Arthur Koestler

The Sleepwalkers

A History of Man's changing vision
of the Universe

With an Introduction by
Herbert Butterfield

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1 Dawn

1. *Awakening*

We can add to our knowledge, but we cannot subtract from it. When I try to see the Universe as a Babylonian saw it around 3000 B.C., I must grope my way back to my own childhood. At the age of about four I had what I felt to be a satisfactory understanding of God and the world. I remember an occasion when my father pointed his finger at the white ceiling, which was decorated with a frieze of dancing figures, and explained that God was up there, watching me. I immediately became convinced that the dancers were God and henceforth addressed my prayers to them, asking for their protection against the terrors of day and night. Much in the same manner, I like to imagine, did the luminous figures on the dark ceiling of the world appear as living divinities to Babylonians and Egyptians. The Twins, the Bear, the Serpent were as familiar to them as my fluted dancers to me; they were thought to be not very far away, and they held power of life and death, harvest and rain.

The world of the Babylonians, Egyptians, and Hebrews was an oyster, with water underneath, and more water overhead, supported by the solid firmament. It was of moderate dimensions, and as safely closed in on all sides as a cot in the nursery or a babe in the womb. The Babylonians' oyster was round, the earth was a hollow mountain, placed in its centre, floating on the waters of the deep; above it was a solid dome, covered by the upper waters. The upper waters seeped through the dome as rain, and the lower waters rose in fountains and springs. Sun, moon, and stars progressed in a slow dance across the dome, entering the scene through doors in the East and vanishing through doors in the West.

The universe of the Egyptians was a more rectangular oyster or box; the earth was its floor, the sky was either a cow whose feet rested on the four corners of the earth, or a woman sup-

porting herself on her elbows and knees; later, a vaulted metal lid. Around the inner walls of the box, on a kind of elevated gallery, flowed a river on which the sun and moon gods sailed their barques, entering and vanishing through various stage doors. The fixed stars were lamps, suspended from the vault, or carried by other gods. The planets sailed their own boats along canals originating in the Milky Way, the celestial twin of the Nile. Towards the fifteenth of each month, the moon god was attacked by a ferocious sow, and devoured in a fortnight of agony; then he was re-born again. Sometimes the sow swallowed him whole, causing a lunar eclipse; sometimes a serpent swallowed the sun, causing a solar eclipse. But these tragedies were, like those in a dream, both real and not; inside his box or womb, the dreamer felt fairly safe.

This feeling of safety was derived from the discovery that, in spite of the tumultuous private lives of the sun and moon gods, their appearances and movements remained utterly dependable and predictable. They brought night and day, the seasons and the rain, harvest, and sowing time, in regular cycles. The mother leaning over the cradle is an unpredictable goddess; but her feeding breast can be depended on to appear when needed. The dreaming mind may go through wild adventures, it may travel through Olympus and Tartarus, but the pulse of the dreamer has a regular beat that can be counted. The first to learn counting the pulse of the stars were the Babylonians.

Some six thousand years ago, when the human mind was still half asleep, Chaldean priests were standing on watch-towers, scanning the stars, making maps and time-tables of their motions. Clay tablets dating from the reign of Sargon of Akkad, around 3800 B.C., show an already old-established astronomical tradition.[1] The time-tables became calendars which regulated organized activity, from the growing of crops to religious ceremonies. Their observations became amazingly precise: they computed the length of the year with a deviation of less than 0·001 per cent from the correct value,[2] and their figures relating to the motions of sun and moon have only three times the margin of error of nineteenth-century astronomers armed with mammoth telescopes.[3] In this respect, theirs was an

Exact Science; their observations were verifiable, and enabled them to make precise predictions of astronomical events; though based on mythological assumptions. the theory 'worked'. Thus at the very beginning of this long journey, Science emerges in the shape of Janus, the double-faced god, guardian of doors and gates: the face in front alert and observant, while the other, dreamy and glassy-eyed, stares in the opposite direction.

The most fascinating objects in the sky – from both points of view – were the planets, or vagabond stars. Only seven of these existed among the thousands of lights suspended from the firmament. They were the Sun, the Moon, Nebo – Mercury, Ishtar – Venus, Nergal – Mars, Marduk – Jupiter, and Ninib – Saturn. All other stars remained stationary, fixed in the pattern of the firmament, revolving once a day round the earth-mountain, but never changing their places in the pattern. The seven vagabond stars revolved with them, but at the same time they had a motion of their own, like flies wandering over the surface of a spinning globe. Yet they did not wander all across the sky: their movements were confined to a narrow lane, or belt, which was looped around the firmament at an angle of about twenty-three degrees to the equator. This belt – the Zodiac – was divided into twelve sections, and each section was named after a constellation of fixed stars in the neighbourhood. The Zodiac was the lovers' lane in the skies, along which the planets ambled. The passing of a planet through one of the sections had a double significance: it yielded figures for the observer's time-table, and symbolic messages of the mythological drama played out behind the scenes. Astrology and Astronomy remain to this day complementary fields of vision of Janus sapiens.

2. *Ionian Fever*

Where Babylon and Egypt left off, Greece took over. At the beginning, Greek cosmology moved much on the same lines – Homer's world is another, more colourful oyster, a floating disc surrounded by Okeanus. But about the time when the texts

of the Odyssey and Iliad became consolidated in their final version, a new development started in Ionia on the Aegean coast. The sixth pre-Christian century – the miraculous century of Buddha, Confucius, and Lao-tze, of the Ionian philosophers and Pythagoras – was a turning point for the human species. A March breeze seemed to blow across this planet from China to Samos, stirring man into awareness, like the breath in Adam's nostrils. In the Ionian school of philosophy, rational thought was emerging from the mythological dream-world. It was the beginning of the great adventure: the Promethean quest for natural explanations and rational causes, which, within the next two thousand years, would transform the species more radically than the previous two hundred thousand had done.

Thales of Miletos, who brought abstract geometry to Greece, and predicted an eclipse of the sun, believed, like Homer, that the earth was a circular disc floating on water, but he did not stop there; discarding the explanations of mythology, he asked the revolutionary question out of what basic raw material, and by what process of nature, the universe was formed. His answer was, that the basic stuff or element must be water, because all things are born from moisture, including air, which is water evaporated. Others taught that the prime material was not water, but air or fire; however, their answers were less important than the fact that they were learning to ask a new type of question, which was addressed not to an oracle, but to dumb nature. It was a wildly exhilarating game; to appreciate it, one must again travel back along one's own private time-track to the fantasies of early adolescence when the brain, intoxicated with its newly discovered powers, let speculation run riot. 'A case in point,' Plato reports, 'is that of Thales, who, when he was star-gazing and looking upward, fell into a well, and was rallied (so it is said) by a clever and pretty maidservant from Thrace because he was eager to know what went on in the heaven, but did not notice what was in front of him, nay, at his very feet.'[4]

The second of the Ionian philosophers, Anaximander, displays all the symptoms of the intellectual fever spreading

through Greece. His universe is no longer a closed box, but infinite in extension and duration. The raw material is none of the familiar forms of matter, but a substance without definite properties except for being indestructible and everlasting. Out of this stuff all things are developed, and into it they return; before this our world, infinite multitudes of other universes have already existed, and been dissolved again into the amorphous mass. The earth is a cylindrical column, surrounded by air; it floats upright in the centre of the universe without support or anything to stand on, yet it does not fall because, being in the centre, it has no preferred direction towards which to lean; if it did, this would disturb the symmetry and balance of the whole. The spherical heavens enclose the atmosphere 'like the bark of a tree', and there are several layers of this enclosure to accommodate the various stellar objects. But these are not what they seem, and are not 'objects' at all. The sun is merely a hole in the rim of a huge wheel. The rim is filled with fire, and as it turns round the earth, so does the hole in it – a puncture in a gigantic tyre filled with flames. For the moon we are given a similar explanation; its phases are due to recurrent partial stoppages of the puncture, and so are the eclipses. The stars are pin-holes in a dark fabric through which we glimpse the cosmic fire filling the space between two layers of 'bark'.

It is not easy to see how the whole thing works, but it is the first approach to a mechanical model of the universe. The boat of the sun god is replaced by the wheels of a clockwork. Yet the machinery looks as if it had been dreamed up by a surrealist painter; the punctured fire-wheels are certainly closer to Picasso than to Newton. As we move along past other cosmologies, we shall get this impression over and again.

The system of Anaximenes, who was an associate of Anaximander, is less inspired; but he seems to have been the originator of the important idea that the stars are attached 'like nails' to a transparent sphere of crystalline material, which turns round the earth 'like a hat round the head'. It sounded so plausible and convincing, that the crystal spheres were to dominate cosmology until the beginning of modern times.

The Ionian philosophers' home was Miletos in Asia Minor; but there existed rival schools in the Greek towns of Southern Italy, and rival theories within each school. The founder of the Eleatic school, Xenophanes of Kolophon, is a sceptic who wrote poetry to the age of ninety-two, and sounds as if he had served as a model for the author of Ecclesiastes:

> From earth are all things and to earth all things return. From earth and water come all of us. . . . No man hath certainly known, nor shall certainly know, that which he saith about the gods and about all things; for, be that which he saith ever so perfect, yet does he not know it; all things are matters of opinion. . . . Men imagine gods to be born, and to have clothes and voices and shapes like theirs. . . . Yea, the gods of the Ethiopians are black and flat-nosed, the gods of the Thracians are red-haired and blue-eyed. . . . Yea, if oxen and horses and lions had hands, and could shape with their hands images as men do, horses would fashion their gods as horses, and oxen as oxen. . . . Homer and Hesiod have ascribed to the gods all things that are a shame and a disgrace among men, theft, adultery, deceit, and other lawless acts. . . .

As against this:

> There is one God . . . neither in shape nor thought like unto mortals. . . . He abideth ever in the same place motionless . . . and without effort swayeth all things by his force of mind. . . .[5]

The Ionians were optimistic, heathenly materialists; Xenophanes was a pantheist of a sorrowful brand, to whom change was an illusion, and effort vanity. His cosmology reflects his philosophical temper; it is radically different from the Ionians'. His earth is not a floating disc, or column, but is 'rooted in the infinite'. The sun and the stars have neither substance nor permanence, they are merely cloudy exhalations of the earth which have caught fire. The stars are burnt out at dawn, and in the evening a new set of stars is formed from new exhalations. Similarly, a new sun is born every morning from the crowding together of sparks. The moon is a compressed, luminous cloud, which dissolves in a month; then a new cloud starts forming. Over different regions of the earth, there are different suns and moons, all cloudy illusions.

In this manner do the earliest rational theories of the Universe betray the bias and temperament of their makers. It is generally believed that with the progress of scientific method, the theories became more objective and reliable. Whether this belief is justified, we shall see. But *à propos* of Xenophanes we may note that two thousand years later Galileo also insisted on regarding comets as atmospheric illusions – for purely personal reasons, and against the evidence of his telescope.

Neither the cosmology of Anaxagoras, nor of Xenophanes, gained a considerable following. Every philosopher of the period seems to have had his own theory regarding the nature of the universe around him. To quote Professor Burnet, 'no sooner did an Ionian philosopher learn half a dozen geometrical propositions and hear that the phenomena of the heavens recur in cycles than he set to work to look for law everywhere in nature and with an audacity amounting to *hybris* to construct a system of the universe'.[6] But their divers speculations had this one feature in common, that the sun-eating serpents and Olympian string-pullers were discarded; each theory, however strange and bizarre, was concerned with natural causes.

The sixth century scene evokes the image of an orchestra expectantly tuning up, each player absorbed in his own instrument only, deaf to the caterwaulings of the others. Then there is a dramatic silence, the conductor enters the stage, raps three times with his baton, and harmony emerges from the chaos. The maestro is Pythagoras of Samos, whose influence on the ideas, and thereby on the destiny, of the human race was probably greater than that of any single man before or after him.

2 The Harmony of the Spheres

1. *Pythagoras of Samos*

Pythagoras was born in the early decades of that tremendous century of awakening, the sixth; and may have seen it go out, for he lived at least eighty, and possibly over ninety, years. Into that long life-span he packed, in the words of Empedokles, 'all things that are contained in ten, even in twenty, generations of men'.

It is impossible to decide whether a particular detail of the Pythagorean universe was the work of the master, or filled in by a pupil – a remark which equally applies to Leonardo or Michelangelo. But there can be no doubt that the basic features were conceived by a single mind; that Pythagoras of Samos was both the founder of a new religious philosophy, and the founder of Science, as the world is understood today.

It seems reasonably certain that he was the son of a silversmith and gem engraver named Mnesarchos; that he was a pupil of Anaximander, the atheist, but also of Pherekydes, the mystic who taught the transmigration of souls. He must have travelled extensively in Asia Minor and Egypt, as many educated citizens of the Greek Islands did; and it is said that he was charged with diplomatic missions by Polycrates, the enterprising autocrat of Samos. Polycrates was an enlightened tyrant who favoured commerce, piracy, engineering, and the fine arts; the greatest poet of the time, Anakreon, and the greatest engineer, Eupalinos from Megara, both lived at his court. According to a story by Herodotus, he became so powerful that, to placate the jealousy of the gods, he threw his most precious signet ring into the deep waters. A few days later, his cook cut open a large fish, freshly caught, and found the ring in its stomach. The doomed Polycrates promptly walked into a trap set by a small Persian ruler, and was crucified. But by that time Pythagoras, with his family, had emigrated from

Samos, and around 530 B.C. settled in Kroton – which, next to its rival Sybaris, was the largest Greek town in Southern Italy. The reputation which preceded him must have been tremendous, for the Pythagorean Brotherhood which he founded on his arrival soon ruled the town, and for a time gained supremacy over a considerable part of Magna Grecia. But its secular power was short-lived; Pythagoras, at the end of his life, was banished from Kroton to Metapontion; his disciples were exiled or slain, and their meeting-houses burnt down.

