187 a 1:

> ἔνιοι δ' ἐνέδοσαν τοῖς λόγοις ἀμφοτέροις, τῷ μὲν ὅτι πάντα ἕν, εἰ τὸ ὂν ἓν σημαίνει, ὅτι ἔστι τὸ μὴ ὄν, τῷ δὲ ἐκ τῆς διχοτομίας, ἄτομα ποιήσαντες μεγέθη.

I agree with Ross, note ad loc. and Burnet, E.G.P. p. 335, that in view of the second passage that I am about to quote this refers to the atomists, and I refer the reader to Ross' account of the arguments involved. Briefly, the first 'account' is that of Parmenides, to which the atomist reply is that 'being' has more than one sense so that 'not-being' can exist, and the second 'account' is that of Zeno whose arguments against the Pythagorean plurality are incidentally such as to destroy the infinite divisibility of Anaxagoras and lead to the postulation of 'indivisible magnitudes'.

The second Aristotelian passage also refers, specifically under the name of Leucippus, to atomist replies to the Eleatics, but brings in Empedocles as well. It is Chap. 8 of de GC Book I, parts of which have been summarised or quoted on pp. 224 and 229-231 sup.. The most important paragraphs appear as D. 67 A 7.

The most methodical theory of action and passion, says Aristotle, is that of Leucippus and Democritus. The Eleatics, believing in an unchanging 'one' and denying the void and motion, and plurality, criticized the theory of discretes in contact (Empedocles, v. p. 224), that of plurality and void (the Pythagoreans), and that of infinite divisibility (Anaxagoras). Ignoring the senses, they asserted the above belief, some (Melissus) also holding that the One is infinite since a limit implies external void. (Melissus, Frag. 5.)

Leucippus however, Aristotle continues, conceded 'becoming, perishing, motion, and plurality' to the senses, and to the Eleatics that there could be no motion without a void (cf. Melissus, Frag. 7), that concession appearing in the form of an agreement that the void is 'not-being' and that nothing of what 'is' is 'not-being'. From this Leucippus drew the following conclusions:

> τὸ γὰρ κυρίως ὂν παμπλῆρες ὄν. ἀλλ' εἶναι τὸ τοιοῦτον οὐχ ἕν, ἀλλ' ἄπειρα τὸ πλῆθος καὶ ἀόρατα διὰ σμικρότητα τῶν ὄγκων. ταῦτα δ' ἐν τῷ κενῷ φέρεσθαι (κενὸν γὰρ εἶναι), καὶ συνιστάμενα μὲν γένεσιν ποιεῖν, διαλυόμενα δὲ φθοράν. ποιεῖν δὲ καὶ πάσχειν ᾗ τυγχάνουσιν ἁπτόμενα· ταύτῃ γὰρ οὐχ ἓν εἶναι. καὶ συντιθέμενα δὲ καὶ περιπλεκόμενα γεννᾶν.

According to this theory, then, there is no generation of a Many from a true One or vice versa; but change, dissolution, perishing, and growth happen through the void, 'when solids slip in' (sc. into the void between other solids) - just as if into the pores of Empedocles. There follows a passage comparing Leucippus and Empedocles (part is quoted on p. 230 sup.), and then (325 b 24) Leucippus and Plato are compared. Both have indivisibles determined by their shapes, but Leucippus' are solids with an infinite number of shapes while Plato's are planes with a finite number. Leucippus makes becoming and dissolution occur through the void and through contact, for bodies are divisible at the point of contact, but Plato through contact only, for he admits no void. [x]

The chapter concludes with Aristotle's discussion of the atomists' notion that the atoms are each ἀπαθές and μηδενὸς ποιητικὸν πάθους, and with his criticism of the pores of Empedocles (cf. pp. 230-1).

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[x] Aristotle is concerned to show how action and passion come not from active or passive properties of the matter of the atoms but only from their contact. At 323 b 10 he has said that for Democritus action and passion are the same - if apparently different things are affected by each other, it is because they share some identical property.

Philoponus (D. 67 A 7) has a valuable comment concerning contact: it is not meant literally; it means that the atoms are close together and have not much interval between them - for they are completely separated by void. That is why this discretes in contact theory does not incur difficulties over the problem of the One and the Many: the contact does not involve fusion (v. inf.).

The passages that we have considered seem to show that Aristotle regarded the genesis of atomism as an attempt to answer the Eleatics' answer to the Pythagoreans. This is enough for Burnet, who also regards the cosmology as an attempt to fit old Ionian ideas to this new theory (E.G.P., p. 349). When, however, one considers that even Aristotle cannot avoid referring to Empedocles and Anaxagoras, while, as we shall see, the theory of sensation and the cosmology clearly contain ideas derived from the latter pair and others similar to items in contemporary Ionian thought (e.g. that of Diogenes), one is drawn more towards Bailey's view (Greek Atomists and Epicurus, p. 69) that Leucippus was in general theory and cosmology alike a mediator between the views of all his predecessors, and in particular between those of the Eleatics and the Pluralists.

Note: It is true that considerations of Eleatic logic would lead Leucippus to argue about atoms and void in terms of 'being' and 'not-being'; but the physical side of the theory needs no derivation from the aphysical Eleatics. On the one hand there is the Pythagorean replacement of a primitive plurality-and-void theory by a number-atomism so close to Leucippan views in some respects that we are at a loss to decide to which school Ecphantus belonged (pp. 337sq.). On the other hand there is the contrast between Empedocles, whose 'pores' theory, in the view of Aristotle, entails 'discretes in contact', and whose limited plurality did not go far enough, and Anaxagoras, whose infinite plurality went too far in that it admitted infinite divisibility. Take plurality from all three, void from the Pythagoreans, infinity from these and Anaxagoras, indivisibility from these and a conclusion drawn from, though not by, Empedocles, and contact from the latter, together with separation and mixing from both pluralists, and you have the physical basis of atomism without explicit reference to Elea.

In connexion with Leucippus' attitude to the Eleatics, it is worth noting that the Greeks were not the only thinkers who were led by the consideration of concepts such as divisibility to theories of the atomic type. This also occurred in Indian thought. At an early, but uncertain date, the Vaicesika Sutra and the Aphorisms of Kanada expound a system of elastic structured atoms of four elements (corresponding closely to the Empedoclean). (For details v. Bailey, Op. cit., p. 64.)

We have now seen the origin of atomism. The crucial point in the theory is the existence of void, of 'not-being'. This is asserted in Frag. 156 of Democritus, quoted by Plutarch:

μὴ μᾶλλον τὸ δὲν ἢ τὸ μηδὲν εἶναι.

Plutarch explains δέν as a name coined for σῶμα as an opposite to μηδέν, which represents τὸ κενόν, since this too has φύσιν τινὰ καὶ ὑπόστασιν ἰδίαν. This fragment is paraphrased in D. 67 A 6 by Aristotle and in D. 67 A 8 by Simplicius in terms of τὸ ὄν and τὸ μὴ ὄν. * The former attributes the idea to both Leucippus and Democritus, the latter specifically to Leucippus. Probably the form (no more X than Y) is Leucippan and the expression by means of the newly coined word is Democritean (cf. D. 68 A 37).

Leucippus' void has none of the attributes of the corporeal (cf. Timaeus 31b: visibility and tangibility), but, argued Leucippus, this does not mean that it has no existence at all. It exists as something non-corporeal. In asserting the existence of both Being and Not-being he did not incur a charge of dualism - there is only one fully real, physically perceptible, existent, and the basic unity of the Universe is preserved (cf. Bailey, p. 75).

In addition to this quasi-logical argument, physics provided Leucippus with what may appear stronger 'proofs' for the void. We saw on p. 186 that Parmenides' statement that motion is impossible was invalid even for his

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* Since there is such a profusion of source material I shall for brevity refer in this chapter normally to Diels-Kranz numbers, with the author's name where relevant, and where I give several references for a single point they are intended to be typical but not necessarily exhaustive.

own plenum since motion by mutual displacement is possible even without void. We also saw on p. 211 that Empedocles accepted Parmenides' denial of the void but not that of motion for this reason, as did Anaxagoras (and Plato and Aristotle). *

Melissus, in reply, strongly reaffirmed the denial of the void, and even more strongly claimed that motion entails void and that 'no void' entails no motion (Frag. 7). Leucippus, in conceding motion to the phenomena, conceded this very point to the Eleatics (p. 421 sup.), so that the common-sense acceptance of motion 'proved' the void. (Cf. Simpl., 67 A 8.)

Aristotle discusses this at length in Phys. IV, and especially at 213 a 27sq. (67 A 19). After drawing a distinction between διάστημα, ἐν ᾧ μηδέν ἐστι σῶμα αἰσθητόν and ἀήρ, which appears to be void, he comments that those who argued against the void (e.g. Anaxagoras with

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* Note that the word κίνησις often connotes ἀλλοίωσις as well as φορά, and when considering the arguments of the Eleatics or their opponents one must bear this in mind. To the pluralists as to the atomists 'alteration' was not qualitative change but 'separation and coming together' - a form of motion. (Cf. Arist., 67 A 46a: a criticism of this idea in the light of the bursting power of steam - interpreted as water changing into aer - and its apparent implication of expansion and the void.)

the clepsydra and wine-skins, v. pp. 248-9) did not go to the root of the problem. They should not have shown that aer is a thing, but that there is not any void internal to body so that it is not continuous, as Leucippus and Democritus and others (sc. Xuthus, Ecphantus, Metrodorus of Chios?) claimed, nor any void external to continuous body,as the Pythagoreans claimed. Those in favour of the void kept more to the point. They had four main 'proofs':

1. From motion (a plenum has no room to admit anything or one might get two or more bodies in one place. Frag. 7 of Melissus is referred to).
2. From compression (cf. the wine-cask problem, Arist., Probl. 938 b 14).
3. From growth (similar argument to that in No. 1).
4. From absorption (cf. the ashes problem, Arist., Probl. 938 b 24).