This is the meagre stem of more or less established fact, around which the ivy of legend began to grow even during the master's lifetime. He soon achieved semi-divine status; according to Aristotle, the Krotonians believed him to be a son of the Hyperborean Apollo, and there was a saying that 'among rational creatures there are gods and men and beings like Pythagoras'. He worked miracles, conversed with demons from heaven, descended to Hades, and possessed such power over men, that after his first sermon to the Krotonians, six hundred joined the communal life of the Brotherhood without even going home to bid their families farewell. Among his disciples his authority was absolute – 'the master said so' was their law.

2. *The Unifying Vision*

Myths grow like crystals, according to their own, recurrent pattern; but there must be a suitable core to start their growth. Mediocrities or cranks have no myth-generating power; they may create a fashion, but it soon peters out. Yet the Pythagorean vision of the world was so enduring, that it still permeates our thinking, even our vocabulary. The very term 'philosophy' is Pythagorean in origin; so is the word 'harmony' in its broader sense; and when we call numbers 'figures', we talk the jargon of the Brotherhood.[1]

The essence and power of that vision lies in its all-embracing, unifying character; it unites religion and science, mathematics and music, medicine and cosmology, body, mind, and spirit in an inspired and luminous synthesis. In the Pythagorean philosophy all component parts interlock: it presents a homo-

geneous surface, like a sphere, so that it is difficult to decide from which side to cut into it. But the simplest approach is through music. The Pythagorean discovery that the pitch of a note depends on the length of the string which produces it, and that concordant intervals in the scale are produced by simple numerical ratios (2 : 1 octave, 3 : 2 fifth, 4 : 3 fourth, etc.), was epoch-making: it was the first successful reduction of quality to quantity, the first step towards the mathematization of human experience – and therefore the beginning of Science.

But here an important distinction must be made. The twentieth-century European regards with justified misgivings the 'reduction' of the world around him, of his experiences and emotions, into a set of abstract formulae, deprived of colour, warmth, meaning, and value. To the Pythagoreans, on the contrary, the mathematization of experience meant not an impoverishment, but an enrichment. Numbers were sacred to them as the purest of ideas, disembodied and ethereal; hence the marriage of music to numbers could only ennoble it. The religious and emotional *ekstasis* derived from music was canalized by the adept into intellectual *ekstasis*, the contemplation of the divine dance of numbers. The gross strings of the lyre are recognized to be of subordinate importance; they can be made of different materials, in various thicknesses and lengths, so long as the proportions are preserved: what produces the music are the ratios, the numbers, the pattern of the scale. Numbers are eternal while everything else is perishable; they are of the nature not of matter, but of mind; they permit mental operations of the most surprising and delightful kind without reference to the coarse external world of the senses – which is how the divine mind must be supposed to operate. The ecstatic contemplation of geometrical forms and mathematical laws is therefore the most effective means of purging the soul of earthly passion, and the principal link between man and divinity.

The Ionian philosophers had been materialists in the sense that the chief accent of their inquiry was on the stuff from which the universe was made; the Pythagoreans' chief accent was on form, proportion, and pattern; on the *eidos* and *schema*,

on the relation, not on the relata. Pythagoras is to Thales what Gestalt philosophy is to the materialism of the nineteenth century. The pendulum has been set swinging; its ticking will be heard through the entire course of history, as the blob alternates between the extreme positions of 'all is body', 'all is mind'; as the emphasis shifts from 'substance' to 'form', from 'structure' to 'function', from 'atoms' to 'patterns', from 'corpuscles' to 'waves' and back again.

The line connecting music with numbers became the axis of the Pythagorean system. This axis was then extended in both directions: towards the stars on one side, the body and soul of man on the other. The bearings, on which the axis and the whole system turned, were the basic concepts of *armonia*: harmony, and *katharsis*: purge, purification.

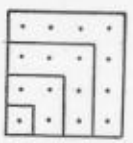
The Pythagoreans were, among other things, healers; we are told that 'they used medicine to purge the body, and music to purge the soul'.[2] One of the oldest forms, indeed, of psychotherapy consists in inducing the patient, by wild pipe music or drums, to dance himself into a frenzy followed by exhaustion and a trance-like, curative sleep – the ancestral version of shock-treatment and abreaction therapy. But such violent measures were only needed where the patient's soul-strings were out of tune – overstrung or limp. This is to be taken literally, for the Pythagoreans regarded the body as a kind of musical instrument where each string must have the right tension and the correct balance between opposites such as 'high' and 'low', 'hot' and 'cold', 'wet' and 'dry'. The metaphors borrowed from music which we still apply in medicine – 'tone', 'tonic', 'well-tempered', 'temperance', are also part of our Pythagorean heritage.

However, the concept *armonia* did not have quite the same meaning that we lend to 'harmony'. It is not the pleasing effect of simultaneously-sounded concordant strings – 'harmony' in that sense was absent from classical Greek music – but something more austere: *armonia* is simply the attunement of the strings to the intervals in the scale, and the pattern of the scale itself. It means that balance and order, not sweet pleasure, are the law of the world.

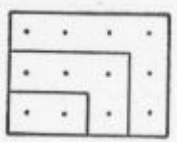
Sweetness does not enter the Pythagorean universe. But it contains one of the most powerful tonics ever administered to the human brain. It lies in the Pythagorean tenets that 'philosophy is the highest music', and that the highest form of philosophy is concerned with numbers: for ultimately 'all things are numbers'. The meaning of this oft-quoted saying may perhaps be paraphrased thus: 'all things have form, all things *are* form; and all forms can be defined by numbers'. Thus the form of the square corresponds to a 'square number', i.e. $16 = 4 + 4$, whereas 12 is an oblong number, and 6 a triangular number:

Numbers were regarded by the Pythagoreans as patterns of dots which form characteristic figures, as on the sides of a dice; and though we use arabic symbols, which have no resemblance to these dot-patterns, we still call numbers 'figures', i.e. shapes.

Between these number-shapes unexpected and marvellous relations were found to exist. For instance, the series of 'square numbers' was formed simply by the addition of successive odd numbers: $\boxed{1}+3=\boxed{4}+5=\boxed{9}+7=\boxed{16}+9=\boxed{25}$ and so forth:



The addition of even numbers formed 'oblong numbers', where the ratio of the sides represented exactly the concordant intervals of the musical octave: 2 (2 : 1, octave) + 4 = 6 (3 : 2, fifth) + 6 = 12 (4 : 3, fourth).



In a similar manner, 'cubic' numbers and 'pyramidal' numbers were obtained. Mnesarchos had been a gem engraver, so Pythagoras in his youth must have been familiar with crystals whose form imitated those of pure number-shapes: quartz the pyramid and double pyramid, beryl the hexagon, garnet the dodocaeder. It all went to show that Reality could be reduced to number-series and number-ratios, if only the rules of the game were known. To discover these was the chief task of the *Philosophos*, the Lover of Wisdom.

An example of the magic of numbers is the famous theorem, by which alone Pythagoras is consciously remembered today – the visible peak of the submerged iceberg.* There is no obvious relationship between the lengths of the sides of a right-angled triangle; but if we build a square over each side, the areas of the two smaller squares will exactly equal the area of the larger. If such wonderfully ordered laws, hitherto hidden from the human eye, could be discovered by the contemplation of number-shapes, was it not legitimate to hope that soon all secrets of the universe would be revealed through them? Numbers were not thrown into the world at random; they arranged themselves into balanced patterns, like the shapes of crystals and the concordant intervals of the scale, according to the universal laws of harmony.

3. *'Soft Stillness and the Night'*

Extended to the stars, the doctrine took the form of the 'Harmony of the Spheres'. The Ionian philosophers had begun to prise open the cosmic oyster, and to set the earth adrift; in Anaximander's universe the earth-disc no longer floats in water, but stands in the centre, supported by nothing and surrounded by air. In the Pythagorean universe the disc changes into a spherical ball.[3] Around it, the sun, moon, and planets revolve in concentric circles, each fastened to a sphere or wheel. The swift revolution of each of these bodies causes a swish, or musical

* Ironically, Pythagoras seems to have had no complete proof of the Pythagorean theorem.

hum, in the air. Evidently each planet will hum on a different pitch, depending on the ratios of their respective orbits – just as the tone of a string depends on its length. Thus the orbits in which the planets move form a kind of huge lyre whose strings are curved into circles. It seemed equally evident that the intervals between the orbital cords must be governed by the laws of harmony. According to Pliny,[4] Pythagoras thought that the musical interval formed by earth and moon was that of a tone; moon to Mercury, a semi-tone; Mercury to Venus, a semi-tone; Venus to Sun, a minor third; Sun to Mars, a tone; Mars to Jupiter, a semi-tone; Jupiter to Saturn, a semi-tone; Saturn to the sphere of the fixed stars, a minor third. The resulting 'Pythagorean Scale' is C, D, ♭ E, G, A, ♭ B, B, D – though the accounts of the scale given by different writers vary slightly.

According to tradition, the Master alone had the gift of actually hearing the music of the spheres. Ordinary mortals lack this gift, either because they are from the moment of birth, unknowingly but constantly bathed in the celestial humming; or because – as Lorenzo explains to Jessica – they are too grossly constituted:

> . . . soft stillness and the night
> Become the touches of sweet harmony . . .
> Look how the floor of heaven
> Is thick inlaid with patines of bright gold;
> There's not the smallest orb which thou behold'st
> But in his motion like an angel sings . . .
> Such harmony is in immortal souls;
> But, whilst this muddy vesture of decay
> Doth grossly close it in, we cannot hear it.[5]

The Pythagorean dream of musical harmony governing the motion of the stars never lost its mysterious impact, its power to call forth responses from the depth of the unconscious mind. It reverberates through the centuries, from Kroton to Elizabethan England; I shall quote two more versions of it – with a purpose that will become apparent later. The first is Dryden's well-known:

> From harmony, from heavenly harmony,
> This universal frame began:
> When nature underneath a heap
> Of jarring atoms lay
> And could not heave her head.
> The tuneful voice we heard from high:
> Arise, ye more than dead.

The second is from Milton's *Arcades*:

> But els in deep of night when drowsiness
> Hath lockt up mortal sense, then listen I
> To the celestial Sirens harmony . . .
> Such sweet compulsion doth in music ly,
> To lull the daughters of *Necessity*,
> And keep unsteddy Nature to her law,
> And the low world in measur'd motion draw
> After the heavenly tune, which none can hear
> Of human mould with grosse unpurged ear.

But, one might ask, was the 'Harmony of the Spheres' a poetic conceit or a scientific concept? A working hypothesis or a dream dreamt through a mystic's ear? In the light of the data which astronomers collected in the centuries that followed, it certainly appeared as a dream; and even Aristotle laughed 'harmony, heavenly harmony' out of the courts of earnest, exact science. Yet we shall see how, after an immense detour, at the turn of the sixteenth century, one Johannes Kepler became enamoured with the Pythagorean dream, and on this foundation of fantasy, by methods of reasoning equally unsound, built the solid edifice of modern astronomy. It is one of the most astonishing episodes in the history of thought, and an antidote to the pious belief that the Progress of Science is governed by logic.

4. *Religion and Science Meet*

If Anaximander's universe reminds one of a Picasso painting, the Pythagorean world resembles a cosmic musical box playing the same Bach prelude from eternity to eternity. It is not surprising, then, that the religious beliefs of the Pythagorean

Brotherhood are closely related to the figure of Orpheus, the divine fiddler, whose music held not only the Prince of Darkness, but also beasts, trees, and rivers under its spell.

Orpheus is a late arrival on the Greek stage, overcrowded with gods and demigods. The little we know about his cult is clouded in conjecture and controversy; but we know, at least in broad outlines, its background. At an unknown date, but probably not much before the sixth century, the cult of Dionysus-Bacchus, the 'raging' goat-god of fertility and wine, spread from barbaric Thracia into Greece. The initial success of Bacchism was probably due to that general sense of frustration which Xenophanes so eloquently expressed. The Olympian Pantheon had come to resemble an assembly of wax-works, whose formalized worship could no more satisfy truly religious needs than the pantheism – this 'polite atheism' as it has been called – of the Ionian sages. A spiritual void tends to creat emotional outbreaks; the Bacchae of Euripides, frenzied worshippers of the horned god, appears as the forerunners of the medieval tarantula dancers, the bright young things of the roaring twenties, the maenads of the Hitler youth. The outbreak seems to have been sporadic and short-lived: the Greeks, being Greeks, soon realized that these excesses led neither to mystic union with God, nor back to nature, but merely to mass-hysteria:

> Theban women leaving
> Their spinning and their weaving
> Stung with the maddening trance
> Of Dionysus! ...
> Brute with bloody jaws agape
> God-defying, gross and grim,
> Slander of the human shape.[6]

The authorities seemed to have acted with eminent reasonableness: they promoted Bacchus-Dionysus to the official Pantheon with a rank equal to Apollo's. His frenzy was tamed, his wine watered down, his worship regulated, and used as a harmless safety-valve.

But the mystic craving must have persisted, at least in a sensitivized minority, and the pendulum now began to swing in

the opposite direction: from carnal ecstasy to other-worldliness. In the most telling variant of the legend, Orpheus appears as a victim of Bacchic fury: when, having finally lost his wife, he decides to turn his back on sex, the women of Thrace tear him to pieces, and his head floats down the Hebrus – still singing. It sounds like a cautionary tale; but the tearing and devouring of the living god, and his subsequent rebirth, is a *leitmotif* that recurs in Orphism on a different level of meaning. In Orphic mythology, Dionysus (or his Thracian version, Zagreus) is the beautiful son of Zeus and Persephone; the evil Titans tear him to pieces and eat him, all but his heart, which is given to Zeus, and he is born a second time. The Titans are slain by Zeus' thunderbolt; but out of their ashes man is born. By devouring the god's flesh, the Titans have acquired a spark of divinity which is transmitted to man; and so is the desperate evil that resided in the Titans. But it is in the power of man to redeem this original sin, to purge himself of the evil portion of his heritage by leading an other-worldly life and performing certain ascetic rites. In this manner he can obtain liberation from the 'wheel of rebirth' – his imprisonment in successive animal and even vegetable bodies, which are like carnal tombs to his immortal soul – and regain his lost divine status.

The Orphic cult was thus in almost every respect a reversal of the Dionysian; it retained the name of the god and some features of his legend, but all with a changed emphasis and different meaning (a process that will repeat itself at other turning points of religious history). The Bacchic technique of obtaining emotional release by furiously clutching at the Now and Here, is replaced by renunciation with an eye on after-life. Physical intoxication is superseded by mental intoxication; the 'juice that streams from the vine-clusters to give us joy and oblivion' now serves only as a sacramental symbol; it will eventually be taken over, together with the symbolic swallowing of the slain god and other basic elements of Orphism, by Christianity. 'I am perishing with thirst, give me to drink of the waters of memory', says a verse on an Orphic gold tablet, alluding to the divine origin of the soul: the aim is no longer oblivion but remembrance of a knowledge which it once possesed. Even

words change their meaning: 'orgy' no longer means Bacchic revelry, but religious ecstasy leading to liberation from the wheel of rebirth.[7] A similar development is the transformation of the carnal union between the King and the Shulamite into the mystic union of Christ and his Church; and, in more recent times, the shift of meaning in words like 'rapture' and 'ravishment'.

Orphism was the first universal religion in the sense that it was not regarded as a tribal or national monopoly, but open to all who accepted its tenets; and it profoundly influenced all subsequent religious development. It would nevertheless be a mistake to attribute too much intellectual and spiritual refinement to it; the Orphic purification rites, which are the hub of the whole system, still contain a series of primitive taboos – not to eat meat, or beans, not to touch a white cock, not to look in a mirror beside the light.

But this is precisely the point where Pythagoras gave Orphism a new meaning, the point where religious intuition and rational science were brought together in a synthesis of breathtaking originality. The link is the concept of *katharsis*. It was a central concept in Bacchism, Orphism, in the cult of the Delian Apollo, in Pythagorean medicine and science; but it had different meanings, and entailed different techniques in all of them (as it still does in the various schools of modern psychotherapy). Was there anything in common between the raving Bacchante and the aloof mathematician, the fiddle of Orpheus and a laxative pill? Yes: the same yearning for release from various forms of enslavement, from passions and tensions of body and mind, from death and the void, from the legacy of the Titans in man's estate – the yearning to re-light the divine spark. But the methods of achieving this must differ according to the person. They must be graded according to the disciple's lights and degree of initiation. Pythagoras replaced the soul-purging all-cures of competing sects, by an elaborate hierarchy of kathartic techniques; he purified the very concept of purification, as it were.

At the bottom of the scale are simple taboos, taken over from Orphism, such as the interdiction of eating meat and

beans; for the coarse-natured the penance of self-denial is the only effective purge. At the highest level katharsis of the soul is achieved by contemplating the essence of all reality, the harmony of forms, the dance of numbers. 'Pure science' – a strange expression that we still use – is thus both an intellectual delight and a way to spiritual release; the way to the mystic union between the thoughts of the creature and the spirit of its creator. 'The function of geometry,' says Plutarch of the Pythagoreans, 'is to draw us away from the world of the senses and of corruption, to the world of the intellect and the eternal. For the contemplation of the eternal is the end of philosophy as the contemplation of the mysteries is the end of religion.'[8] But to the true Pythagorean, the two have become indistinguishable.

The historical importance of the idea that disinterested science leads to purification of the soul and its ultimate liberation, can hardly be exaggerated. The Egyptians embalmed their corpses so that the soul might return to them and need not be reincarnated again; the Buddhists practised non-attachment to escape the wheel; both attitudes were negative and socially sterile. The Pythagorean concept of harnessing science to the contemplation of the eternal, entered, via Plato and Aristotle, into the spirit of Christianity and became a decisive factor in the making of the Western world.

Earlier in this chapter I have tried to show how, by relating music to astronomy and both to mathematics, emotional experience became enriched and deepened by intellectual insight. Cosmic wonder and aesthetic delight no longer live apart from the exercise of reason; they are all inter-related. Now the final step has been taken: the mystic intuitions of religion have also been integrated into the whole. Again, the process is accompanied by subtle changes in the meaning of certain key-words, such as *theoria* – theory. The word was derived from *theorio* – 'to behold, contemplate' (*thea*: spectacle, *theoris*: spectator, audience). But in orphic usage, *theoria* came to signify 'a state of fervent religious contemplation, in which the spectator is identified with the suffering god, dies in his death, and rises again in his new birth'.[9] As the Pythagoreans canalized religious fervour into intellectual fervour, ritual ecstasy into the ecstasy

of discovery, *theoria* gradually changed its meaning into 'theory' in the modern sense. But though the raucous cry of the ritual worshippers was replaced by the Eureka of the new theorizers, they remained aware of the common source from which both sprang. They were aware that the symbols of mythology and the symbols of mathematical science were different aspects of the same, indivisible Reality.* They did not live in a 'divided house of faith and reason'; the two were interlocking, like ground-plan and elevation on an architect's drawing. It is a state of mind very difficult for twentieth-century man to imagine – or even to believe that it could ever have existed. It may help to remember though, that some of the greatest pre-Socratic sages formulated their philosophies in verse; the unitary source of inspiration of prophet, poet, and philosopher was still taken for granted.

It did not last long. Within a few centuries, the unitary awareness faded, religious and rational philosophizing split apart – were partially reunited, then divorced again; with results that will become apparent as the story unfolds.

The Pythagorean synthesis would have been incomplete had it not also included precepts for a way of life.

The Brotherhood was a religious order, but at the same time an academy of science, and a power in Italian politics. The ascetic rules of life seem to have anticipated the Essenes', which in turn served as a model to primitive Christian communities. They shared all property, led a communal existence, and gave equal status to women. They observed rites and abstinences, gave much time to contemplation and examinations of conscience. According to the degree of purification which a Brother achieved, he was gradually initiated into the higher mysteries of musical, mathematical, and astronomical *theoria*. The secrecy surrounding these was partly due to the tradition of the older mystery cults, whose adepts had known that the Bacchic,

* Hence the short-cuts, or short-circuits, between different sets of symbols in Pythagorean mystic number-lore, such as the correlation of odd and even numbers were male and female, right and left; or the magic quality attributed to the pentagram.

and even the Orphic, ecstasies would cause havoc if offered to all and sundry. But the Pythagoreans also realized that similar dangers inhered in the orgies of reasoning. They apparently had an intuition of the *hybris* of science, and recognized it as a potential means both of man's liberation and destruction; hence their insistence that only those purified in body and spirit should be trusted with its secrets. In a word, they believed that scientists ought to be vegetarians, as Catholics believe that priests ought to live in celibacy.

It may be thought that this interpretation of the Pythagorean insistence on secretiveness is far-fetched, or that it implies prophetic foresight on their part. The answer to this is that Pythagoras was, by personal experience, well aware of the immense technological potentialities of geometry. I have mentioned already that Polycrates, and the islanders he ruled, were devoted to engineering. Herodotus, who knew the island well, reports:[10]

> I have written thus at length of the Samians, because they are the makers of the three greatest works to be seen in any Greek land. First of these is the double-mouthed tunnel they pierced for a hundred and fifty fathoms through the base of a high hill ... through which the water, coming from an abundant spring, is carried by its pipes to the city of Samos.

Herodotus is fond of telling tall stories, and his report was not taken very seriously, until, at the beginning of our century, the tunnel was actually found and excavated. It is no less than nine hundred yards long, complete with water-course and inspection-pathway, and its shape shows that it was begun from *both* ends. It further shows that the two digging parties, one working from the north, the other from the south, had met in the centre only a couple of feet apart. Having watched this fantastic feat being performed (by Eupalinos, who also built the second marvel mentioned by Herodotus, a huge mole to protect the Samian war-fleet), even a lesser genius than Pythagoras might have realized that Science may become a hymn to the creator or a Pandora's box, and that it should be trusted only to saints. It is said, incidentally, that Pythagoras, like St Francis,

preached to animals, which would seem rather odd behaviour in a modern mathematician; but in the Pythagorean view nothing could be more natural.

5. *Tragedy and greatness of the Pythagoreans*

Towards the end of the Master's life, or shortly after his death, two misfortunes befell the Pythagoreans, which would have meant the end of any sect or school with a less universal outlook. They triumphantly survived both.

One blow was the discovery of a type of numbers such as $\sqrt{2}$ – the square root of 2 – which could not be fitted into any dot-diagram. And such numbers were common: they are, for instance, represented by the diagonal of any square. Let the side of the square be called a, and the diagonal d. It can be proved that if I assign to a any precise numerical value, then it becomes impossible to assign a precise numerical value to d. The side and the square are 'incommensurable'; their ratio a/d cannot be represented by any real numbers or fractions thereof; it is an irrational' number; *it is both odd and even at the same time.** I can easily *draw* the diagonal of a square, but I cannot express its length in numbers – I cannot count the number of dots it contains. The point-to-point correspondence between arithmetic and geometry has broken down – and with it the universe of number-shapes.

It is said that the Pythagoreans kept the discovery of irrational numbers – they called them *arrhētos*, unspeakable – a secret, and that Hippasos, the disciple who let the scandal leak out, was put to death. There is also another version, in Proclos:[11]

* The simplest manner of proving this is as follows. Let d be represented by a fraction $\frac{m}{n}$, where m and n are unknown. Let $a=1$, then $d^2=1^2+1^2$ and $d=\sqrt{2}$. Then $\frac{m^2}{n^2}=2$. If m and n have a common factor, divide it out, then either m or n must be odd. Now $m^2=2n^2$, therefore m^2 is even, therefore m is even, therefore n is odd. Suppose $m=2p$. Then $4p^2=2n^2$, therefore $n=2p^2$ and therefore n is even, *contra hyp.* Therefore no fraction $\frac{m}{n}$ will measure the diagonal.

It is told that those who first brought out the irrationals from concealment into the open perished in shipwreck, to a man. For the unutterable and the formless must needs be concealed. And those who uncovered and touched this image of life were instantly destroyed and shall remain forever exposed to the play of the eternal waves.

Yet, Pythagoreanism survived. It had the elastic adaptability of all truly great ideological systems which, when some part is knocked out of them, display the self-regenerating powers of a growing crystal or a living organism. The mathematization of the world by means of atom-like dots proved a premature short-cut; but on a higher turn of the spiral, mathematical equations proved once again the most serviceable symbols for representing the physical aspect of reality. We shall meet with further examples of prophetic intuition supported by the wrong reasons; and we shall find that they are rather the rule than the exception.

Nobody before the Pythagoreans had thought that mathematical relations held the secret of the universe. Twenty-five centuries later, Europe is still blessed and cursed with their heritage. To non-European civilizations, the idea that numbers are the key to both wisdom and power, seems never to have occurred.

The second blow was the dissolution of the Brotherhood. We know little of its causes; it probably had something to do with the equalitarian principles and communist practices of the order, the emancipation of women, and its quasi-monotheistic doctrine – the eternal messianic heresy. But persecution remained confined to the Pythagoreans as an organized body – and probably prevented them from degenerating into sectarian orthodoxy. The Master's principal pupils – among them Philolaus and Lysis – who had gone into exile, were soon allowed to return to Southern Italy and to resume teaching. A century later, that teaching became one of the sources of Platonism, and thus entered the mainstream of European thought.

In the words of a modern scholar. 'Pythagoras is the founder

of European culture in the Western Mediterranean sphere.'[12] Plato and Aristotle, Euclid and Archimedes, are landmarks on the road; but Pythagoras stands at the point of departure, where it is decided which direction the road will take. Before that decision, the future orientation of Greco-European civilization was still undecided: it may have taken the direction of the Chinese, or Indian, or pre-Columbian cultures, all of which were still equally unshaped and undecided at the time of the great sixth-century dawn. I do not mean to say that if Confucius and Pythagoras had exchanged their places of birth, China would have beaten us to the Scientific Revolution, and Europe become a land of tea-sipping mandarins. The interactions of climate, race, and spirit, the directional influence of outstanding individuals on the course of History, are so obscure that no predictions are possible even in reverse; all 'if' statements about the past are as dubious as prophecies of the future are. It seems fairly plausible that if Alexander or Ghengis Khan had never been born, some other individual would have filled his place and executed the design of the Hellenic or Mongolic expansion; but the Alexanders of philosophy and religion, of science and art, seem less expendable; their impact seems less determined by economic challenges and social pressures; and they seem to have a much wider range of possibilities to influence the direction, shape, and texture of civilizations. If conquerors be regarded as the engine-drivers of History, then the conquerors of thought are perhaps the pointsmen who, less conspicuous to the traveller's eye, determine the direction of the journey.

3 The Earth Adrift

I have tried to give a brief general description of Pythagorean philosophy, including aspects of it that are only indirectly related to the subject of this book. In the following sections, some important schools of Greek philosophy and science – Eleatics and Stoics, Atomists and Hippocratics – will hardly be mentioned at all, until we arrive at the next turning point in cosmology, Plato and Aristotle. The development of man's views about the cosmos cannot be treated in isolation from the philosophical background which coloured these views; on the other hand, if the narrative is not to be swallowed up by the background, the latter can only be sketched in at certain turning points of the tale, where the general philosophical climate had a direct impact on cosmology and altered its course. Thus, for instance, the political views of Plato, or of the religious convictions of Cardinal Bellarmine, profoundly influenced astronomical developments for centuries, and must accordingly be discussed; whereas men like Empedokles and Democritus, Socrates, and Zeno, who had a lot to say about the stars, but nothing that is really relevant to our subject, must be passed in silence.