The first and third proofs were used by Leucippus (cf. p. 422), and the other two may well have been used by him or Democritus, though we have no direct evidence. *

Aristotle's definition of διάστημα, the fact that it makes bodies μὴ συνεχές (cf. 67 A 7 sup., Simpl., 67 A 14, Arist. de Cael., 67 A 19), and the description of void

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* They certainly were by Epicurus and Lucretius, who added a fifth: what happens when two surfaces in contact are swiftly separated - cf. Lucr. I 384sq..

as μανόν (67 A 6, attributed to Leucippus and Democritus), make it clear that the early atomists conceived of the void as 'interval', as 'space' in the sense of that which is by nature empty of and opposite to body, and not as 'place' or 'extension', as 'space' in the sense also given to it in ancient and modern times of that which may or may not be occupied by matter or of that which Pythagoreans and modern mathematicians deal with in their abstract theories.

Space, then, is not the whole universe as it is for some modern astronomers: it exists both within and without that which the atomists signified by the term 'the cosmos' (Simpl., 67 A 20), and it is infinite in extent (Aët., 67 A 15, cf. 67 A 16, 68 A 37 and A 43). Some ancient commentators confuse the senses of 'space' just discussed so that they speak of the void as a 'place' (68 A 37, A 43) _in_ which there may be atoms or cosmoi (67 A 21), using it as a synonym for the Ionian 'apeiron' (67 A 16); but though Epicurus may at times have thought of it in this way, it is clear that Leucippus did not. The void is that which is in between particles of the Real, it is Not-being.

Given that Not-being exists in this sense, two axioms of vital importance to atomism have to be stated.

They are the outcome of Parmenidean logic (cf. Par. Frag. 8, 62-69K, p. 184 sup.), and appear in D.L. ix 44 (68 A 1):

1. μηδέν τε ἐκ τοῦ μὴ ὄντος γίνεσθαι. (Cf. 68 A 57.)

2. μηδὲ εἰς τὸ μὴ ὂν φθείρεσθαι.

To these Epicurus added a third axiom, and 'proofs' for all three. The new axiom, reminiscent of Heracleitus as well as of Parmenides, is that the sum of all things is constant (cf. Lucr. II 303) - the Law of the Conservation of Matter. We find that there is in fact an infinite amount of matter (cf. D.L., 67 A 1, et al.); but it is a constant amount, for there is no way in which matter can be created or destroyed: in other words, the third axiom is not really an addition, but a deduction from the first two.

Note: This third axiom survived until very recently, when the astrophysicists, in order to explain the source of stellar energy, postulated the annihilation of matter with the production of an equivalent amount of energy. The law then became the Law of the Conservation of Energy, and matter and energy were considered to be equivalent, two aspects of one principle. (The latter law, at least as far as it applies to kinetic energy, was in a sense stated by the ancients also, v. Lucr. II 297sq.). The annihilation of matter conflicts with the second axiom. Very recently, again, the work of Cambridge mathematicians, especially Bondi, Gold, Lyttleton and Hoyle, has resulted in the postulate of the continual creation of matter (Hoyle, Nature of the Universe, p. 104). This conflicts with the first axiom, and the two innovations together destroy the third. It is ironic that refinements of the Atomic Age should destroy the declared foundations of the original theory.

derives matter from non-material non-extended principles). Leucippus, however, accepted it, and postulated indivisible magnitudes. Just as Anaxagoras himself admitted that in sensation there is a minimum sensible, so too in material existence there must be a minimum existent. * Matter is therefore ultimately indivisible, 'not one, but infinite in number and invisible owing to the smallness of the bodies' (v. p. 421). **

The consideration of plurality leads to the same conclusion. Melissus, in Frag. 7, had argued against the pluralists for an eternal, infinite, unique, homogeneous, and immutable Real, motionless because there is no void

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* Anaxagoras Frag. 21; cf. Frag. 1 and D. 59 A 43, 46, and 92. See Bailey, p. 73, and cf. Simplicius in 67 A 13.

** It was felt necessary to give physical as well as logical reasons for the indivisibility of the atoms.

The atoms are ἀπαθεῖς: 67 A 13, 68 A 1, 49, and 57. This is explained by Simpl. in 67 A 14 as being so διὰ τὸ ναστὰς (cf. 68 A 46) εἶναι καὶ ἀμοίρους τοῦ κενοῦ.

Other reasons were given also, but the atomists did not agree over them. L. gave τὸ σμικρὸν καὶ ἀμερές: 67 A 13, cf. 68 A 49 and 48 respectively. D. did not accept smallness (v. inf.); and E. objected, like Aristotle, to the latter idea, which might be taken to entail lack of magnitude (v. Bailey pp. 79 and 125-6), while retaining 'apathy'. D. concentrated on the atoms' indissoluble firmness and solidity, i.e. their στερρότης: 68 A 1, 43, 56, and 57, or their σκληρότης: 68 A 49 - Galen says here 'the Epicureans', but may mean to include D. who certainly thought thus.

into which it could move, and had concluded: "It is necessary, therefore, that it be full if void does not exist. If, therefore, it is full, it does not move".

In Frag. 8 he adduced further arguments for unity: if there were a plurality, each member would have to be just like he said the One to be (sc. immutable): the senses affirm a plurality - each perceptible must therefore be immutable; yet the senses also affirm change: this is a contradiction; therefore we must reject the senses.

That is Melissus' conclusion. He ends the fragment by saying that if there has been change, Being has perished and Not-being has come to be; but even in the event of this being so, his premise still stands:

εἰ πολλὰ εἴη, τοιαῦτα χρὴ εἶναι, οἷόν περ τὸ ἕν.

To those who disagreed with Melissus' conclusion, and 'conceded becoming, perishing, motion, and plurality to the senses' (p. 421 sup.), Melissus had himself given several hints about the result. The real must be 'full', motion entails void, and matter must consist of a plurality of indivisibles, each of which must have all the properties of the Eleatic One except uniqueness and Melissus' infinite extent. These indivisibles are called αἱ ἄτομοι or τὰ ἄτομα. Every perceptible body contains a number of them that is theoretically denumerable (cf. Eurytus' 'number of the thing') separated by διαστήματα of τὸ κενόν.

Let us now leave the origin and theoretical basis of atomism and consider the general theory itself. Simplicius in D. 67 A 8 (from Theophrastus' Phys. Op. Frag. 8), after referring to Eleatic views, gives the outline of the theory in a form specifically attributed to Leucippus, using words and turns of expression that appear to be quotations or paraphrases of those of Leucippus. Some of these we have already met (v. pp. 424-5 and 431) and others we shall discuss later. For this reason it is worth quoting in Greek:

> οὗτος ἄπειρα καὶ ἀεὶ κινούμενα ὑπέθετο στοιχεῖα τὰς ἀτόμους καὶ τῶν ἐν αὐτοῖς σχημάτων ἄπειρον τὸ πλῆθος διὰ τὸ μηδὲν μᾶλλον τοιοῦτον ἢ τοιοῦτον εἶναι καὶ γένεσιν καὶ μεταβολὴν ἀδιάλειπτον ἐν τοῖς οὖσι θεωρῶν. ἔτι δὲ οὐδὲν μᾶλλον τὸ ὂν ἢ τὸ μὴ ὂν ὑπάρχειν, καὶ αἴτια ὁμοίως εἶναι τοῖς γινομένοις ἄμφω. τὴν γὰρ τῶν ἀτόμων οὐσίαν ναστὴν καὶ πλήρη ὑποτιθέμενος ὂν ἔλεγεν εἶναι καὶ ἐν τῷ κενῷ φέρεσθαι, ὅπερ μὴ ὂν ἐκάλει καὶ οὐκ ἔλαττον τοῦ ὄντος εἶναί φησι.

Simplicius then introduces the theory of Democritus as similarly postulating as principles τὸ πλῆρες καὶ τὸ κενόν (68 A 38).

We can confirm and amplify this outline from other sources. The two principles represent τὸ ὄν and τὸ μὴ ὄν, for which Democritus used the names δέν and οὐδέν or μηδέν, * and their respective natures were to be πλῆρες and κενόν, terms actually used as names for them. ** It may be that Leucippus used these words with the πλέων and κενόν of Melissus (Frag. 7) in mind, as Burnet suggested (E.G.P. p. 337).

Atoms and void are the only true existents, and everything else in the phenomena is dependent upon them, cf. Democritus, Frag. 125:

> νόμῳ χροιή, νόμῳ γλυκύ, νόμῳ πικρόν, ἐτεῇ δ' ἄτομα καὶ κενόν.

Galen, Sextus, and Diogenes Laertius, quoting this, say that it was an attack on the senses' appreciation of qualities. *** In 68 A 49 Galen amplifies this: the qualities, apparently perceived by the senses are in fact subjective, νομιστὶ καὶ πρὸς ἡμᾶς, while objective reality

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* Cf. D. 67 A 6, 7; 68 A 37, 38, 40, 44, 45: and v. Frag. 156 and 68 A 37 and 49.

** Cf. 67 A 1, 6, 8 (Cicero), 10, 12; 68 A 38, 40, 44, 45, 60.

*** Galen 68 B 125: Sextus 68 B 9: D.L. 68 B 117.

is only possessed by δὲν καὶ μηδέν. * This notion, shared by Diogenes (cf. 67 A 32), expressed as it now is in the terminology of the Sophists, may derive from the attitude to the senses of Anaxagoras (cf. 59 A 95-7).