1. *Philolaus and the Central Fire*

From the end of the sixth century B.C. onward, the idea that the earth was a sphere, freely floating in air, made steady headway. Herodotus[1] mentions a rumour that there exist people far up in the north who sleep six months of the year – which shows that some of the implications of the earth's roundness (such as the polar night) had already been grasped. The next, revolutionary step was taken by a pupil of Pythagoras, Philolaus, the first philosopher to attribute *motion* to our globe. The earth became air-borne.

this tremendous innovation we
vas the realization that there is
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nd planets should turn round the
ame time slowly crawl along the
ions. Everything would be much
he *daily* revolution of the entire
' the earth's own motion. If the
hed in space, could she not also
)vious idea of letting the earth
t occur to Philolaus. Instead, he
)ur hours, round an extraneous
one complete circle a day, the
the illusion, like a traveller on a
osmic fair was turning in the

)ut, Philolaus placed the 'watch-
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fire' is not to be confused with
i; for the inhabited part of the
)urs – was always turned away
e moon is always turned away
ween the earth and the central
sible planet: the *antichton* or
apparently, to protect the anti-
' the central fire. The ancient
ions of the earth, beyond the
:d in eternal twilight[2] was now
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1 was invented merely to bring
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. revolved in concentric orbits
innermost, then the earth, the
ts; then came the sphere carry-
is outer shell there was a wall
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fire' was the second and main source from which the universe drew its light and breath. The sun served merely as a kind of transparent window or lens, through which the outer light was filtered and distributed. The picture reminds one of Anaximander's holes in the flame-filled tyre. But these fantastic imaginations were perhaps less fantastic than the notion of a ball of fire hurtling across the sky through eternity, without burning out; a preposterous idea at which the mind boggles. Looking at the sky with eyes washed clean of theories, is it not more convincing to regard the sun and stars as holes in the curtain enclosing the world?

The only heavenly object considered to be similar to the earth was the moon. It was supposed to be inhabited by plants and animals fifteen times as strong as ours, because the moon enjoyed daylight for fifteen days in succession. Other Pythagoreans thought that the lights and shadows on the moon were reflections of our oceans. As for eclipses, some were caused by the earth, some by the counter-earth, which also accounted for the faint ashen light on the lunar disc at new moon. Still others seem to have assumed the existence of several counter-earths. It must have been a lively debate.

2. *Herakleides and the Sun-Centred Universe*

In spite of its poetic oddities, the system of Philolaus opened up a new cosmic perspective. It broke away from the geocentric tradition – the sturdy conviction that this earth occupies the centre of the Universe, from which, massive and immobile, it never budges an inch.

But it was also a landmark in another direction. It separated neatly two phenomena which had previously been mixed up: the succession of day and night, that is, the *diurnal* rotation of the sky as a whole; and the *annual* motions of the seven wandering planets.

The next improvement of the model concerned the daily motions. The central fire dropped out; the earth, instead of going round it, was now made to spin on her own axis, like a

top. The reason was, presumably,[4] that the Greek seafarers' growing contacts with distant regions – from the Ganges to the Tagus, from the island of Thule to Taprobrana – had failed to produce any sign, or even rumour, of the central fire or the *antichton*, both of which should have been visible from the other side of the earth. I have said before that the Pythagoreans' world-view was elastic and adaptable. They did not drop the idea of the central fire as a source of heat and energy; but they transferred it from outer space into the core of the earth, and the counter-earth they simply identified with the moon.[5]

The next great pioneer in the Pythagorean tradition is Herakleides of Pontus. He lived in the fourth century B.C., studied under Plato, and presumably also under Aristotle; hence, by chronological order, he ought to be discussed after these. But I shall first follow the development of the Pythagorean cosmology, the boldest and most hopeful in antiquity, to its end – which came in the generation of Herakleides.

Herakleides took the earth's rotation round its own axis for granted. This explained the daily round of the skies, but left the problem of the annual motion of the planets untouched. By now, these annual motions had become the central problem of astronomy and cosmology. The multitude of fixed stars presented no problem. They never altered their positions relative to each other or to the earth.[6] They were a permanent guarantee of law and order and regularity in the universe, and could be imagined, without much difficulty, as a pattern of pin-heads (or pin-holes) in the celestial pin-cushion which either turned, as a unit, around the earth, or appeared to do so owing to the earth's rotation. But the planets, the tramp stars, moved with a shocking irregularity. Their only reassuring feature was that they all moved along the same narrow belt or lane looped around the sky (the Zodiac): which meant that their orbits all lay very nearly in the same plane.

To get an idea of how the Greeks perceived the universe, imagine all transatlantic traffic – submarines, ships, aircraft – to be confined to the same trade-route. The 'orbits' of all craft will then be along concentric circles round the earth's centre,

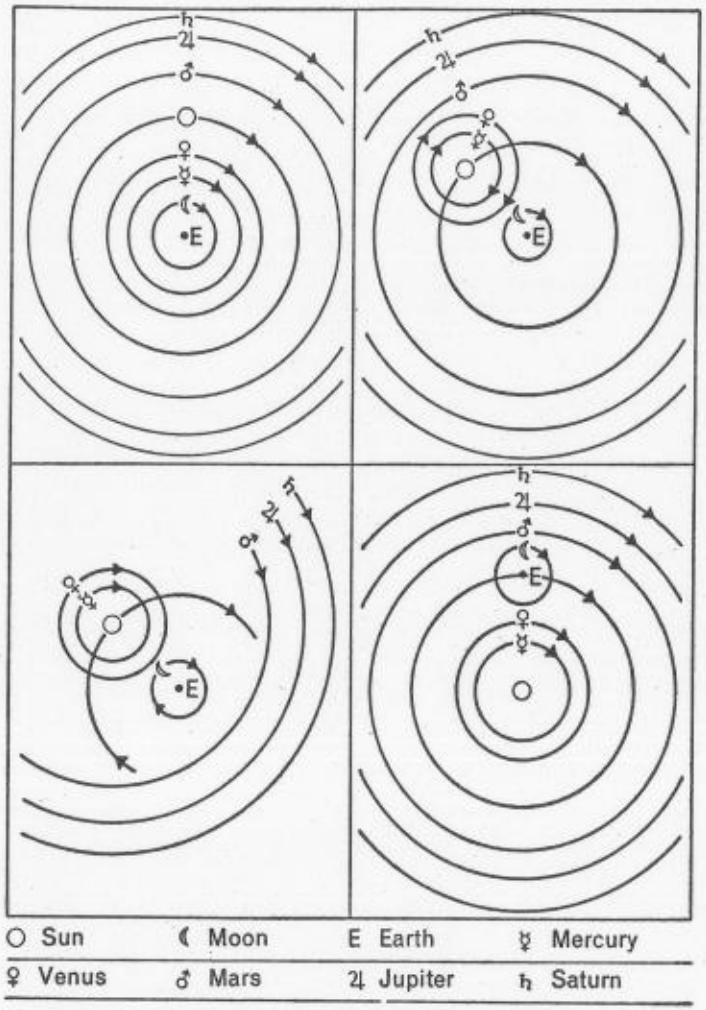
all in the same plane. Let an observer lie on his back in a cavity in the centre of the transparent earth, and watch the traffic. It will appear to him as points moving at different speeds along a single line: his zodiacal lane. If the transparent sphere is set rotating round the observer (who, himself, remains at rest) the traffic-lane will rotate with the sphere, but the traffic will still remain confined to this lane. The traffic consists of: two submarines ploughing the waters at different depths under the lane: they are the 'lower' planets, Mercury and Venus; then a single ship with blazing lights: the sun; then three aeroplanes at different heights: the 'upper' planets, Mars, Jupiter, and Saturn, in that order. Saturn would be very high up in the stratosphere; above it there is only the sphere of the fixed stars. As for the moon, she is so close to the observer in the centre, that she must be considered a ball rolling on the concave wall inside his cavity; but still in the same plane with all the other craft. This, then, in broad outlines, is the antique model of the world (Fig. A).

But model A could never be made to work properly. To our hind-sight, the reason is obvious: the planets were arranged in the wrong order; the sun should be in the centre, and the earth should take the sun's place between the 'lower' and 'upper' planets, taking the moon with her (Fig. D). This basic fault in the model caused incomprehensible irregularities in the apparent motions of the planets.

By the time of Herakleides, these irregularities had become the principal worry of the philosophers concerned with the universe. The sun and moon seemed to move in a more or less regular manner along the traffic lane; but the five planets travelled in a most erratic way. A planet would amble for a while along the lane, in the general direction of the traffic, West to East; but at intervals he would slow down, come to a stop as if he had reached a station in the sky, and retrace his steps; then change his mind again, turn round and resume his wandering in the original direction. Venus behaved even more capriciously. The pronounced periodical changes in her brightness and size seemed to indicate that she alternately approached and receded from us, and this suggested that she

(A) Classical geocentric system

(B) 'Egyptian' System of Herakleides



(C) System of Tycho de Brahe (and of Herakleides?)

(D) Aristarchus' heliocentric system

did not really move in a circle round the earth, but along some unthinkable, wavy line. Moreover, both she and Mercury, the second inner planet, now raced ahead of the steadily moving sun, now fell behind, but always stuck close to him, like dolphins playing around a ship. Accordingly, Venus at times apeared as Phosphoros the 'morning star', rising with the sun in her wake, at other times as Hesperos the 'evening star' at the sun's tail; Pythagoras seems to have been the first to recognize that they were one and the same planet.

Once more, in the rear-view mirror, Herakleides' solution of the puzzle seems simple enough. If Venus moved in an irregular manner relative to the earth, the supposed centre of her orbit, yet danced attendance to the sun, then she obviously was attached to the sun, and not to the earth: she was a satellite of the sun. And since Mercury behaved in the same manner, both inner planets must revolve round the sun – and with the sun round the earth, like a wheel turning on a wheel.

Figure B on page 48 explains at a single glance why Venus alternately approaches and recedes from the earth; why she is at times ahead of, at others behind, the sun; and also why she intermittently moves in reverse gear along the Zodiacal lane.[7]

It all looks beautifully obvious – in the rear mirror. But there are situations where it needs great imaginative power, combined with disrespect for the traditional current of thought, to discover the obvious. The scant information we have about the personality of Herakleides shows that he had both: originality, and contempt for academic tradition. He was nicknamed by his acquaintances the *paradoxolog* – a maker of paradoxes; Cicero relates that he was fond of telling 'puerile fables' and 'marvellous stories'; and Proclus tells us that he had the audacity to contradict Plato, who taught the immobility of the earth.[8]

The idea that the two lower planets – and only these two – were satellites of the sun, while the sun itself and the remaining planets still revolved round the earth, became later known by the misnomer 'Egyptian System' and gained great popularity (Fig. B, p. 48). It was evidently a half-way house between the geocentric (earth-centred) and heliocentric (sun-centred)

conceptions of the universe. We do not know whether Herakleides stopped there, or whether he took the further step of letting the three outer planets also go around the sun, and the sun, with all his five satellites, go round the earth (Fig. C, p. 48). It would have been a logical step, and some modern scholars believe that Herakleides did reach this three-quarter-way house.[9] Some even believe that he also took the ultimate step of making *all* the planets, including the earth, revolve around the sun.

But whether he went the whole way to the modern conception of the solar system or not, is merely a matter of historic curiosity, for his successor, Aristarchus, certainly did.

3. *The Greek Copernicus*

Aristarchus, last of the line of the Pythagorean astronomers, came, like the Master, from Samos; and he is supposed to have been born, symbolically, in the same year, 310 B.C., in which Herakleides died.* Only one short treatise of his survives: *On the Sizes and Distances of the Sun and Moon*. It shows that he had the basic gifts required of a modern scientist: originality of thought and meticulousness in observation. The elegant method he designed for calculating the distance of the sun was followed by astronomers throughout the Middle Ages; if his actual figures were wrong, it was due to the fact that he was born two thousand years before the telescope. But though an equal distance separated him from the invention of the pendulum clock, he improved the estimates of the length of the solar year by adding 1/1623 to the previous estimate of 365¼ days.

The treatise in which Aristarchus proclaimed that the sun, not the earth, was the centre of our world around which all planets revolve – this crowning achievement of Pythagorean cosmology, which Copernicus was to rediscover seventeen

* These dates are rather conjectural. But astronomers have a knack for timing their life-orbits: Galileo died in the year Newton was born; and Newton was born exactly a hundred years after Copernicus died.

centuries later – is lost. But fortunately, we have the testimony of no smaller authorities than Archimedes and Plutarch, among others; and the fact that Aristarchus taught the heliocentric system is unanimously accepted by the ancient sources and modern scholars.

Archimedes, the greatest mathematician, physicist, and inventor of antiquity, was a younger contemporary of Aristarchus. One of his most curious works is a little treatise called *The Sand Reckoner*, dedicated to King Gelon of Syracuse. It contains the crucial phrase: 'For he (Aristarchus of Samos) supposed that the fixed stars and the sun are immovable, but that the earth is carried round the sun in a circle. . . .'[10]

Plutarch's reference to Aristarchus is equally important. In his treatise *On the Face in the Moon Disc*, one of the characters refers to Aristarchus of Samos who thought 'that the heaven is at rest, but that the earth revolves in an oblique orbit, while it also rotates about its own axis'.[11]

Thus Aristarchus of Samos had carried the development which started with Pythagoras and was continued by Philolaus and Herakleides, to its logical conclusion: the sun-centred universe. But here the development comes to an abrupt end. Aristarchus had no disciples and found no followers.[12] For nearly two millennia the heliocentric system was forgotten – or, shall one say, repressed from consciousness? – until an obscure Canon in Varmia, a remote outpost in Christendom, picked up the thread where the Samian had left off.

This paradox would be easier to understand if Aristarchus had been a crank, or a dilettante whose ideas were not taken seriously. But his treatise *On the Sizes and Distances of the Sun and Moon* became a classic of antiquity, and shows him as one of the foremost astronomers of his time; his fame was so great that nearly three centuries later Vitruvius, the Roman architect, starts his list of universal geniuses of the past with: 'Men of this type are rare, men such as were in times past Aristarchus of Samos. . . .'[13]

In spite of all this, his correct hypothesis was rejected in favour of a monstrous system of astronomy, which strikes us today as an affront to human intelligence, and which reigned

supreme for fifteen hundred years. The reasons for this benightedness will emerge only gradually, for we are faced here with one of the most astonishing examples of the devious, nay crooked ways of the 'Progress of Science' – which is one of the main topics of this book.

4 The Failure of Nerve

1. *Plato and Aristotle*

By the end of the third century, B.C., the heroic period of Greek science was over. From Plato and Aristotle onward, natural science begins to fall into disrepute and decay, and the achievements of the Greeks are only rediscovered a millennium and a half later. The Promethean venture which had started around 600 B.C., had within three centuries spent its elan; it was followed by a period of hibernation, which lasted five times as long.

From Aristarchus there is, logically, only one step to Copernicus; from Hippocrates, only a step to Paracelsus; from Archimedes, only a step to Galileo. And yet the continuity was broken for a time-span nearly as long as that from the beginning of the Christian era to our day. Looking back at the road along which human science travelled, one has the image of a destroyed bridge with rafters jutting out from both sides; and in between, nothing.

We know all this happened; if we knew exactly why it happened, we would probably have the remedy to the ills of our own time. For the breakdown of civilization during the Dark Ages is in some respects the reverse of the breakdown that started, though less dramatically, in the Age of Enlightenment. The former can be broadly described as a withdrawal from the material world, contempt for knowledge, science, and technology; rejection of the body and its pleasures in favour of the life of the spirit. It reads like a mirror-writing to the tenets of the age of scientific materialism which begins with Galileo and ends with the totalitarian state and the hydrogen bomb. They have only one factor in common: the divorce of reason from belief.

On the watershed that separates the heroic age of science from the age of its decline, stand the twin peaks, Plato and

Aristotle. Two quotations may illustrate the contrast in philosophical climate on the two sides of the watershed. The first is a passage from a writer belonging to the Hippocratic school, and dates presumably from the fourth century B.C. 'It seems to me,' he says, dealing with that mysterious affliction, epilepsy, 'that the disease is no more "divine" than any other. It has a natural cause, just as other diseases have. Men think it divine merely because they do not understand it. But if they called everything divine which they do not understand, why, there would be no end of divine things!'[1] The second quotation is from Plato's *Republic* and sums up his attitude to astronomy. The stars, he explains, however beautiful, are merely part of the *visible* world which is but a dim and distorted shadow or copy of the *real* world of ideas; the endeavour to determine exactly the motions of these imperfect bodies is therefore absurd. Instead: 'let us concentrate on (abstract) problems, said I, in astronomy as in geometry, and dismiss the heavenly bodies, if we intend truly to apprehend astronomy'.[2]

Plato is equally hostile to the Pythagoreans' first and favourite branch of science. 'The teachers of harmony,' he lets Socrates complain, 'compares the sounds and consonances which are heard only, and their labour, like that of the astronomers, is vain'.[3]

None of this was probably meant to be taken quite literally, but it was – by that extremist school of Neoplatonism which dominated Western philosophy for several centuries, and stifled all progress in science – until, in fact, Aristotle was rediscovered and interest in nature revived. I have called them twin peaks separating two epochs of thought; but insofar as their influence on the future is concerned, Plato and Aristotle should rather be called twin-stars with a single centre of gravity, which circle round each other and alternate in casting their light on the generations that succeed them. Until the end of the twelfth century, as we shall see, Plato reigned supreme; then Aristotle was resurrected and remained for two hundred years *the* philosopher, as he was commonly called; then Plato made a come-back, in an entirely different guise. Professor

Whitehead's famous remark: 'the safest general characterization of the European philosophical tradition is that it consists in a series of footnotes to Plato' could be amended by: 'Science, up to the Renaissance, consisted in a series of footnotes to Aristotle.'

The secret of their extraordinary influence, intermittently stimulating and choking European thought, during such a near-astronomical period, has been the subject of passionate and never-ending controversy. It is, of course, not due to any single reason, but to the confluence of a multitude of causes at a particularly critical point of history. To mention only a few, starting with the most obvious: they are the first philosophers of antiquity whose writings survived not in odd fragments, in second- or third-hand quotations, but in massive bulk (Plato's authenticated dialogues alone make a volume of the length of the Bible), embracing all domains of knowledge and the essence of the teachings of those who came before them; as if after an atomic war, among the torn and charred fragments, a complete *Encyclopaedia Britannica* had been preserved. Apart from bringing together all the relevant items of available knowledge in an individual synthesis, they were of course, in their own right, original thinkers of great creative power in such varied fields as metaphysics, biology, logics, epistemology, and physics. They both founded 'schools' of a new kind: the first Academy and the first Lyceum, which survived for centuries as organized institutions, and transformed the founders' once fluid ideas into rigid ideologies, Aristotle's hypotheses into dogmas, Plato's visions into theology. Then again, they were truly twin-stars, born to complement each other; Plato the mystic, Aristotle the logician; Plato the belittler of natural science, Aristotle the observer of dolphins and whales; Plato, the spinner of allegorical yarns, Aristotle the dialectician and casuist; Plato, vague and ambiguous, Aristotle precise and pedantic. Lastly – for this catalogue could be continued forever – they evolved systems of philosophy which, though different and even opposed in detail, taken jointly seemed to provide a complete answer to the predicament of their time.

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formulations, but not only does he regard slavery as the natural basis of the social order – 'the slave is totally devoid of any faculty of reasoning'[6]; he also deplores the existence of a 'middle' class of free artisans and professional men, because their superficial resemblance to the rulers brings discredit on the latter. Accordingly, all professionals are to be deprived of the rights of citizenship in the Model State. It is important to understand the source of this contempt of Aristotle for artisans, craftsmen, architects, engineers, and the like – by contrast, say, to the high esteem in which an Eupalinos, the tunnel-builder, had been held in Samos. The point is that Aristotle believed them no longer to be necessary, because *applied science and technology had already completed their task*. Nothing further need, or could, be invented to make life more comfortable and enjoyable, because 'nearly all requisites of comfort and social refinement have been secured' and 'everything of these kinds has already been provided'.[7] Pure science and philosophy 'which deal neither with the necessities nor with the enjoyment of life' only arose, in Aristotle's view, after the practical sciences had done all that they can ever do, and material progress had come to a halt.

Even these cursory remarks may indicate the general mood underlying these philosophies: the unconscious yearning for stability and permanence in a crumbling world where 'change' can only be a change for the worse, and 'progress' can only mean progress toward disaster. 'Change' for Plato is virtually synonymous with degeneration; his history of creation is a story of the successive emergence of ever lower and less worthy forms of life – from God who is pure self-contained Goodness, to the World of Reality which consists only of perfect Forms or Ideas, to the World of Appearance, which is a shadow and copy of the former; and so down to man: 'Those of the men first created who led a life of cowardice and injustice were suitably reborn as women in the second generation, and this is why it was at this particular juncture that the gods contrived the lust for copulation.' After the women we come to the animals: 'Beasts who go on all fours came from men who were wholly unconversant with philosophy and had never gazed

on the heavens'.[8] It is a tale of the Fall in permanence: a theory of *descent* and *devolution* – as opposed to evolution by ascent.

As so often with Plato, it is impossible to say whether all this is to be taken literally, or allegorically, or as an esoteric leg-pull. But there can be no doubt concerning the basic trend of the whole system.

We shall have to hark back time and again to Plato, to pick up the scent of some particular later development. For the time being, let us retain this essential clue to Plato's cosmology: his fear of change, his contempt and loathing for the concepts of evolution and mutability. It will reverberate all through the Middle Ages, together with its concomitant yearning for a world of eternal, changeless perfection:

> Then agin I think on that which Nature said
> Of that same time when no more change shall be,
> But steadfast rest of all things, firmly stay'd
> Upon the pillars of eternity,
> That is contrary to mutability.[9]

This 'mutation phobia' seems to be mainly responsible for the repellent aspects of Platonism. The Pythagorean synthesis of religion and science, of the mystical and empirical approach is now in shambles. The mysticism of the Pythagoreans is carried to sterile extremes, while empirical science is ridiculed and discouraged. Physics is separated from mathematics and made into a department of theology. The Pythagorean Brotherhood is transformed into the Guides of a totalitarian Utopia; the transmigration of souls on their way to God is debased by old-wife's tales, or edifying lies, about cowards being punished by feminine reincarnations; orphic asceticism curdles into hatred of the body and contempt for the senses. True knowledge cannot be obtained by the study of nature; for 'if we would have true knowledge of anything, we must be quit of the body. ... While in company with the body, the soul cannot have true knowledge'.[10]

All this is not an expression of humility – neither of the humility of the mystic seeker for God, nor the humility of

reason acknowledging its limits; it is the half-frightened, half-arrogant philosophy of the genius of a doomed aristocracy and a bankrupt civilization. When reality becomes unbearable, the mind must withdraw from it and create a world of artificial perfection. Plato's world of pure Ideas and Forms, which alone is to be considered as real, whereas the world of nature which we perceive is merely its cheap Woolworth copy, is a flight into delusion. The intuitive truth expressed in the allegory of the Cave is here carried to absurdity by over-concretization – as if the author of the line 'this world is a vale of tears' were to proceed with a factual survey of the distribution of tear-drops in the vale.

Once again one must remember, that in the surrealistic cosmogony of the *Timaeus* it is impossible to draw the line between philosophy and poetry, metaphorical and factual statement; and that long passages in the *Parmenides* virtually destroy the doctrine that the world is a copy of models in heaven. But if some of my previous paragraphs sound like a harsh and one-sided view of what Plato meant, this is essentially *what he came to mean* to a long row of future generations – the one-sided shadow that he threw. We shall also see that the *second* Platonic revival, in the fifteenth century, highlighted a quite different side of Plato, and threw his shadow into the opposite direction. But that turn is still a long way ahead.

2. *Rise of the Circular Dogma*

I must now turn to Plato's contribution to astronomy – which insofar as concrete advances are concerned, is nil; for he understood little of astronomy, and was evidently bored by it. The few passages where he feels moved to broach the subject are so muddled, ambiguous, or self-contradictory, that all scholarly efforts have failed to explain their meaning.[11]

However, by a process of metaphysical and *a priori* reasoning, Plato came to certain general conclusions regarding the shape and motions of the universe. These conclusions, of paramount importance for everything which follows, were

that *the shape of the world must be a perfect sphere, and that all motion must be in perfect circles at uniform speed.*

And he gave the universe the figure which is proper and natural. ... Wherefore he turned it, as in a lathe, round and spherical, with its extremities equidistant in all directions from the centre, the figure of all figures most perfect and most like to itself, for he deemed the like more beautiful than the unlike. To the whole he gave, on the outside round about, a surface perfectly finished and smooth, for many reasons. It had no need of eyes, for nothing visible was left outside it; nor of hearing, for there was nothing audible outside it; and there was no breath outside it requiring to be inhaled. ... He allotted to it the motion which was proper to its bodily form, that motion of the seven motions which is most bound up with understanding and intelligence. Wherefore, turning it round in one and the same place upon itself, he made it move with circular rotation; all the other six motions [i.e., straight motion up and down, forward and back, right and left] he took away from it and made it exempt from their wanderings. And since for this revolution it had no need of feet, he created it without legs and without feet. ... Smooth and even and everywhere equidistant from the centre, a body whole and perfect, made up of perfect bodies. ...[12]

Accordingly, the task of the mathematicians was now to design a system which would reduce the apparent irregularities in the motions of the planets to regular motions in perfectly regular circles. This task kept them busy for the next two thousand years. With his poetic and innocent demand, Plato laid a curse on astronomy, whose effects were to last till the beginning of the seventeenth century, when Kepler proved that planets move in oval, and not circular orbits. There is perhaps no other example in the history of thought of such dogged, obsessional persistence in error, as the circular fallacy which bedevilled astronomy for two millennia.

But here again, Plato had merely thrown out, in semi-allegorical language, a suggestion which was quite in keeping with the Pythagorean tradition; it was Aristotle who promoted the idea of circular motion to a dogma of astronomy.

3. *The Fear of Change*

In Plato's world the boundaries between the metaphorical and the factual are fluid; all such ambiguity disappears as Aristotle takes over. With pedantic thoroughness the vision is dissected, its poetic tissue is preserved *in vitro*, its volatile spirit condensed and frozen. The result is the Aristotelian model of the universe.

The Ionians had prised the world-oyster open, the Pythagoreans had set the earth-ball adrift in it, the Atomists dissolved its boundaries in the infinite. Aristotle closed the lid again with a bang, shoved the earth back into the world's centre, and deprived it of motion.

I shall describe the model first in its broad outline, and fill in the details later.

The immobile earth is surrounded, as in the earlier cosmologies, by nine concentric, transparent spheres, enclosing each other like the skins of an onion (see Fig. A, p. 48). The innermost skin is the sphere of the moon; the two outermost are the sphere of the fixed stars, and beyond that, the sphere of the Prime Mover, who keeps the whole machinery turning: God.

The God of Aristotle no longer rules the world from the inside, but from the outside. It is the end of the Pythagorean central fire, the hearth of Zeus, as a divine source of cosmic energy; the end of Plato's mystic conception of the *anima mundi*, of the world as a living animal possessed with a divine soul. Aristotle's God, the Unmoved Mover, who spins the world round from outside it, is the God of abstract theology. Goethe's '*Was wär' ein Gott der nur von aussen stiesse*' – seems to be aimed directly at him. The removal of God's home from the centre to the periphery automatically transformed the central region, occupied by earth and moon, into the farthest away from Him: the humblest and lowliest of the whole universe. The space enclosed by the sphere of the moon and containing the earth – the 'sub-lunary region' – is now considered definitely non-U. To this region, and to this region alone, are the horrors of Change, of mutability confined. Beyond the sphere of the moon, the heavens are eternal and unalterable.