The two principles, therefore, serve as the only really existing material causes (to use Aristotelian terminology) for the phenomena; they are consequently called φύσις and are treated ὡς ὕλην. **

The atoms are eternal, ungenerated and indestructible, immutable, and eternally moving in the void. As a result change and becoming are also eternal, as is time itself. *** The atoms are also homogeneous, not only individually, but also as a whole. They have μίαν φύσιν (67 A 19), τὸ γένος ἕν (Arist. Phys. 184 b 21), and a κοινὸν σῶμα (68 A 41, cf. Arist. Met. 1042 b 12), and are ὁμοφυεῖς (68 A 61) and ἀδιάφοροι (68 A 57). There is

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* Cf. 67 A 32, 33; 68 A 1, 64, 112, 123-5, 130, 134-5.

** αἴτια ὡς ὕλην: 67 A 6. στοιχεῖα: 67 A 1, 14; 68 A 37. ἀρχαί: 67 A 1, 68 A 1, et passim. φύσις: 68 A 37, 58. ὡς ὕλην: 68 A 38.

*** Eternal: 68 A 37, 39, 49. Indestructible: 68 A 43. Immutable: 68 A 1, 39, 49, 57. Eternal motion: 67 A 1, 10, 14, 16-8, 24; 68 A 1, 37, 40, 49, 57-8. Eternal change: 67 A 10. Time: 68 A 71.

therefore no problem of the One and the Many (cf. pp. 422, 423 and 425) because the atoms, though one in nature, are many in number, and in perceptible bodies are not fused into a single mass, but remain in close juxtaposition, retaining their individuality. *

The atoms are not merely 'many in number', but in fact infinite. ** Aristotle in 67 A 15, after the passage referred to in the first footnote and after a comparison of the atoms to the Pythagorean numbers, *** goes on:

> ἐπεὶ διαφέρει τὰ σώματα σχήμασιν, ἄπειρα δὲ τὰ σχήματα, ἄπειρα καὶ τὰ ἁπλᾶ σώματά φασιν εἶναι.

The reason for asserting that the shapes (v. inf.) are infinite is given by him in 67 A 9:

> ἐπεὶ δ' ᾤοντο τἀληθὲς ἐν τῷ φαίνεσθαι, ἐναντία δὲ καὶ ἄπειρα τὰ φαινόμενα, τὰ σχήματα ἄπειρα ἐποίησαν.

It follows, incidentally, that an infinity of atoms needs

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* Cf. 67 A 7, 15; 68 A 37, 42.

** Cf. 67 A 7-10, 14, 15, 17, 21, 28; 68 A 1, 37, 38, 43, 57.

*** This comparison (cf. Met. 1039 a 3) is particularly apt if we accept number-atomism. The only basic difference would then be that the Pythagorean indivisible magnitudes were pure magnitude while the Leucippan atoms possessed material solidity as well.

an infinite extent of space to contain it since the atoms have magnitude. This argument is characteristic of Leucippus (cf. Bailey, p. 76-77), resembling the argument from minimum sensible to minimum existent (p. 431 sup.), and appears in place of the more obvious argument - not specifically attributed to him - that since 'the All is infinite' (67 A 1), therefore 'the atoms are infinite in number, and the void infinite in magnitude' (67 A 15).

What can be predicated of these atoms besides eternal immutable existence and plurality? They are, of course, (a) ἀδιαίρετα, (b) στερεά, i.e. full of real matter, also termed (c) πυκνά and (d) ναστά. * They have, however, apart from solidity (and shape and size, v. inf., which are obvious properties of the solid) no other perceptible qualities, for, as we have seen, qualities are subjective and, as we shall see, they depend on four non-qualitative differentiae of the atoms. **

Since the material of the atoms is one in nature

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* Refs.: (a) 67 A 7, 9, 13-15; 68 A 48b, 49, 60, 101, 104: (b) 67 A 6, 7; 68 A 45, 60, cf. 68 A 1, 43, 56, 57: (c) 68 A 135: (d) 67 A 8, 14; 68 A 37, 46, 47, 125.

** Cf. the refs. given on p. 434, and also 68 A 49, 57, 59, 124, 125, 135.

and they have no perceptible qualities, the only way in which they can themselves be differentiated so as to be able to be called the atoms of such and such a phenomenal substance is by difference of shape or size (though we shall see that in compound bodies, molecules in modern terminology, their dispositions relative to each other can also serve to differentiate). In 68 A 120 Simplicius compares Democritus' use of these two differentiae with the Pythagorean (he means their figures built from planes as in the Timaeus - cf. de GC 325 b 24, p. 422 sup.).

Atoms of different shapes form themselves into phenomenal bodies with different apparent qualities. * We saw on p. 436 the argument for an infinite number of shapes from the infinite number of phenomena (67 A 9). Infinity of shapes is asserted for Leucippus in 67 A 7 and 8, for Democritus in 68 A 38, and for both in 67 A 9, 15, and 28. Simplicius in both 67 A 8 (quoted on p. 433) and 68 A 38, which are from Theophrastus, paraphrases or perhaps quotes a further argument for an infinity of

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* Cf. 67 A 6, 14, 15, 19, 24, 32; 68 A 37, 38, 41, 45, 47, 125, 135.

shapes: διὰ τὸ μηδὲν μᾶλλον τοιοῦτον ἢ τοιοῦτον εἶναι. It is formally the same as the argument of Frag. 156 of Democritus (v. p. 425), and Diels and Bailey consider it to be Democritean, presumably for this reason; but in discussing that fragment I concluded that it was the newly coined word in that fragment that was typically Democritean, and that the form was probably Leucippan: I am similarly prepared to accept Simplicius' word for it that our present argument is Leucippan.

Bailey contradicts himself over this. On pp. 81-82 he states correctly (in view of Aristotle's statement in 67 A 7) that Leucippus asserted that the number of different shapes was infinite (saying that having established the fundamental unity of substance against Empedocles and Anaxagoras he took the opportunity of securing variety in other ways). On p. 127, however, he says: "Leucippus ... observing the great variety in things, had been led to assume many different shapes .... Democritus ... seems to have followed out the idea to its conclusion and asserted that the number ... was 'infinite'". The only reason he can give for the latter statement is that 'it sounds more like' Democritus!

Note: several passages name some of the shapes. 67 A 11: levia aspera rutunda angulata hamata curvata adunca. 68 A 80: aspera levia hamata uncinata. 67 A 24: περιφερῆ λεῖα εὐόλισθα. 68 A 37: σκαληνά ἀγκιστρωδῆ κοῖλα κυρτά. 68 A 45: γωνία εὐθύ περιφερές. 68 A 129: στρογγύλον τραχύν πολυγώνιον ἀμφιφερῆ ὀξύν γωνοειδῆ καμπύλον σκολιόν ἰσοσκελῆ λεῖον λεπτόν. 68 A 132 adds ὀξυγώνια. 68 A 135 adds σφαιροειδές πολυκαμπῆ πλατεά and defines σκαληνά as ἅπερ περίπαλαξιν ἔχει πρὸς ἄλληλα καὶ συμπλοκήν.

We gather from 68 A 129-135 that shape is involved to a greater or lesser extent in most perceptible qualities, and particularly in taste and colour.

So much for the shapes of the atoms. An infinite number of shapes implies that some of them would be large enough to be visible (cf. Bailey, p. 81-2), but this was not realised by Leucippus, all of whose atoms were invisibly small (cf. 67 A 7, 29 and, for Epicurus, 68 A 43). Epicurus realised it and consequently made the number inconceivably great but not infinite (Ep. i 42, cf. Lucr. II 480-2).

Democritus on the other hand appears to have realised it and to have accepted the implication. Although invisibility is asserted for him in 68 A 37 and A 64 by Simplicius and Alexander, Diogenes Laertius in 68 A 1 says that the atoms 'are infinite with respect to size and number', which is the result of following the infinity of shapes to its logical conclusion, but is an over-statement.

According to Aëtius (Doxog. Graeci, p. 311, 21-22) Democritus said that it was possible for an atom to be the size of a whole world. In 68 A 43 we have the more cautious statement of Dionysius that he said that some atoms were 'very large', with which Epicurus disagreed. This is probably the true account.

Although, then, all of Leucippus' and most of Democritus' atoms were very small, * there were differences in size between them, and these acted as a second, though less important, differentia alongside shape. ** Aristotle criticized this differentia in de Cael. 303 a 25 (68 A 60a) - unfairly, see Cherniss, Op. cit.,p. 119 - and it does not appear to have been employed to the same extent as was size or the other differentiae that we are about to consider. Many of the passages purporting to give a list of the differentiae omit it. In fact there are only two passages that contain the complete list that includes it: that of Simplicius in 67 A 14 and that of Theophrastus in 68 A 135.

We may now turn to the other members of the list, which are not differentiae of the atoms themselves as individuals but of their dispositions in molecules, and serve alongside shape and size to explain sense qualities.

For these the locus classicus is Arist., Met. 985 b 4sq., 67 A 6. After stating that the full and the empty are the elements, quoting the argument that Not-being exists no less than Being, and comparing atomism to Milesian monism, Aristotle proceeds:

> τὸν αὐτὸν τρόπον καὶ οὗτοι τὰς διαφορὰς αἰτίας τῶν ἄλλων εἶναί φασιν. ταύτας μέντοι τρεῖς εἶναι λέγουσι, σχῆμά τε καὶ τάξιν καὶ θέσιν· διαφέρειν γὰρ φασὶ τὸ ὂν ῥυσμῷ καὶ διαθιγῇ καὶ τροπῇ μονον. τούτων δὲ ὁ μὲν ῥυσμὸς σχῆμά ἐστιν, ἡ δὲ διαθιγὴ τάξις, ἡ δὲ τροπὴ θέσις· διαφέρει γὰρ τὸ μὲν Α τοῦ Ν σχήματι, τὸ δὲ ΑΝ τοῦ ΝΑ τάξει, τὸ δὲ Ι τοῦ Η θέσει.