This splitting-up of the universe into two regions, the one lowly, the other exalted, the one subject to change, the other not, was to become another basic doctrine of medieval philosophy and cosmology. It brought a serene, cosmic reassurance to a frightened world by asserting its essential stability and permanence, but without going so far as to pretend that all change was mere illusion, without denying the reality of growth and decline, generation and destruction. It was not a reconciliation of the temporal and the eternal, merely a confrontation of the two; but to be able to take in both in one glance, as it were, was something of a comfort.

The division was made intellectually more satisfactory and easier to grasp, by assigning to the two parts of the universe different raw materials and different motions. In the sub-lunary region, all matter consisted of various combinations of the four elements, earth, water, air, and fire, which themselves were combinations of two pairs of opposites, hot and cold, dry and wet. The nature of these elements requires that they move in straight lines: earth downward, fire upward, air and water horizontally. The atmosphere fills the whole sub-lunary sphere, though its upper reaches consist not of proper air, but of a substance which, if set in motion, will burn and produce comets and meteors. The four elements are constantly being transformed one into the other, and therein lies the essence of all change.

But if we go beyond the moon's sphere, nothing changes, and none of the four terrestrial elements is present. The heavenly bodies consist of a different, pure, and immutable 'fifth element', which becomes the purer the farther away from the earth. The natural motion of the fifth element, as opposed to the four earthly elements, is circular, because the sphere is the only perfect form, and circular motion is the only perfect motion. Circular motion has no beginning and no end; it returns into itself and goes on forever: it is motion without change.

The system had yet another advantage. It was a compromise between two opposite trends in philosophy. On the one side there was the 'materialistic' trend, which had started with the Ionians, and was continued by men like Anaxagoras, who

believed that *homo sapiens* owed his superiority to the dexterity of his hand; by Heraklitus, who regarded the universe as a product of dynamic forces in eternal flux; and culminated in Leucippus and Democritus, the first atomists. The opposite tendency, which originated with the Eleatics, found its extreme expression in Parmenides, who taught that all apparent change, evolution and decline, were illusions of the senses, because whatever exists cannot arise from anything that does not, or is different from it; and that the Reality behind the illusion is indivisible, unchangeable, and in a state of static perfection. Thus for Heraklitus Reality is a continuous process of Change and Becoming, a world of dynamic stresses, of creative tensions between opposites; whereas for Parmenides Reality is a solid, uncreated, eternal, motionless, changeless, uniform sphere.[13]

The preceding paragraph is, of course, a woeful over-simplification of developments in one of the liveliest periods of philosophic debate; but my purpose is merely to show how neatly the Aristotelian model of the universe solved the basic dilemma by handing over the sub-lunary region to the Materialists, and letting it be governed by Heraklitus' motto 'all is change'; whereas the rest of the universe, eternal and immutable, stood in the sign of the Parmenidian 'nothing ever changes'.

Once again, it was not a reconciliation, merely a juxtaposition, of two world-views, or 'world-feelings', both of which have a profound appeal to the minds of men. This appeal was increased in power when, at a later stage, mere juxtaposition yielded to *gradation* between the opposites; when the original Aristotelian two-storey universe – all basement and loft – was superseded by an elaborately graded, multi-storeyed structure; a cosmic hierarchy where every object and creature had its exact 'place' assigned to it, because its position in the many-layered space between lowly earth and high heaven defined its rank on the Scale of Values, in the Chain of Being. We shall see that this concept of a closed-in cosmos graded like the Civil Service (except that there was no advancement, only demotion) survived for nearly a millennium and a half. It was really a Mandarin Universe. During these long centuries, European

thought had more in common with Chinese or Indian philosophy than with its own past and future.

However, even if European philosophy were only a series of footnotes to Plato, and even though Aristotle had a millennial stranglehold on physics and astronomy, their influence, when all is said, depended not so much on the originality of their teaching, as on a process of natural selection in the evolution of ideas. Out of a number of ideological mutations, a given society will select that philosophy which it unconsciously feels to be best suited for its need. Each time, in subsequent centuries, when the cultural climate changed in Europe, the twin stars also changed their aspect and colour: Augustine and Aquinas, Erasmus and Kepler, Descartes and Newton each read a different message in them. Not only did the ambiguities and contradictions in Plato, the dialectical twists in Aristotle, admit a wide range of interpretations and shifts of emphasis; but, by taking the two jointly or in alternation, by combining selected facets of each, the total effect could virtually be reversed; we shall see that the 'New Platonism' of the sixteenth century was in most respects the opposite of the Neoplatonism of the early Middle Ages.

In this context I must briefly return to Plato's loathing for change – for 'generation and decay' – which made the sublunary sphere such a disreputable slum-district of the universe. Aristotle himself did not share this loathing. As a keen biologist, he regarded all change, all movement in nature as purposeful and goal-directed – even the motions of inanimate bodies: a stone will fall to the earth, as a horse will canter to its stable, because that is its 'natural place' in the universal hierarchy. We shall have occasion, later on, to marvel at the disastrous effects of this Aristotelian brainwave on the course of European science; at the moment, I merely wish to point out that Aristotle's attitude to Change, though he rejects evolution and progress, is not quite as defeatist as Plato's.[14] Yet Neoplatonism, in its dominant trend, ignores Aristotle's dissent on this essential point, and manages to make the worst of both worlds. It adopts the Aristotelian scheme of the universe, but makes the sublunary sphere a Platonic vale of shadows; it follows the Platonic

doctrine of the natural world as a dim copy of ideal Forms – which Aristotle rejected – yet follows Aristotle in placing the Prime Mover outside the confines of the world. It follows both in their anxious effort to build a walled-in universe, protected against the Barbarian incursions of Change; a nest of spheres-within-spheres, eternally revolving in themselves, yet remaining in the same place; thus hiding its one shameful secret, that centre of infection, safely isolated in the sub-lunary quarantine.

In the immortal parable of the Cave, where men stand in their chains backs to the light, perceiving only the play of shadows on the wall, unaware that these are but shadows, unaware of the luminous reality outside the Cave – in this allegory of the human condition, Plato hit an archetypal chord as pregnant with echoes as Pythagoras' Harmony of the Spheres. But when we think of Neoplatonism and scholasticism as concrete philosophies and precepts of life, we may be tempted to reverse the game, and to paint a picture of the founders of the Academy and the Lyceum as two frightened men standing in the self-same Cave, facing the wall, chained to their places in a catastrophic age, turning their back on the flame of Greece's heroic era, and throwing grotesque shadows which are to haunt mankind for a thousand years and more.

5 The Divorce from Reality

1. *Spheres Within Spheres (Eudoxus)*

In a closed universe, where the fixed stars offered as yet no specific problems, the challenge to understanding came from the planets; the chief task of cosmology was to devise a system which explained how sun, moon, and the remaining five planets moved.

This task was further narrowed down when Plato's dictum that all heavenly bodies move in perfect circles, became the first Academic dogma in the first institution that bore that solemn name. The task of Academic astronomy was now to prove that the apparently irregular meanderings of the planets were the result of some combination of several simple, circular, uniform motions.

The first serious attempt was made by Plato's pupil Eudoxus, and improved by the latter's pupil, Calippus. It is an ingenious attempt – Eudoxus was a brilliant mathematician, to whom most of Euclid's fifth book is due. In the earlier geocentric models of the universe, each planet, we remember, was attached to a transparent sphere of its own, and all spheres were turning round the earth. But, since this did not account for the irregularities of their motions, such as standing occasionally still and going backward for a while: their 'stations' and 'retrogressions', Eudoxus assigned to each planet not one, but several spheres. The planet was attached to a point on the equator of a sphere, which rotates round its axis, A. The two ends of this axis are let into the inner surface of a concentric larger sphere S_2, which rotates round a different axis, A_2 and carries A around with it. The axis of S_2 is attached to the next larger sphere S_3, which rotates again round a different axis A_3: and so on. The planet will thus participate in all the independent rotations of the various spheres which form its 'nest'; and by letting each sphere rotate at the appropriate tilt and speed, it

was possible to reproduce roughly – though only very roughly – the actual motion of each planet.[1] The sun and moon needed a nest of three spheres each, the other planets four spheres each, which (with the modest single sphere assigned to the multitude of fixed stars) made altogether twenty-seven spheres. Calippus improved the system at the price of adding seven more spheres, making a total of thirty-four. It is at this point that Aristotle came in.

In the previous chapter I concentrated on the broad outlines and the metaphysical implications of Aristotle's universe, without going into astronomical detail. Thus I spoke of the classic *nine* spheres, from the moon's sphere to that of the Prime Mover (which alone were, in fact, remembered during the Middle Ages), without mentioning that each of these nine spheres was actually a nest of spheres-within-spheres. In reality, Aristotle used altogether fifty-four spheres to account for the motions of the seven planets. The reason for this additional investment of twenty spheres is interesting. Eudoxus and Calippus were not concerned with constructing a model that would be physically possible; they were not concerned with the real machinery of the heavens; they constructed a purely geometrical device, which, they knew, could exist only on paper. Aristotle wanted to do better, and transform it into a true physical model. The difficulty about this was that all adjoining spheres must be mechanically connected, yet the individual motion of each planet must not be transmitted to the others. Aristotle tried to solve this problem by inserting a number of 'neutralizing' spheres, which turned in the opposite direction to the 'working spheres', between two successive nests; in this manner, the effect of the motions of, say, Jupiter on his neighbour was eliminated, and the nest of Mars could be started from scratch, as it were. But insofar as the reproduction of the actual planetary motions is concerned, Aristotle's model was no improvement.

Besides, another difficulty remained. While each sphere participated in the motion of the next larger one enclosing it, it needed a special moving force to impart to it its independent rotation on its own axis; which meant, that there had to be no

less than fifty-five 'unmoved movers', or spirits, to keep the system going.

It was an extremely ingenious system – and completely mad, even by contemporary standards; as shown by the fact that in spite of Aristotle's enormous prestige, it was quickly forgotten and buried. Yet it was only the first of several equally ingenious and equally mad systems which astronomers created out of their tortured brains, in obedience to Plato's post-hypnotic suggestion that all heavenly motion must be circular motion centred round the earth.

There was also a certain dishonesty about it. The spheres of Eudoxus could account – however imprecisely – for the existence of 'stations' and 'retrogressions' in the progress of a planet; but it could never account for the variations in size and brightness, caused by variations of the planet's distance from the earth. These were particularly evident in the case of Venus and Mars, and most of all, the moon: thus central eclipses of the sun are 'annular' or 'total', according to the moon's momentary distance from the earth. Now all this was known before Eudoxus, and thus to Eudoxus himself as well as to Aristotle;[2] yet their system simply ignores the fact: however complicated the planet's motion is, it is confined to a sphere centred on the earth, and its distance to the earth can therefore never vary.

It was this unsatisfactory state of affairs which gave rise to the unorthodox branch of cosmology developed by Herakleides and Aristarchus (*see* Chapter III). The system of Herakleides eliminated (though merely for the inner planets) *both* the most conspicuous scandals: the 'stations-and-retrogressions', and the varying distances from the earth. Moreover, it explained (as a glance at Fig. B on p. 48 will show) the logical relatedness of the two scandals: why Venus was always brightest when she was moving crabwise, and vice versa. When Herakleides and/or Aristarchus made the remaining planets, including the earth, move round the sun, Greek science was on the straight road to the modern universe; then abandoned it again. Aristarchus' sun-centred model was discarded as a freak; and academic science marched on triumphantly from Plato, via Eudoxus, and Aristotle's fifty-five spheres, to an even more ingenious and

improbable artefact: the maze of epicycles devised by Claudius Ptolemy.

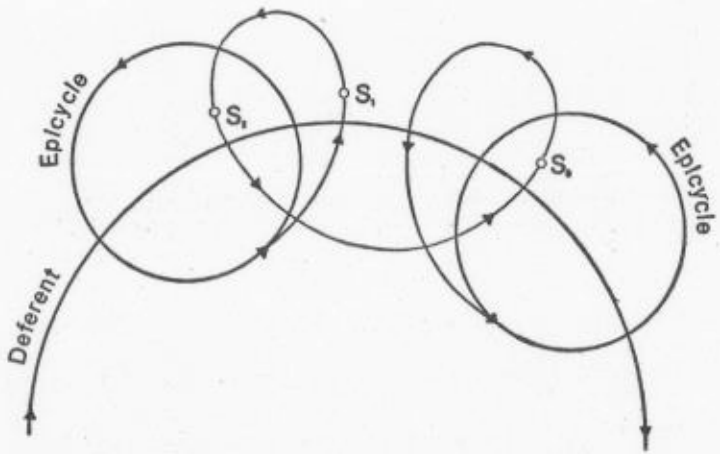
2. *Wheels Within Wheels (Ptolemy)*

If we call Aristotle's world an onion universe, we might as well call Ptolemy's the Ferris Wheel universe. It was begun by Apollonius of Perga in the third century B.C., developed by Hipparchus of Rhodes in the century that followed, and completed by Ptolemy of Alexandria in the second century A.D. The Ptolemaic system remained, with minor modifications, the last word in astronomy until Copernicus.

Any rhythmic movement, even the dance of a bird, can be imagined as being caused by a clockwork in which a great number of invisible wheels cooperate to produce the motions. Ever since 'uniform circular motion' had become the law governing the heavens, the task of astronomy was reduced to designing, on paper, just such imaginary clockworks which explained the dance of the planets as a result of the gyrations of perfectly circular, ethereal components. Eudoxus had used spheres as components; Ptolemy used wheels.

It is perhaps easiest to visualize the Ptolemaic universe not as an ordinary clockwork, but a system of 'Big Wheels' or 'Ferris Wheels' as one sees them in amusement parks – a huge, upright, slowly revolving wheel with seats or small cabins hanging suspended from its rim. Let us imagine the passenger safely strapped to his seat in the little cabin, and let us further imagine that the machinery has gone crazy – the cabin, instead of hanging down quietly from the rim of the Big Wheel, rotates wildly round the pivot from which it is suspended, while the pivot itself revolves slowly with the Wheel. The unhappy passenger – or planet – is now describing a curve in space which is not a circle, but is nevertheless produced by a combination of circular motions. By varying the size of the Wheel, the length of the arm by which the cabin is suspended, and the speeds of the two rotations, an amazing variety of curves can be produced, such as the one shown on the diagram – but also kidney-shaped curves, garlands, ovals, and even straight lines!

Seen from the earth, which is in the centre of the Big Wheel, the planet-passenger in the cabin will move clockwise until he reaches the 'stationary point' S_1, then regress anti-clockwise to S_2, then move again clockwise to S_3, and so on.* The rim of the Big Wheel is called the *deferent*, and the circle described by

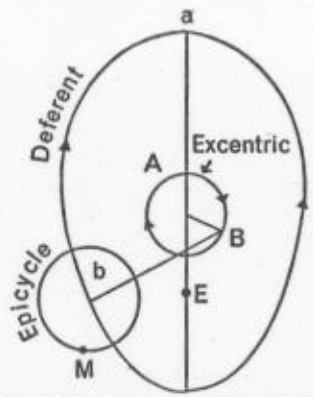


the cabin is called the *epicycle*. By choosing a suitable ratio between the diameters of epicycle and deferent, and suitable velocities for each, it was possible to achieve a fair approximation to the observed motions of the planet, insofar as the 'stations and retrogressions', and its varying distances from the earth were concerned.

These, however, were not the only irregularities in the planetary motions. There was yet another scandal, due (as we today know) to the fact that their orbits are not circular, but elliptic, that is, oval-shaped; they 'bulge'. To do away with this anomaly, another device was brought in, called a 'movable eccentric': the hub of the Big Wheel no longer coincided with

* At this point the reader may think that I am repeating myself – for the diagram on this page seems to express the same idea as Fig. B on p. 48 – the idea of Herakleides. But there is a difference: in Herakleides' scheme the planet's epicycle is centred on the sun. In Ptolemy's, it is centred on nothing. It is a purely geometrical construction.

the earth, but moved on a small circle in the vicinity of the earth; and in this manner a suitably eccentric, i.e. 'bulgy' orbit, was produced.*



Egg-shaped Orbit of Mercury, according to Ptolemy:
E = Earth; M = Mercury.

In the figure above, the hub of the Big Wheel moves clockwise on the small circle, from A to B; the point on the rim from which the cabin is suspended moves anti-clockwise in an egg-shaped curve from a to b; and the cabin spins round the final epicycle. But this was not enough; in the case of some recalcitrant planets it was found necessary to suspend a second cabin from the cabin suspended on the Big Wheel, with a different radius and a different speed; and then a third, fourth, and fifth, until the passenger in the ultimate cabin did indeed describe a trajectory more or less conforming to the one he was meant to describe.

By the time the Ptolemaic system was perfected, the seven passengers, sun, moon, and five planets, needed a machinery of not less than thirty-nine wheels to move through the sky; the outermost wheel, which carried the fixed stars, made the number an even forty. This system was still the only one recognized

* The 'movable eccentric' is in fact merely a kind of epicycle-in-reverse; and since the two are geometrically interchangeable, I shall use the term 'epicycle' for both.

by academic science in Milton's day – and was caricatured by him in a famous passage of *Paradise Lost*:

> From man or angel the great Architect
> Did wisely to conceal, and not divulge,
> His secret to be scanned by them who ought
> Rather admire; or, if they list to try
> Conjecture, he his fabric of the Heavens
> Hath left to their disputes, perhaps to move
> His laughter at their quaint opinions wide
> Hereafter, when they come to model Heaven
> And calculate the stars, how they will wield
> The mighty frame, how build, unbuild, contrive
> To save appearances, how gird the sphere
> With centric and eccentric scribbled o'er,
> Cycle and epicycle, orb in orb.

Alphonso X of Castile, called the Wise, who was a pious man and a great patron of astronomy, put the matter more succinctly. When he was initiated into the Ptolemaic system, he sighed: 'If the Lord Almighty had consulted me before embarking upon the Creation, I should have recommended something simpler.'

3. *The Paradox*

There is something profoundly distasteful about Ptolemy's universe; it is the work of a pedant with much patience and little originality, doggedly piling 'orb in orb'. All the basic ideas of the epicyclic universe, and the geometrical tools for it, had been perfected by his predecessor, Hipparchus; but Hipparchus had only applied them to the construction of orbits for the sun and moon. Ptolemy completed the unfinished job, without contributing any idea of great theoretical value.[3]

Hipparchus flourished around 125 B.C., more than a century after Aristarchus; and Ptolemy flourished around A.D. 150, nearly three centuries after Hipparchus. In this span of time, nearly equal to the duration of the Heroic Age, practically no progress was made. The landmarks were thinning out, and were soon to vanish altogether in the desert; Ptolemy was the last

great astronomer of the Alexandrian School. He picked up the threads which had been left trailing behind Hipparchus, and completed the pattern of loop entwined in loop. It was a monumental and depressing tapestry, the product of tired philosophy and decadent science. But nothing else turned up to replace it for nearly a millennium and a half. Ptolemy's *Almagest*,[4] remained the Bible of astronomy until the beginning of the seventeenth century.

To get this extraordinary phenomenon into a proper perspective, one must not only be on one's guard against the wisdom of hindsight, but also against the opposite attitude, that kind of benevolent condescension which regards the past follies of Science as the unavoidable consequences of ignorance or superstition: 'our forebears just did not know better'. The point I shall try to make is that they did know better; and that to explain the extraordinary *cul de sac* into which cosmology had manoeuvred itself, we must look for more specific causes.

In the first place, the Alexandrian astronomers can hardly be accused of ignorance. They had more precise instruments for observing the stars than Copernicus had. Copernicus himself, as we shall see, hardly bothered with star-gazing; he relied on the observations of Hipparchus and Ptolemy. He knew no more about the actual motions in the sky than they did. Hipparchus' Catalogue of the fixed stars, and Ptolemy's Tables for calculating planetary motions, were so reliable and precise that they served, with some insignificant corrections, as navigational guides to Columbus and Vasco da Gama. Eratosthenes, another Alexandrian, computed the diameter of the earth as 7,850 miles, with an error of only ½ per cent;[5] Hipparchus calculated the distance of the moon as 30¼ earth diameters – with an error of only 0.3 per cent.[6]

Thus, insofar as factual knowledge is concerned, Copernicus was no better off, and in some respects worse off, than the Greek astronomers of Alexandria who lived at the time of Jesus Christ. They had the same observational data, the same instruments, the same know-how in geometry, as he did. They were giants of 'exact science'. Yet they failed to see what Copernicus saw after, and Herakleides-Aristarchus had seen before them:

that the planets' motions were obviously governed by the sun.

Now I have said before that we must beware of the word 'obvious'; but in this particular case its use is legitimate. For Herakleides and the Pythagoreans had not been led to the heliocentric hypothesis by a lucky guess, but by the observed fact that the inner planets behaved like satellites of the sun, and that the outer planets' retrogressions and changes in earth-distance were equally governed by the sun. Thus, by the end of the second century B.C., the Greeks had all the major elements of the puzzle in their hands,[7] and yet failed to put them together; or rather, having put them together, they took them to pieces again. They knew that the orbits, periods, and velocities of the five planets were connected with, and dependent on, the sun – yet in the system of the universe which they bequeathed to the world, they managed to ignore completely this all-important fact.

This mental snow-blindness is all the more remarkable as, *qua philosophers, they were aware of the dominant part played by the sun which, qua astronomers, they nevertheless denied.*

A few quotations will illustrate this parodox. Cicero, for instance, whose knowledge of astronomy is, of course, entirely based on Greek sources, writes in *The Republic*: 'The sun ... rules, prince, and leader of the other stars, sole and ordering principle of the universe (is) so large that its light brightens and fills the all. ... *The orbits of Mercury and Venus follow him as his companions.*'[8]

Pliny writes a century later: 'The sun is carried around in the midst of the planets, *directing not only the calendar and the earth but also the stars themselves and the sky.*'[9]

Plutarch speaks in a similar vein in *On the Face in the Moon Disc*:

> But in general how can we say: the earth is in the centre – in the centre of what? The universe is infinite; and the infinite, which has neither beginning nor end, has no centre either. ... The universe does not assign any fixed centre to the earth, which drifts homelessly and unsteadily through the infinite emptiness without a proper goal. ...[10]

In the fourth century A.D., when darkness was finally closing in on the world of antiquity, Julian the Apostate wrote about the sun: 'He leads the dance of the stars; his foresight guides all generation in nature. Around him, their King, the planets dance their rounds; they revolve around him in the perfect harmony of their distances which are exactly circumscribed, as the sages affirm, who contemplate the events in the skies. . .'[11]

Lastly Macrobius, who lived around 400 A.D., comments on the passage from Cicero which I have just quoted:

> He calls the sun the ruler of the other stars because the sun regulates their progression and retrogression within spatial limits, for there are spatial limits which confine the planets in their advance and regress relative to the sun. Thus the force and power of the sun regulates the course of the other stars within fixed limits.[12]

Here, then, is evidence that to the very end of the antique world, the teaching of Herakleides and Aristarchus was well remembered; that a truth, once found, can be hidden away, buried under the surface, but not undone. And yet the Ptolemaic earth-centred universe, ignoring the specific role of the sun, held the monopoly in scientific thought for fifteen centuries. Is there an explanation for this remarkable paradox?

It has been frequently suggested that the explanation is fear of religious persecution. But all the evidence quoted in support of this view consists of a single, facetious remark by a character in Plutarch's dialogue *On the Face in the Moon Disc*, which I have mentioned before. The character, Lucius, is playfully accused of 'turning the universe upside down' by pretending that the moon consists of solid matter like the earth; he is then invited to explain his views further:

> Lucius smiled and said: 'Very well; only do not bring against me a charge of impiety such as Cleanthes used to say that it behoved Greeks to bring against Aristarchus of Samos for moving the Hearth of the Universe, because he tried to save the phenomena by the assumption that the heaven is at rest, but that the earth revolves in an oblique orbit, while also rotating about its own axis.'[13]

However, the charge was never brought; neither Aristarchus, who was held in the highest esteem, nor Herakleides or any

other adherent of the earth's motion, was persecuted or indicted. If Cleanthes had really tried to have anybody indicted on the grounds of 'moving the Hearth of the Universe', then the first person charged with impiety would have been the venerated Aristotle; for Aristarchus merely made the Hearth move with the earth through space, whereas Aristotle removed the Hearth to the periphery of the world, deprived the earth altogether of the divine presence, and made it the lowliest place in the world. In reality, the 'Hearth of the Universe' was no more than a poetic allusion to the Pythagorean Central Fire, and it would be absurd to regard it as a religious dogma. Cleanthes himself was a mystically inclined, and rather sour Stoic philosopher, who wrote a hymn to Zeus and despised science. His attitude to Aristarchus, a scientist and a Samian to boot, that island from which no good has ever come, was evidently 'the fellow deserves to be hanged'. Apart from this bit of academic gossip in Plutarch, there is no mention in any of the sources of religious intolerance towards science in the Hellenistic Age.[14]

4. *Knowing and Un-Knowing*

Thus neither ignorance, nor the threats of an imaginary Alexandrian inquisition, can serve to explain why the Greek astronomers, after having discovered the heliocentric system, turned their backs on it.[15] However, they never did so entirely; as the passages previously quoted, from Cicero and Plutarch to Macrobius, indicate, they knew that the sun governed the motions of the planets, but at the same time closed their eyes to the fact. But perhaps it is this irrationality itself which provides the clue to the solution, by jolting us out of the habit of treating the history of science in purely rational terms. Why should we allow artists, conquerors, and statesmen to be guided by irrational motives, but not the heroes of science? The post-Aristotelian astronomers denied the rule of the sun over the planets and affirmed it at the same time; while conscious reasoning rejects such a paradox, it is in the nature of the unconscious that it may simultaneously affirm and deny, say yes and no to

the same question; to know and to un-know, as it were. Greek science in the age of decline was faced with an insoluble conflict, which resulted in a split of the mind; and this 'controlled schizophrenia' continued throughout the Dark and Middle Ages, until it came to be almost taken for granted as the normal condition of man. It was maintained, not by threats from outside, but by a kind of censor planted inside the mind, who kept it separated into strictly non-communicating compartments.

Their main concern was 'to save the appearances'. The original meaning of this ominous phrase was that a theory must do justice to the observed phenomena or 'appearances'; in plain words, that it must agree with the facts. But gradually, the phrase came to mean something different. The astronomer 'saved' the phenomena if he succeeded in inventing a hypothesis which resolved the irregular motions of the planets along irregularly shaped orbits into regular motions along circular orbits – *regardless whether the hypothesis was true or not*, i.e. whether it was physically possible or not. Astronomy, after Aristotle, becomes an abstract sky-geometry, divorced from physical reality. Its principal task is to explain away the scandal of non-circular motions in the sky. It serves a practical purpose as a method for computing tables of the motions of the sun, moon, and planets; but as to the real nature of the universe, it has nothing to say.

Ptolemy himself is quite explicit about this: 'We believe that the object which the astronomer must strive to achieve is this: to demonstrate that all the phenomena in the sky are produced by uniform and circular motions. ...'[16] And elsewhere: 'Having set ourselves the task to prove that the apparent irregularities of the five planets, the sun and moon can all be represented by means of uniform circular motions, because only such motions are appropriate to their divine nature. ... We are entitled to regard the accomplishment of this task as the ultimate aim of mathematical science based on philosophy.'[17] Ptolemy also makes it clear why astronomy must renounce all attempts to explain the *physical* reality behind it: because the heavenly bodies, being of a divine nature, obey laws different from those to be found on earth. No common link exists

between the two; therefore we can know nothing about the physics of the skies.