Aëtius (67 A 32) points out that only atoms and void exist φύσει, and these differentiae explain the apparent properties of things as our senses perceive them.

Aristotle says in de GC 315 b 33 that the three major differentiae, shape (σχῆμα), position (or orientation - θέσις), and arrangement (or order - τάξις), account for becoming and alteration; and Simplicius says in 67 A 14 that the complete list accounts for becoming, explaining the mechanism and giving examples (v. inf.). The same author in 68 A 38, while making a similar statement, shows how they can explain the infinity of phenomena. Hermias in 68 A 44 likewise accounts for becoming by shape and position.

Aristotle emphasizes in Met. 1042 b 12 that these are differentiae of a matter that always retains its own single nature, and Alexander makes the same point in 68 A 64 in connexion with mixtures.

There is, however, as we have seen, a fundamental difference between shape and size on the one hand and position and arrangement on the other. For example in 68 A 45 Aristotle explains that position refers to e.g. upwards, downwards, forwards, and backwards, viz. to position (orientation) relative to other atoms, and shape refers to e.g. straight, bent, and rounded, viz. to the shape of an individual atom. This distinction appears in the phenomena: shape and size tend to account for becoming and position and arrangement for alteration, cf. Aristotle in 67 A 9 and 68 A 38. This distinction was ignored in the passages referred to on p. 442.

As far as sensible qualities are concerned, shape naturally tends to affect them all, but is particularly relevant to taste, and to a less extent to colour and to temperature: size is particularly relevant to phenomenal weight (v. inf.): position and, to a less extent, arrangement are of primary importance in colour (cf. 68 A 120-135). So much for the moment for the differentiae, but v. inf..

We have referred on pp. 438 and 441 to compound bodies, to which I have applied the modern term 'molecules'. Perceptible bodies are in fact congeries of atoms, interconnected as in our molecules, but larger than these. A body to which we give a name, e.g. air or water, since we recognise some specific nexus of qualities in it, may actually contain atoms of all sorts and sizes - it is, as it were, a πανσπερμία (cf. 67 A 15 and 28). That word recalls Anaxagoras to mind; and there is similarity between the theories on this point. The body's perceptible qualities depend upon the differentiae of the majority of the component atoms: they are an epiphenomenon of the statistical distribution of differentiae, just as an Anaxagorean body most manifestly is that of which it has most in it.

How do these congeries of atoms in contact form? For the answer we must look to the cosmogony. The process of formation of a universe and a molecule is one and the same: συμπλοκή and περιπάλαξις (Arist. in 67 A 15).

We have a number of accounts of the details of the process, some written from the macroscopic point of view and some from the microscopic; and they are unusually consistent. Moreover they almost all employ identical terminology, so that it is obvious that atomism established for itself a technical vocabulary that found general acceptance. Therefore it will not be necessary to quote, examine, and interpret in detail each source. I shall give one connected account that is in the main a synthesis of the following: 67 A 1, 6, 7, 9, 10, 14, 15, 23, 24, and 68 A 1, 37, 38, 43, 47, 49, 56-8, 61; B 167, 168. Of these the most important are Aristotle in 67 A 7, 15; 68 A 37: Simplicius in 67 A 14; 68 A 37, 58: Diogenes Laertius in 67 A 1: Hippolytus in 67 A 10: Aëtius and Epicurus in 67 A 24.

In the beginning there is an apeiron surrounding the place where a universe or a molecule is about to be generated. This consists of a boundless extent of space containing atoms in random distribution and with random motions. Some parts of this void are more full or empty of atoms than others.

By ἀποτομὴ ἐκ τῆς ἀπείρου many atoms of all sorts of shapes and sizes move εἰς μέγα κενόν. They can move freely in this since the void yields and does not resist. Their random motions are referred to as περιπάλαξις, from περιπαλάσσεσθαι. For the cause of motion v. p. 449.

Many of these varied atoms collect together (ἀθροίζεσθαι) and form a vortex (δίνη) as they flow along together (συρρεῖν). The cause of the vortex is Necessity (v. p. 449). Owing to their disordered rush (ῥύμη ἄτακτος) they catch each other up (ἐπικαταλαμβάνειν) and collide with each other (προσκρούειν, συμπίπτειν, ἀλληλοτυπεῖν), as they circle round in all sorts of ways. Some rebound (ἀποπάλλεσθαι) and separate (διακρίνεσθαι), others combine (συμπλέκεσθαι), the process being one of like to like (in shape or size), somewhat as in the processes described by Anaxagoras and Plato. *

When the atoms can no longer whirl in equilibrium because of the congestion, the finer bodies are sifted out (διαττᾶσθαι) or squeezed out (ἐκθλίβεσθαι) into the outer void. This squeezing of the smaller, rounder, smoother atoms out from between the larger has, as it were, a πληκτικὴ δύναμις, which lasts for some time. Meanwhile the remainder of the atoms become entangled (περιπλέκεσθαι), for they catch on to each other (ἐπιλαμβάνεσθαι) and cohere (συμμένειν) and unite their motions (συγκατατρέχειν) because they are, so to speak, hooked (ἀγκιστρώδη), and

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* For Anaxagoras cf. pp. 264 sq.. For Plato cf. Timaeus 52D sq., p. 380 sup.. Plato's account has both similarities and significant differences. Cf. with the congestion and sifting of the next paragraph Timaeus 58A (σφίγγειν) and 52E and see my p. 396 and the words of Cornford ad locc..

when they come into contact (συμψαύειν) they hold on to each other (ἀντέχεσθαι) by fitting into each other and clinging together (ἐπαλλαγαὶ καὶ ἀντιλήψεις) because of their symmetry (συμμετρία) - cf. Empedocles' symmetrical pores p. 229 sup..

The outward thrust temporarily ceases, and the cohering bodies merge together into a first spherical system like a membrane or cloak (ὑμήν, χιτών) enclosing (περιέχειν) all sorts of atoms. This membrane becomes thinned out because the atoms within it are in continuous contact (ἐπίψαυσις) in the whirl, and so, because of the resistance of the middle (ἡ τοῦ μέσου ἀντέρεισις) characteristic of the eddy type of vortex, the larger tend to be carried towards the centre, where they cohere to form the earth.

The membrane, however, is now increased (αὔξεσθαι) as additional atoms separate out from outside (ἐπέκκρισις), for it adds these on to itself (ἐπικτᾶσθαι) as it comes into contact with them through its whirling motion. It also catches the lighter of the bodies that have been squeezed outwards, and prevents them from moving inwards again. Cohesion occurs among these additional bodies so that lumps, which will be the stars, form on the membrane, which will be the heaven. These secondary 'systems' are at first moist and muddy, but as they whirl round they dry out and are inflamed. Meanwhile other atoms are continuing to move outwards from the middle by the process of ἔκθλιψις.

These, after the heaven has been formed, make up air and fire. The process makes the air windy (πνευματούμενος), and it carries the stars along with it in its motion in the vortex, and maintains them in their orbits aloft. Other matter left on the earth is condensed by the wind and the stars' rays and is compressed (προσθλίβεσθαι); the smaller-shaped parts of this form moisture, and this, being fluid, finds its own level in the hollows of the earth. Thus are the infinite universes formed. They grow and decay and pass away of Necessity, their passing away being by dispersion (διασείειν, διασπείρειν).

On the microscopic scale individual molecules are compounded by the same process as that described on p. 446-7: collection, collision, entanglement, cohesion, and unison of motion through contact by fitting into and clinging to each other. Thus these ἀθροίσματα, or συγκρίματα, (molecules) are formed by σύγκρισις (συνίστασθαι, συντίθεσθαι), which is the process of γένεσις. The result is a σύνθετον (compound). Conversely, if Necessity scatters the compound, the process of διάκρισις, or διάλυσις, leads to φθορά.

Meanwhile the slipping in or mixing in (ὑπεισδύεσθαι, ἐμμείγνυσθαι) of extra atoms into the διαστήματα of void within a compound may cause αὔξησις if they fit well, ἀλλοίωσις if they cause a redistribution (affecting the θέσις and τάξις of the atoms), and φθίσις, or even διάλυσις if they fit badly and split the compound.

Within a compound molecule there is still atomic motion (παλμός, περιπάλαξις). Thus motion of the atoms is indeed 'eternal'. As to its cause, I refer the reader to Burnet and Bailey, with whom I entirely agree. Weight may have been the cause for Epicurus, but for the early atomists weight is a subjective epiphenomenon of size and of amount of contained void; and as such it only manifests itself within a vortex. The original motions before a vortex forms are quite random, and if a cause must be given it is Necessity - the law of the atoms' own nature, cf. p. 376.

But for Leucippus at least no cause need be sought, for those who seek a cause (e.g. Empedocles and Anaxagoras) start from a homogeneous mass of some sort and have to explain separation by a cause, but Leucippus' atoms are already separate and already in motion throughout time, which is eternal and uncreated, so that no 'moving cause' is required, while their directions of motion are random and disordered, and so need no cause. Cherniss (Op. cit. p. 403) suggests also that Melissus' claim (Frag. 7) that a commencement of motion contradicts the law of identity causes Leucippus to revert to the old idea of a causeless eternal motion held by the Milesians.

Although these original motions are either causeless or (for Democritus) caused by Necessity, the falling into a vortex motion appears to be due to chance, at least for Democritus; but he conceived of chance as an operation of Necessity, but an operation that is ἄδηλον αἰτίαν ἀνθρωπίνῳ λογισμῷ (v. 68 A 70, and 59 A 66, where the same idea is attributed to Anaxagoras).

Note: Epicurus gave weight as the cause of the original motion, no longer conceived of as random, but as 'downwards' (better: towards the centre - but of what? There is no vortex yet, and infinity has no centre or bottom, cf. 68 A 56, Cicero). He used language remarkably similar to that of the modern theory of infinitesimals to show that the velocity of this fall must be inconceivably great, since it is unimpeded by the void. Moreover he realised that in a void all bodies will fall with equal velocities whatever their weight. See 68 A 61, where his own words are given, and cf. Lucr. II 215sq.

In order to account for free will in a system in which even the human soul is made of material atoms (v.

inf.), and possibly also in order to account for contingency in inanimate nature, he introduced the 'exiguum clinamen' that causes the freely falling atoms to collide with each other. Then, because of their variations in shape, they can become entangled and form compound bodies as for Leucippus.

The blows that they deal each other as they swerve and collide cause changes of direction. Thus after a number of them has collided they will have motions in all possible directions. In other words Epicurus gives a cause for the original causeless random state postulated by Leucippus. The collisions do not cause any change in velocity. Where modern kinematics have the law of conservation of momentum, Epicurus has conservation of velocity. The Greeks never reached that conception of mass as opposed to gravitational weight that is essential to any true theory of momentum and inertia.

Since the velocity of the freely moving atoms is regarded as constant and of the highest possible magnitude, and since it is the same in no matter which direction the atom may be moving, it is to Epicurus in very much the same position as the velocity of light is to modern relativity theory.

About the παλμός (p. 449) there is yet more to be said. Within a molecule the atoms are more or less entangled. But there is always a certain amount of void between them (Philoponus in 67 A 6): there is no idea of coalescence. Thus far the theory is parallel to our own. But the Greek atoms, unlike ours, have no separable parts, and are unacting and unacted upon. Our atoms cohere because some of the outer orbital electrons rotate round the entire molecule and not merely round their own individual atoms. The Greek atoms can form into molecules only when their shapes are such that they become entangled. Even when they are actually hooked together, the diameter of the 'eye' into which the 'hook' of the hooked atom fits will be greater than the cross-section of the material of that hook itself, so that the interlocked atoms can rattle! Therefore, as in modern science but for a different reason, sub-molecular atomic motion is still possible owing to the interstitial void that is contained even by apparently static and solid bodies. This 'vibration' represents that degree of the original random motions that the constituent atoms of a compound may still retain in spite of the entanglement that compels them to share in the joint motion of the whole compound. The standard analogy for this vibratory motion is the motion of motes in a sunbeam (cf. Anaxagoras' use of this analogy p. 291 sup., and Arist. de Anima 404 a 1-25, where it is attributed to Democritus and to the Pythagoreans in connexion with the soul).

Since we lack detailed discussions of this vibration in our source material for the early atomists, we must turn to Epicurus and Lucretius (remembering that they will presumably have amplified and refined the original account). Only by doing so can we fully appreciate the atomists' conception of the gaseous state of matter. I shall quote in translation first Epicurus, Ep. i 43 (Bailey p. 331), and then Lucretius, ii 95sq.:

> The atoms move continuously for all time. ... Some are borne on, separating to a long distance from each other, while others again have the 'vibration', whenever they happen to be checked by the 'entanglement' or to be covered over by atoms interlaced round them.
>
> Since this is agreed, surely no rest is granted to the atoms throughout the profound void, but rather, driven by incessant and varied motions, some leap back with great intervals after being pressed together, and others after the blow are tossed about within a narrow space. Those which, being in a more condensed combination, collide and rebound over tiny intervals, checked by the complexity of their own shapes, form the strong roots of stone and the fierce bodies of iron and other things of their kind. There are few that travel freely through the great void. The rest leap and rebound a long distance over long intervals: these supply the rare air for us and the bright light of the sun. ...
> (Lucretius continues with the motes in the sunbeam.)

Here with wonderful clarity we are given a full exposition of the 'kinetic theory of matter' described in modern terms in Chap. 1 sup.. The gaseous state with its long mean free paths, and the solid state with its small vibrations, are accurately described, while the verb 'to be covered over' may possibly represent Epicurus' notion of the surface tension of a liquid. Even if this is not so, even if neither passage in fact describes the liquid state, it is there by interpolation from those actually given. This is a startling achievement, perhaps indeed arrived at through the contemplation of the motes, or perhaps by pure thought. For all that modern science coined the actual word 'gas', there is no doubt that the atomists fully understood the physical reality that the word denotes.

In addition to the 'vibration' in short, intermediate, or long mean free paths in random directions, of course, all the atoms in a molecule share in the joint motion of the whole. Vortical horizontal movements, downward movements due to 'resistance of the middle', and upward movements due to 'squeezing out' and others due simply to rebounds after a collision are all occurring. The direction and velocity of the compound's motion is the statistical resultant of the individual motions. Velocity and direction are a function of the number of collisions, so that: "Anticope is the inverse determinant of speed" (Bailey, p. 335).

We have now had one half of the answer to the question 'how did the atomists explain air?': it is a σύγκριμα that is, as it were, a πανσπερμία of various types of atoms (infinitesimal portions of 'the full') and that contains interstitial void as a result of which the atoms can be oscillated with a considerable mean free path. Although a πανσπερμία, it is characterized by containing a majority of a certain type of atom. The other half of our answer to the question consists of a description of this majority type. Lack of detailed source material will make it seem vaguer, and again it will be necessary to have recourse to the opinions of the later atomists, with the same mental reservations.

Our first clue is that air is something like fire and something like the soul; so let us first examine these. Aristotle's account (de Anima, 404 a 1 - 405 a 13) is too long to quote: I give W.S.Hett's rendering of the relevant parts from the Loeb edition:

> Democritus argues that the soul is fire in some sense and heat. For forms and atoms being countless, he calls the spherical ones fire and soul, like what are called 'motes' in the air, which can be seen when the sunbeams pass through our windows; the whole πανσπερμία of which he calls the elements of which all nature is composed. And Leucippus adopts a similar position. It is the spherical atoms which they call the soul, because such shapes can most readily pass through anything, and can move other things by virtue of their own motion, supposing, as they do, that the soul is that which imparts motion to living things. They consider that this is why respiration is the essential condition of life; for the surrounding atmosphere exerts pressure upon bodies and thus forces out the atoms which produce movement in living things, because they themselves are never at rest. The resulting shortage is reinforced from outside, when other similar atoms enter in the act of breathing; for they prevent the atoms which are in the bodies at the time from escaping by checking the compression and the hardening; and animals can live just so long as they are competent to do this. ...

Aristotle now compares this theory with the early theory of the Pythagoreans, some of whom identified the soul with the motes. We can recognise the attitude to respiration as being essential to life and the idea that soul can be breathed in. The Milesians, the Pythagoreans, and Heracleitus thought along these lines. Aristotle next considers the pluralists and the Timaeus, and returns to Democritus at 405 a 5:

> Democritus has explained with greater precision why each of these things is so; for he identifies the soul and the mind. This, he says, consists of primary and indivisible bodies, and its power of producing movement is due to the smallness of its parts and its shape; for he calls the spherical the most easily moved of all shapes; and this characteristic is shared by mind and fire.

We appear to have here a perfectly clear picture. The soul is fire (cf. Aët. IV 3, 7, D. 67 A 28). Fire atoms are spherical, and that is why the soul can initiate movement. These spherical atoms are found in the free state in atmospheric air, and can be breathed in.

The spherical shape of fire atoms is confirmed by Aristotle in de Cael. 303 a 13, 67 A 15, where he unfairly accuses the atomists of having made no use of shape except for fire:

> ποῖον δὲ καὶ τί ἑκάστου τὸ σχῆμα τῶν στοιχείων, οὐθὲν ἐπιδιώρισαν, ἀλλὰ μόνον τῷ πυρὶ τὴν σφαῖραν ἀπέδωκαν· ἀέρα δὲ καὶ ὕδωρ καὶ τἆλλα μεγέθει καὶ μικρό-

τητι διεῖλον, ὡς οὖσαν αὐτῶν τὴν φύσιν οἷον πανσπερμίαν πάντων τῶν στοιχείων.

The spherical shape of soul atoms is assured by the argument from mobility. Aristotle and the tradition that followed him are not correct, however, in identifying the soul with fire. The individual atoms of both were spherical, but bodies get their characteristics from the position and arrangement of compounded atoms, not just from the shape. Fire and the soul have similarly shaped atoms, and consequently share mobility; but they do not share any other differentiae, so that they are not identical.

The above passage purports to say that the distinguishing mark of air is its size rather than its shape. Yet from the cosmogony one could infer that since air and fire behave similarly (p. 448) in undergoing 'squeezing out' the atoms of air as well as of fire are 'smaller, rounder, smoother' (p. 446). That they have 'finer parts' is confirmed by Hermias in Irris. 12, D. 67 A 17:

καὶ τὰ μὲν λεπτομερῆ ἄνω χωρήσαντα πῦρ καὶ ἀέρα γενέσθαι, τὰ δὲ παχυμερῆ κάτω ὑποστάντα ὕδωρ καὶ γῆν.

Simplicius, however, says in Phys. 36, 1, 67 A 14:

κατὰ τὴν τῶν σχημάτων αὐτῶν καὶ τῆς θέσεως καὶ τῆς τάξεως διαφορὰν τὰ μὲν θερμὰ γίνεσθαι καὶ πύρια τῶν σωμάτων, ὅσα ἐξ ὀξυτέρων καὶ λεπτομερεστέρων καὶ κατὰ ὁμοίαν θέσιν κειμένων σύγκειται τῶν πρώτων σωμάτων, τὰ δὲ ψυχρὰ καὶ ὑδατώδη, ὅσα ἐκ τῶν ἐναντίων...

The expression 'sharper' must surely be wrong. It fits the Pythagorean-Platonic fire pyramids, not the sphere. The sphericity of fire is certain: it is mentioned again and again, e.g. in 68 A 74 (Aëtius), A 102 (id.), A 106 (Aristotle - a passage that amplifies the theory of respiration given in the de Anima passage on p. 455 sup., and that states definitely that atmospheric air contains a great quantity of 'mind' and 'soul' atoms).

In spite of the denial of characteristic shapes to any other so-called element but fire in de Cael. 303 a 13 (p. 456 - a denial repeated at 303 a 25, 68 A 60a where again size is made the differentia) Aristotle admits elsewhere that other shapes were specified, even naming some in Frag. 208, which is quoted by Simplicius in 68 A 37. But in default of any explicit statement of the shape of air atoms, we shall have to infer what that shape must have been.

We have already seen that air is a mixture of all sorts of atoms (p. 444) and we now learn from the passages about respiration that the mixture contained free fire and soul atoms, i.e. free spherical atoms that could link together in different positions and arrangements so as to form molecules of either soul or fire. Could they also link up in yet a third way so as to form molecules of pure air? That is a possibility, for as we have seen the cosmogony derives fire and air (and also the heaven) from the same type of atom: Aëtius' description of this type in his long account (67 A 24) is: "Small and round and smooth and slippery".

Another possibility is that the atoms of air are similar to those of fire, but larger (cf. Aristotle's comment) and perhaps a little coarser - less 'fine-parted', smooth, and slippery - and with not so perfectly spherical a shape. Perhaps too, since Greek science regards the fiery state as ultra-gaseous and the soul, when considered as corporeal, as the least bodily body (Arist. de An. 405 a 5, 68 A 101), the molecular arrangements may have given these an even greater mean free path than had the air atoms. In other words, fire and soul molecules may have had more void per unit volume.

The smoothness of air atoms and the comparatively large amount of interstitial void explains its relative lack of resistance to moving objects, as is stated in Plut., Quaest. 734F, 68 A 77:

> ... δι' ἀέρος λείου τῆς φορᾶς αὐτοῖς γιγνομένης ἀκωλύτου καὶ ταχείας.

The point here is that air permits the passage of 'idols', sc. the effluences from objects that are emitted as in the theory of Empedocles and pass through the air as the vehicle of sight. They are open-structured atomic films, so to speak; and we now realise that atmospheric air contains these too as part of the mixture. It also contains the 'idols' of sound. (This simple statement about 'idols' probably adequately represents Leucippus' theory - Democritus made the matter more complicated by having his idols 'stamped' on the air.)

It is a fair inference from the description of the mechanics of sensation and of the differentiae as regards their contribution towards the perception of sense-qualities in Theophrastus, de Sens. 49sq., 68 A 135, that it is the diffuse arrangement of air that makes it colourless, for the atoms are not close enough for colour to be manifested; for this is a function of position (especially) and arrangement as well as of shape. Moreover the transparency of air is obviously due to the very fact mentioned above, that the idols can pass through because of the diffuse arrangement. The atoms are also presumably too smooth and too distant from each other for taste or odour to be appreciated. But this is all guesswork.

Let us turn to the later atomists in order to try to gain a little more certain information. We have been speaking of air as a mixture containing soul atoms. Epicurus in Ep. i 63 puts it the other way round making soul a mixture. He says:

> The soul is a body with fine parts, dispersed all over the body, and most closely resembling pneuma that has a certain admixture of heat, in some parts like to one of these and in others to the other. ... All this is made clear ... by what we lose as we die.

It is, of course, heat and breath that we lose at the moment of death. To these Stob. Ecl. p. 798 adds a further pair, aer and the nameless element:

> Epicurus (sc. said that the soul is) a mixture of four things: it consists of the fiery, the airy, the breathy, and a fourth nameless thing; the latter was its perceptive part. Of these, the breath effects motion, the aer rest, the heat the warmth that appears in our bodies, and the fourth our sensation. For sensation is in none of the three that have names.
>
> (Cf. Lucr. iii 231-245.)

This last pair must have been Epicurean additions to the original theory; but it is interesting to note the same distinction between pneuma as air in motion and aer as air at rest that we have noticed in the pre-Socratics.

It is not surprising to find that the soul is here treated as a mixture containing heat (not, therefore, pace Aristotle, identical with soul) and air. For not only

Epicurus' soul and Democritus' air, but all phenomenal things alike are mixtures, being molecules compounded of all sorts of atoms. Heat, too, is a mixture. In discussing 'fumum nebulas flammasque' in ii 457sq. Lucretius says that such hot things are not necessarily completely composed of spherical fire atoms. They are dispersible, and so do not contain complicated shapes that could lead to great entanglement; but they burn or scald and penetrate stones, so that they must contain an admixture of sharp-pointed atoms. This recalls Simplicius' error (p. 458 sup.) and may explain both it and another passage, Theophrastus, de Ign. 52, D. 68 A 73, which links sharpness and the pyramidal shape with fire.

In general one may say that the atmospheric air is a mixture: a mechanical mixture containing above all atoms that are smooth and round and small and far apart, some of which are so smooth and round that they could combine into fire or soul molecules, and others less so. There are also, however, atoms of other shapes; but these tend to be of a small and pointed character rather than large and complicated and in danger of entanglement.

This mixture is extremely inconstant. Atoms escape into it from other bodies by squeezing out, evaporation, or plain kinematic escape, and the converse process continually occurs also (cf. Lucr. v 273sq.). The characteristics of what we call 'air', then, will be the statistical resultant of the various tendencies of the contents of the mixture. For example the normal atmosphere will have a temperature lower than that of fire but higher than that of the 'vis frigida venti'. The average air atom will be coarser and less smooth and well-rounded than those of fire, but finer and smoother and better rounded than those of other things.

The idea of atmospheric air as a mixture is already familiar. We have seen it in Heracleitus, Empedocles, Anaxagoras and others. Even Diogenes of Apollonia saw that air must exist in different degrees of purity.

The properties of air are explained by the various differentiae. The size and shape correspond to our differentia of 'atomic number', which subsumes both the size of an atom (depending on the number of sub-atomic particles) and its layout (depending on the various orbits in which the outer electrons can revolve). The position and arrangement correspond to our chemical formulae for molecules. To position (orientation) corresponds our isomeric differences (laevo- and dextro-compounds etc.)

and to arrangement our molecular diagrams. These differentiae explain the properties, then; and the list of the properties of air known to the Greeks in the times of Democritus and Plato differs, apart from what can be discovered only in the modern laboratory with its advanced equipment, but little from the list of those known now.

Between the atomic school and the Academy there is the greatest possible contrast. Democritus was, like Plato, a moral philosopher who decided to give his ethics as scientific a basis as possible. Plato decided from his ethics what he wanted his science to be like, and made it so at the expense, if necessary, of the phenomena. The atomists, on the other hand, believed that we must support the evidence of the senses as far as possible. Democritus, a materialist, found this not difficult. Epicurus, who believed in free will, found it more difficult.

Note: The main point in which Epicurus has met criticism is in the introduction of the 'exiguum clinamen' to explain free will. I would answer that at least, although perhaps attemting the impossible, he managed to arrive in one simple step from the swerve to the picture of random atomic motions from which Democritean materialism starts, and his ethical principle has not caused him to abandon the phenomena. Modern thought has attempted to achieve very much the same thing. Heisenberg's Principle of Indeterminacy has been elevated by some into the same position as that occupied by the swerve, and often by men who understand that principle far less well than the Epicureans understood their swerve.

Epicurus' theory of the criteria of truth caused some of his practical science to be inadequate, but only to the extent of his refusing to choose between two observationally possible alternative explanations, and not to the Platonic extent of advancing explanations that were observationally quite impossible.

The atomic theory was the acme of Greek science. Some of its bases have not stood the test of time: some of its details were already known to be wrong at the time when modern science was ripe for receiving inspiration from it. Our atomic theory has developed by a combination of a few brainwaves and a very great deal of hard work in the laboratory. To have arrived at so good a theory by pure thought aided by only the most elementary methods of observation and without the benefit of the calculus and wave-mechanics must be hailed as one of the greatest of human achievements. I have insistently argued that the Greek atomic theory itself is not an 'anticipation' of ours. I am bound, however, to admit that the kinematic theory of the states of matter was such an anticipation, and so was the idea of equal gravitational velocity in vacuo.

We find in the theories of the contemporaries and successors of the atomists no further great advances, and in some we find a considerable deterioration in quality.

Even Aristotle incurs such a charge. His weakness as a critic has been displayed by Cherniss. As a positive physical scientist he is hampered by an inadequate ability in mathematics, and by a stubbornness that tends to make him try to twist the facts or the theories of others in order to make them fit into his own theories. (I imply nothing here about his ability as a logician or philosopher or biological scientist - I am considering him solely from the point of view of a student of the physics and chemistry of the atmosphere and the heavens.)

The post-Aristotelians, apart from the later atomists - who were, after all, not original thinkers but improvers - are a great disappointment to the scientist. There are a few interesting points in Stoicism, great improvements, admittedly, in technology and in descriptive astronomy, and significant discoveries in mathematics, but in the theory of matter and in cosmogony or cosmology there is little or nothing to admire. We leave Greek science, therefore, at its highest peak.

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APPENDIX.

This appendix contains a brief account of the part played by aer in certain psychological and physiological theories. I propose to treat this subject fully in a later paper, and only a very general outline is given here. The major sources for this subject are the de Anima of Aristotle, the de Sensu of Theophrastus, and the doxology that descends from them (the relevant passages are grouped together by Diels for each thinker), and the Hippocratic Corpus.

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Section A

The Air and the Soul and Life.

We saw on p. 23 that the Orphic Poems said that the soul was breathed in from outside and that it was borne by the winds. This idea of the soul as something of the nature of air was widespread in early days for the reasons given on pp. 48-9, where we saw that Anaximander and Anaximenes (along with Anaxagoras and Archelaus) were said to have believed that the soul was 'air-like'. We saw too that a parallel was drawn between the microcosm and the macrocosm, with both man and the universe, as living creatures, breathing in the life-giving pneuma or the soul, and that the first breath and the 'last gasp' were considered as the termini of life, as they still were by the atomists (p. 455).

This parallel and the connection of respiration and air in the form of pneuma with life and the soul was in fact characteristic of both the whole Ionian school and the early Pythagoreans, as well as of the Orphics. The Pythagoreans and the atomists both drew attention to the motes in the sunbeam in this connexion (de.Anima 404 a 1sqq.).

For Anaximander (probably) and for Anaximenes and Diogenes of Apollonia (certainly) the soul was aer, cf. pp. 50, 303-4, and 310. Such a soul, though a material substance, was both cognitive and a source of motion.

Even when the soul was not actually aer, it was something similar. For Heracleitus it was the bright pure exhalation from the sea, cf. pp. 173-8, and we saw that for him too there was a connexion with respiration even though his universe did not breathe.

For some at least of the early Pythagoreans the soul consisted of a mixture of 'the hot aether and the cold aether', which we saw to represent fire and air, cf.

pp. 108-9. Parmenides' soul may have been of this type too, as he was an ex-Pythagorean, cf. p. 200.

Anaxagoras stood apart from all others in the eyes of Plato and Aristotle. His 'Mind' was not aer, but was something quite separate. But although he appears to have been striving to express the concept of a non-material entity, his actual words describe a very pure and subtle material substance. In this sense the word 'air-like' referred to on p. 467 is fitting. Archelaus' mind or soul was half way between that of Diogenes and that of Anaxagoras, cf. pp. 320-2. Hippo's principle was 'moisture' and we saw reason to believe that by this he meant something like Anaximenes' aer and that he connected it with breath and life, cf. pp. 297-8. Finally, we saw that the atomists made fire, air, and the soul of atoms of similar shape.

Even when, therefore, an Ionian or early Pythagorean did not equate the soul with aer, he at least made it 'air-like'; and all these notions of the soul have in common the equation of it with a physical substance that was very subtle and tenuous, the 'most bodiless of bodies' as Aristotle puts it. All except Anaxagoras connected the soul with respiration or aer-pneuma with life and motion.

The idea that we can breathe in reason was a common tenet in Ionian thought, and so was the notion of soul as a mobile form of matter that could cause motion in other matter. If this notion was analysed at all, the conclusion was that the mobility was due to the 'fineness of its parts'.

The Western school had a different type of soul. In the case of Empedocles our information is uncertain. Cherniss has shown that Empedocles seems to have tried to separate body and soul. He attempted to explain even thought and sensation mechanistically, and soul stands apart as consciousness and as a personality that can survive and undergo metempsychosis. If there were no soul sensation would continue but consciousness would not. Aristotle made an unsuccessful attempt to equate Empedocles' soul with a mixture of the four elements or with a ratio or 'harmony' applied to them. There is also the suggestion that Empedocles equated soul with blood (cf. p. 297), but this is an ancient misinterpretation of Frag. 105. The blood round the heart was the seat of the mechanistic cognition.

The other great Western theory, the later Pythagorean, also had an immaterial, non-air-like, soul. Alcmaeon had an immortal soul akin to the divine, whose chief attribute was eternal motion, which implied immortality, cf. p. 113. The soul's immortality was, of course, standard in Pythagoreanism as in any theory that postulated metempsychosis.

Mature Pythagoreanism (?Philolaus?) seems to have postulated that the soul is a 'harmony' (of opposites?). The meaning is unclear. In a sense the same could be said of Plato's soul, one part at least of which was immortal and connected with eternal motion and the divine as with Alcmaeon's, and was, according to the Timaeus, constructed out of immaterial principles (logical in origin) by a mathematical process analogous to the construction of a scale or 'harmony'. This type of immaterial soul does not concern us since it in no way resembles aer.

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Section B

The Air and Sensation.

We have no real information about Milesian theories of sense-perception, if indeed there were any. It had already been realised at the time when our knowledge starts with the early Pythagoreans and Alcmaeon that air acts in some way as a medium for the transmission of light, sound, and odour - with touch and taste we shall not be concerned as they involve either direct contact or a liquid medium. For the details of the mechanism of these three sensations I am much indebted to Beare's Greek Theories of Elementary Cognition.

Greek theories of vision sprang from three observations: the 'image in the pupil' (to which I shall refer for brevity by the word 'emphasis') that one can see in the eye of another - which is actually a reflection and not concerned with the mechanism of sight at all; the 'flash' or 'fire' seen when the eye is pressed - which is actually caused by the pressure's acting as a retinal stimulus, and is therefore also not concerned; and the 'water' inside the eye - which, again, is not really concerned, being actually just a medium.

The result of this concentration upon three comparative irrelevancies was that the Greeks, even those who had moderately sound ideas about light, never satisfactorily explained sight.

From the 'flash' the early Pythagoreans seem to have inferred that the eye contains fire, which issues from the eye as a 'visual ray' that apperceives the object. To look at a thing is to direct a physical visual ray at it. Such a theory is attributed to Archytas (D. 47 A 25).

Alcmaeon combined this idea with the idea that the eye also contains water, which reflects the image, giving the emphasis. His unconvincing combination of the two ideas is discussed on p. 114.

Empedocles believed that like is perceived by like. Effluences come from the objects of sense and fit the passages, the pores, with which they are symmetrical, cf. p. 229, so that they are conveyed to the seat of cognition, the blood round the heart, by such passages. The eye consists of fire in the middle with air and water around it and an outer shell of earth (the cornea). In the latter are pores symmetrical with fire and water arranged alternately, for the fire can pass through to the outside as in a lantern. By the fire we perceive light things, and by the water dark, as the correct effluences enter each type of pore. The fire passes outwards as a visual ray, but we are not told how far. I agree with Beare and Cherniss against Zeller and Burnet that it probably only went as far as the outside surface of the cornea where it would meet the effluences. As for the light perceived, we have seen on p. 241 that Empedocles arrived at a moderately successful account of the properties of light, which was a form of 'fire'.

For Plato too the visual ray was a form of 'fire' known as light. This form was not associated with heat, cf. p. 401. The visual ray on emerging from the eye is in some way coalesced with the light of day, which is akin to it, along the line of sight. The resultant homogeneous whole, in a receptive state, meets the effluences from the object, which represent colour and are themselves reflexions of light from the object, and coalesces with them too, conveying them back to the soul. Light thus acts as a medium, situated in, or travelling through, the air. This third factor is a refinement on the dual scheme of Empedocles. That the two theories are akin is shown by the fact that Plato refers to colour (the effluences) as a symmetrical flame. However Plato seems to have combined the accounts of Archytas, who concentrated upon the visual ray, and Empedocles, who concentrated upon the effluences and whose 'fire' probably did not go out to meet the latter (v. sup.). It is to be noted that the emphasis plays no part in any of these theories.

Again there is a contrast between East and West, for in Ionian thought the emphasis assumed great importance. Anaxagoras (who opposed Empedocles' perception of like by like) said that vision was the reflexion in the pupil of an image by that which was of contrary colour to that of the image. Of course the colour concerned in each case was the one 'most manifest' in the mixture. Colour is thus an attribute of a substance, not something separable as an effluence.

Diogenes also believed in reflexion by opposites that resulted in the emphasis. The external aer conveyed the image to the eye, and this incoming aer mixed with the internal aer to give the emphasis. This impression was then conveyed to the air passages of the brain and thence to the heart by the air.

Leucippus reverted to the perception of like by like, and, believing that the mechanism of all senses is touch, said that the eye is moist and porous, and conveys incoming images to the soul (which is dispersed throughout the body in the form of spherical atoms). These images are material effluences, atomic 'idols' given off by bodies like films, which travel through the medium of the air since the void interstices between air atoms are large enough for them to pass through. Reflexion of these images by the water of the pupil acting as a mirror gives the emphasis.

Democritus strained this theory by positing an impression of the idols that was 'stamped upon' the air between the object and the eye. This stamping compresses the air, and it is the compressed air that enters the eye, not the original idol. Vision is therefore at second hand, and the impression that we receive may be blurred by the air since it is subject to atomic collisions en route. Hence come optical illusions: Democritus was concerned to explain away the apparent fallibility of the senses, which he trusted for knowledge of reality more fully than did his opponents - in a vacuum vision would be perfect for there would be no intervention by air and the idols would arrive unimpaired. Democritus was also concerned to distinguish between primary and secondary qualities. Colour is basically a function of shape and position - but these are 'by nature' whereas our appreciation of colour, as of other qualities, is 'by convention'.

We have already examined Alcmaeon's account of hearing and odour. We saw that sound is transmitted by the motion of the air and perceived by resonance within the ear, and that odour is received by inhaling. We also saw on p. 361 that by the time of Archytas the Pythagoreans (who were from the start interested in acoustics) had refined this theory into one almost acceptable today apart from the association of pitch with velocity instead of with frequency. Plato's theory clearly derives from the same source. It is that sound (originating as air set in motion by blows from the source) is the blow inflicted by air on the brain and blood through the ears and passed on to the soul; the motion that it causes, starting in the head and ending in the region of the liver is hearing. A rapid motion produces a high pitched sound and vice versa. Regularity of motion is connected with purity of timbre (correct if one substitutes 'wave-form' for 'motion'). Volume is connected with the degree of motion (amplitude, as we term it). Sound is transmitted in the same manner as that in which projectiles are kept moving, by the 'circular thrust', cf. p. 410-1. It is therefore not a true case of transmission through an elastic medium as in the case of our compression-wave theory, but rather of the motion of particles of air from the source to the ear as if they were projectiles. It is the surface of these moving portions of air that impinges upon the brain and blood, so that Plutarch can speak of the sound of 'Pythagoras, Plato, and Aristotle' as being incorporeal and moved together with bodies (Beare p. 108). Plato's account of odour has already been referred to on pp. 402-6. Odours are vapour or mist.

Other Greek accounts of sound are less impressive than the one just discussed. Empedocles believed that hearing was caused by the impact of pneuma on the cartilage that is hung inside the ear like a gong, which is struck and oscillates (Beare's interpretation contra Zeller). Empedocles' 'effluences' were in this case portions of air; and they excited resonance in the inner ear. The 'gong' analogy corresponds to the 'lantern' analogy in vision. The 'cartilage', described by Theophrastus as a 'fleshy shoot' will have been something discovered by Empedocles by dissection, probably the eardrum.

Odour for Empedocles again consisted of effluences, which came from fine and light bodies, were carried in by respiration, and passed into those pores in the nasal passages into which they would fit.

Anaxagoras' account of hearing is still wider of the mark. Sound rushes into the hollow formed by the bone round the brain. The sound of the voice is produced by the pneuma (air in motion), which collides against the aer ('firm' air, air at rest), and by recoil from the blow is borne along into the organ of hearing in the same way as that in which echo is produced - by resonance. Odour is introduced by respiration. It may have consisted of rare air; but Anaxagoras' account is not clearly handed down.

Diogenes used the ear as an organ to receive in its internal air the impression of the sound from the external air, and to pass this on (via the brain) to the heart. Odour, whose nature he did not specify, entered along with the inspired air, and was symmetrical with the air around the brain. It then entered the porous brain's veins and thence was conveyed to the heart.

To the atomists sound, like sight, came from idols thrown off by the source and conveyed by the air as a medium to the organ and thence to the soul. The ear is not the only part of the body receptive to sound (correct). The density of the outer ear prevents the atomic idols from slipping out and being lost; that is why the ear is the best part of the body at hearing. After Leucippus had formulated the theory, Democritus again complicated it by introducing the idea of 'stamped' impressions in the intervening air. Odour, of which Democritus left no detailed account, was due to fine effluences from what was heavy, which were inhaled. Like all the other senses smell was basically a mode of touch.

From this section we see that all early Greek accounts of the three senses that normally operate through the air as a medium at least agree that air was the medium, even though they do not consider it as an elastic medium through which electromagnetic waves can pass (although 'idols' can pass through it).Some make the air a mere medium through which some other tenuous entity passes, while others identify a particular type or conformation of air with the light, sound, or odour concerned. In the case of light and odour air is in fact a true medium through which something else passes (light or aromatic vapour), but in the case of sound air is more vitally involved, being itself the vibrating body. Light and odour could penetrate a vacuum; sound could not. Those thinkers who spoke of recoil or rebounding or of a blow in connexion with air were getting close to the addition of elasticity as a property of air alongside mere resistance.

As I have said, taste and touch do not directly involve aer, and so this concludes my account of theories of sensation.

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Section C

The Air and Respiration.

It is necessary, finally, to consider respiration, not from the anatomical point of view - we are not concerned with the respiratory system itself - but from the point of view of its purpose, in order to answer the question 'what does the body use air for?'.

We have already either in the body of the text or in Section A of this appendix answered that question on behalf of many of the Greek philosophers, and shall now be mainly concerned with the medical theoreticians.

Nothing more need be said concerning the typically Ionian connexion with life and the soul in the early days except to call attention to pp. 177-8, where I discuss the possibly Heracleitan theory that breathing in the bright exhalation may be equivalent to breathing in reason, and to say that respiration would have the result of replenishing the body's stock of the matter that the soul is composed.

There was a school of Heracleitans, and they may have been responsible for the theory referred to loc. cit. that Sextus attributed to Heracleitus himself. This same school either contained or influenced the writer of the Hippocratic treatise Nutriment of about 400 b.c. which, alongside many obviously Heracleitan notions, includes the idea that air is food passing through the arteries from the heart while blood passes through the veins from the liver. This introduces us to a serious flaw in Greek studies of the respiratory and circulatory systems. The most commonly available type of corpse for doctors to study or dissect would be one that had bled to death from war wounds. In such a corpse the arteries might be empty of blood or at least full of a mixture of air and blood. The inference would be that the arteries were air vessels - they are included among the 'pores' which we have so frequently encountered - into which sometimes blood had seeped because of the wound.

Consequently it is a commonplace of Greek medicine to find the arteries included in the respiratory system, and even the heart too, since they are connected to it. This explains why we find the Greeks believing in transpiration through 'pores' as well as respiration through the nostrils and mouth, and why the 'pores' are sometimes called 'veins'.

We have already on pp. 244sq. examined the mechanics of Empedocles' theory of transpiration. He shares with Alcmaeon the honour of having given the impetus to the formation to the tradition known as the Sicilian school of medicine.

I can do little better than quote Cornford's account of this school, whose theories in fact combined bad anatomy with bad dynamics. It appears in Plato's Cosmology, p. 307:

> Empedocles' doctrine was reproduced by Philistion, who taught that the purpose of respiration is to cool the natural heat of the body and that health depends on the unimpeded passage of the breath, not only through mouth and nostrils, but all over the body. Diocles also held that the body has a natural heat residing in the blood, which conveys life and movement in the veins throughout the whole frame. His account of the cycle of respiration was the same as Plato's: inhalation (or exhalation) through mouth and nose coincides with exhalation (or inhalation) through the pores. In opposition to the Coan school, which held that the breath first reaches the brain and is then dispersed throughout the rest of the body, the Sicilians taught that the heart is the central seat of the breath of life or breath-soul, which passes thence to the rest of the body through the veins and is the power that moves the limbs. This breath also conveys sense-perception. It is in perpetual motion, circulating through the veins together with the blood. According to this doctrine, then, the breath and the blood travel together through the same channels: respiration and the circulation of the blood are a single process; and since the blood actually consists of the digested food, the same system conveys to all parts of the body their proper nourishment.

Respiration, then, has as its main purpose the cooling of the innate heat of the body.

Diogenes would not have agreed with this. For him aer is the prime element (and the matter of soul), and as such is responsible for all bodily affections. We live by breathing aer, whence comes our soul and intelligence, and deprived of it we die. The Hippocratic On Breaths is in this spirit, and its author works out in great detail and in a rather sophistic manner a theory of air as the sole cause of disease in the body.

Philolaus, from what we know of him, would have agreed with the theory of respiration as a means of cooling, cf. p. 102. But the atomists would not. We saw on p. 455 that they, like Diogenes, believed that respiration was a life-preserver. It prevented the escape of soul atoms and replenishes the body's supply.

However the main opponents of the Sicilian school were the members of the school of Cos. Not only did Hippocrates and his followers believe that the air goes to the brain and is then dispersed to the rest of the body (v. p. 484), but also that the arteries contain air only, not air and blood together. Air excreted from ill-digested food caused disease, pain arising when the 'wind' within us in its motion through the hollow parts of the body impinges upon tender fleshy blood-filled parts like the liver.

The major cause of disease, however, was not air (except in so far as adverse climatic, atmospheric, conditions could induce it), but a state of imbalance between the 'powers' associated with the four 'humours'. These powers are the familiar ones that descend from the opposites of Anaximander. The Coan idea of four humours with certain powers contrasts with the Sicilian four (Empedoclean) elements, whose imbalance similarly caused disease. Both traditions of healthy balance presumably spring from Alcmaeon's notion of 'isonomy' between his (many) opposites.

To sum up, we have found two main traditions, again associated with East and West. The former is that air in respiration maintains life because it really is soul (and intelligence) or because it is analogous to soul, and is consequently in truth 'the breath of life'. The latter is that air is a refrigerating agent. There is also a minor tradition that air, or at any rate bad air, is a cause, or the cause, of disease. We seek in vain, apart from one or two hints mentioned in the body of the text, for any connexion of respiration with combustion (which is analogous to it chemically) or with the removal of waste (sc. carbon dioxide) or with the provision of fuel (sc.

oxygen). We cannot blame the Greeks for this, however. Although medicine was the one Greek science that did employ modern scientific methods, it did not have the tools (e.g. microscopes) or conditions (live bodies operated upon while under safe anaesthetics) that would have enabled it to observe accurately and interpret its observations correctly, and it had no laboratory chemists to provide information about the true nature and properties of the substances of which the body is composed.

It will be seen that a consideration of Greek medicine does not add appreciably to our list of the properties of air known to the Greeks; but the very lack of practical knowledge about the behaviour of air in a sphere of great importance to human well-being gives us a salutary warning lest we enthuse too greatly over the theoretical achievements extolled at the conclusion of the body of the text.

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