Ptolemy was a wholehearted Platonist; the effect of the twin-stars on the course of science now makes itself fully felt. The divorce which they effected between the four elements of the sublunary region and the fifth element of the heavens, leads directly to a divorce of sky-geometry from physics, of astronomy from reality. The split world is reflected in the split mind. It knows that *in reality the* sun has a physical influence on the planets; but reality is no longer its concern.[18]

The situation is summed up in a striking passage by Theon of Smyrna, a contemporary of Ptolemy. After expressing his opinion that Mercury and Venus may, after all, be revolving round the sun, he goes on to say that the sun should be called the heart of the universe, which is both 'a world and an animal'.

> But [he reflects] in animated bodies the centre of the animal is different from the centre of its mass. For instance, for us who are both men and animals, the centre of the animated creature is in the heart, always in motion and always warm, and therefore the source of all the faculties of the soul, of desire, imagination, and intelligence; but the centre of our volume is elsewhere, about the navel. . . . Similarly, . . . the mathematical centre of the universe is where the earth is, cold and immovable, but the centre of the world as an animal is in the sun, which is, so to say, the heart of the universe.[19]

The passage is both appealing and appalling; it strikes a note which will reverberate throughout the Dark and Middle Ages. It appeals to the archetypal craving to comprehend the world as a live, pulsating animal; and it appalls by its unholy mix-up of allegorical and physical statements, by its pedantic variations on the inspired Platonic leg-pull. The contrast between navel and heart is witty but unconvincing; it does not explain why two planets should revolve round the heart and the other three round the navel. Did Theon and his readers believe in this sort of thing? The answer is, apparently, that one compartment of their minds did, the other did not; the process of divorcement was nearly completed. Observational astronomy was still progressing; but what a regression in philosophy compared to the

Pythagorean, and even the Ionian, school of seven centuries before!

5. *The New Mythology*

It looks as if the wheel had come full circle, back to the early Babylonians. They too had been highly competent observers and calendar-makers, who combined their exact science with a mythological dream-world. In the universe of Ptolemy, interlocking canals of perfect circles have replaced the heavenly waterways, along which the star-gods sail their barges on their precisely charted journeys. The Platonic mythology of the sky was more abstract and less colourful, but as irrational and dream-born as the older one.

The three fundamental conceits of this new mythology were: the dualism of the celestial and sub-lunary worlds; the immobility of the earth in the centre; and the circularity of all heavenly motion. I have tried to show that the common denominator of the three, and the secret of their unconscious appeal, was the fear of change, the craving for stability and permanence in a disintegrating culture. A modicum of split-mindedness and double-think was perhaps not too high a price to pay for allaying the fear of the unknown.

But whether the price was high or low, it had to be paid: the universe was put into the deep freeze, science was paralysed, and the manufacture of artificial moons and nuclear warheads was delayed by a millennium or more. Whether, *sub specie aeternitatis*, this was a Good Thing or a Bad Thing, we shall never know; but as far as our limited topic is concerned, it was clearly a bad thing. The earth-centred, dualistic, circular view of the cosmos excluded all progress and all compromise for fear of endangering its main principle, stability. Thus, it could not even be admitted that the two inner planets circled round the sun, because once you gave way on this apparently harmless minor point, the next logical step would be to extend the idea to the outer planets and to the earth itself – as the development of the Herakleidian deviation had clearly shown. The frightened mind, always on the defensive, is particularly aware of the dangers of yielding an inch to the devil.

The anxiety complex of the late Greek cosmologists becomes almost palpable in a curious passage[20] by Ptolemy himself, in which he defends the immobility of the earth. He starts with the usual commonsense argument that if the earth moved, 'all the animals and all separate weights would be left behind floating on the air' – which sounds plausible enough, though the Pythagoreans and atomists had long before Ptolemy realized its fallacious nature. But then Ptolemy continues to say that if the earth were really moving, it would 'at its great speed, have fallen completely out of the universe itself'. Now this is not plausible even on a naïve level, for the only motion attributed to the earth was a circular motion round the sun, which entailed no risk of falling out of the universe, just as the sun incurred no risk by circling the earth. Ptolemy, of course, knew this quite well – or, more precisely, one compartment of his mind knew it, while the other was hypnotized by the fear that once the earth's stability was shaken, the world would fly to pieces.

The myth of the perfect circle had an equally deep-rooted, spell-binding power. It is, after all, one of the oldest symbols; the ritual of drawing a magic circle around a person protects him against hostile spirits and perils of the soul; it marks off a place as an inviolable sanctuary; it was commonly used in tracing out the *sulcus primigenius*, the first furrow, when founding a new city. Apart from being a symbol of stability and protection, the circle, or wheel, had a technological plausibility, as it were, as a suitable element for any machine. But on the other hand, the planetary orbits were evidently *not* circles; they were eccentric, bulging, oval – or egg-shaped. They could be made *to appear* as the product of a combination of circles by geometrical artifices, but only at the price of renouncing any semblance of physical reality. There exist some fragmentary remains, dating from the first century A.D., of a small-sized Greek planetarium – a mechanical model designed to reproduce the motions of sun, moon, and perhaps also of the planets. But its wheels, or at least some of them, are not circular – they are egg-shaped.[21] A glance a the orbit of Mercury in

the Ptolemaic system on p. 71 shows a similar egg-shaped curve staring into one's face. All these pointers were ignored, relegated into limbo as a sacrifice to circle-worship.

And yet there was nothing *a priori* frightening about oval or elliptic curves. They too were 'closed' curves, returning into themselves, and displayed a reassuring symmetry and mathematical harmony. By an ironical coincidence, we owe the first exhaustive study of the geometrical properties of the ellipse to the same man, Apollonius of Perga, who, never realizing that he had the solution in his hands, started the development of the epicyclic monster-universe. We shall see that, two thousand years later, Johannes Kepler, who cured astronomy of the circular obsession, still hesitated to adopt elliptical orbits, because, he wrote, if the answer were as simple as that, 'then the problem would already have been solved by Archimedes and Apollonius'.[22]

6. *The Cubist Universe*

Before bidding farewell to the Greek world, an imaginary parallel may help to bring matters into focus.

In 1907, simultaneously with the Cézanne memorial exhibition in Paris, a collection of the master's letters was published. A passage in one of the letters ran:

> Everything in nature is modelled on the sphere, the cone and the cylinder. One must teach oneself to base one's painting on these simple figures – then one can accomplish anything one likes.

And further:

> One must treat nature by reducing its forms to cylinder, sphere, and cone, all put into perspective, meaning that each side of an object, each plane, is directed towards a central plane.[23]

This pronouncement became the gospel of a school of painting known under the misnomer 'Cubism'. Picasso's first 'Cubist' picture was in fact constructed entirely of cylinders, cones, and circles; while other members of the movement saw

nature in terms of angular bodies – pyramids, and bricks, and octaeders.*

But whether they painted in terms of cubes, cylinders, or cones, the declared aim of the Cubists was to resolve every object to a configuration of regular geometrical solids. Now the human face is not constructed out of regular solids any more than the orbits of the planets are made of regular circles; but in both cases it is possible to 'save the phenomena': in Picasso's *Femme au miroir*, the reduction of the model's eyes and upper lip to an interplay of spheres, pyramids, and parallelepipedes, displays the same ingenuity and inspired madness as Eudoxus' spheres pivoting within spheres.

It is rather depressing to imagine what would have happened to painting if Cézanne's Cubist pronouncement had been turned into a dogma as Plato's spherist pronouncement was. Picasso would have been condemned to go on painting more elaborate cylindrical bowls to the bitter end; and lesser talents would have found out soon that it is easier to save the phenomena with compass and ruler on graph-paper under a neon lamp, than by facing the scandals of nature. Luckily, Cubism was only a passing phase because painters are free to choose their style; but the astronomers of the past were not. The style in which the cosmos was presented had, as we saw, a direct bearing on the fundamental questions of philosophy; and later, during the Middle Ages it acquired a bearing on theology. The curse of 'spherism' upon man's vision of the universe lasted for two thousand years.

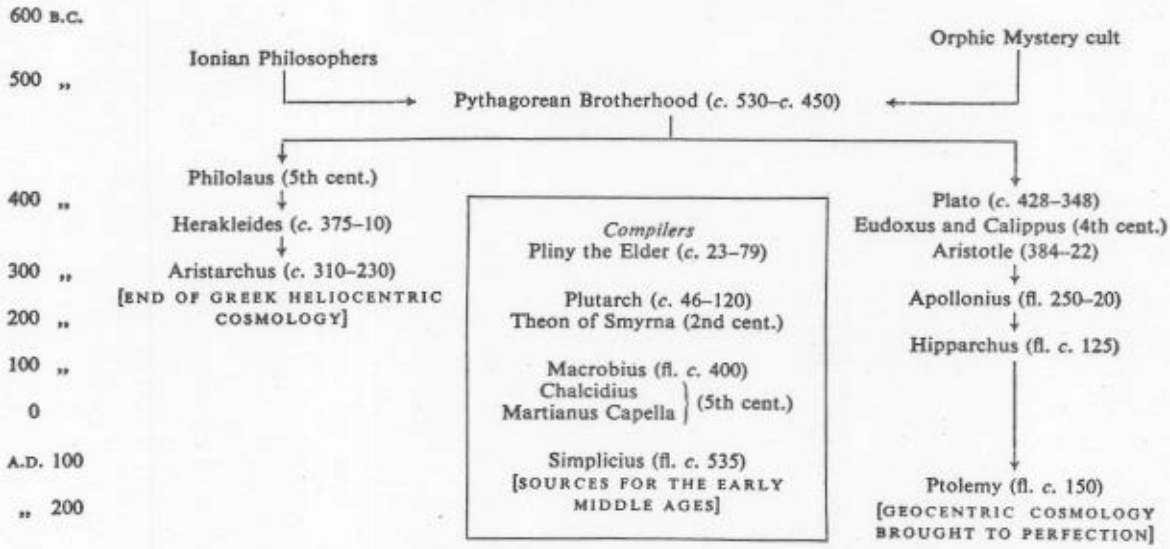
During the last few centuries, from about A.D. 1600 onwards, the progress of science has been continuous and without a break; so we are tempted to extend the curve back into the past and to fall into the mistaken belief that the advance of knowledge has always been a continuous, cumulative process along a road which steadily mounts from the beginnings of civilization to our present dizzy height. This, of course, is not

* The name of the movement derives from a slighting remark by Matisse, who said of a landscape by Braque that it was 'entirely constructed in little cubes'.[24]

the case. In the sixth century B.C., educated men knew that the earth was a sphere; in the sixth century A.D., they again thought it was a disc, or resembling in shape the Holy Tabernacle.

In looking back at the part of the road travelled so far, we may well wonder at the shortness of those stretches where the progress of science was guided by rational thought. There are tunnels on the road, whose length in time is measured in miles, alternating with stretches in full sunlight of no more than a few yards. Up to the sixth century B.C., the tunnel is filled with mythological figures; then for three centuries there is a shrill light; then we plunge into another tunnel, filled with different dreams.

*Chronological Table to Part One**



* Only the main lines of development of cosmological systems are represented.

Part Two. Dark Interlude

1 The Rectangular Universe

1. *The City of God*

Plato had said that mortal man was prevented from hearing the Harmony of the Spheres by the grossness of his bodily senses, the Christian Platonists said that he lost that faculty with the Fall.

When Plato's images strike an archetypal chord, they continue to reverberate on unexpected levels of meaning, which sometimes reverse the messages originally intended. Thus one might venture to say that it was Plato who caused that Fall of philosophy which made his followers deaf to the harmonies of nature. The sin which led to the Fall was the destruction of the Pythagorean union of natural and religious philosophy, the denial of science as a way of worship, the splitting up of the very texture of the universe into a vile lowland and ethereal highlands, made of different materials, governed by different laws.

'This 'dualism of despair', as one might call it, was carried over into medieval philosophy by the Neoplatonists. It was the legacy of one bankrupt civilization: Greece at the age of the Macedonian conquest, to another bankrupt civilization: the Latin world at the age of its conquest by the Germanic tribes. From the third century A.D to the end of the Empire, Neoplatonism had reigned without a rival at the three main centres of philosophy, Alexandria, Rome, and the Athenian Academy. By that process of natural selection in the realm of ideas which we have already seen at work, the Middle Ages took over precisely those elements in Neoplatonism which appealed to their mystic aspirations toward the Kingdom of Heaven, and which echoed their despair of this world as 'the lowest and vilest element in the scheme of things;[1] while the more optimistic aspects of Neoplatonism were ignored. Of Plato himself only the *Timaeus*, that masterpiece of ambiguity, was

available in Latin translation (the knowledge of Greek was dying out); and though Plotinus, the most influential among the Neoplatonists, affirmed that the material world partook to some extent of the goodness and beauty of its Creator, he was best remembered for the saying that he 'blushed because he had a body'. It was in this distorted and extreme form that Neoplatonism was absorbed into Christianity after the collapse of the Roman Empire, and became the main link between antiquity and medieval Europe.

The dramatic symbol of this fusion is the chapter in St Augustine's *Confessions* in which he describes how God 'brought in my way by means of a certain man – an incredibly conceited man – some books of the Platonists translated from Greek into Latin'.[2] Their impact on him was so powerful that, 'being admonished by all this to return to myself, I entered into my own depth'[3] and was thus set on the road to conversion. Although, after his conversion, he complained about the Neoplatonists' failure to realize that the Word was made Flesh in Christ, this proved no obstacle. The mystic union between Platonism and Christianity was consummated in the *Confessions* and the *City of God*.

A modern translator of the *Confessions* wrote about Augustine:

> In him the Western Church produced its first towering intellect – and indeed its last for another six hundred years. . . . What he was to mean for the future can only be indicated. All the men who had to bring Europe through the six or seven centuries that followed fed upon him. We see Pope Gregory the Great at the end of the sixth century reading and rereading the *Confessions*. We see the Emperor Charlemagne at the end of the eighth century using the *City of God* as a kind of Bible.[4]

Now this Bible of the Middle Ages, the *City of God*, was begun in 413, under the impact of the sack of Rome; and Augustine died in 430, while the Vandals were besieging his episcopal city of Hyppo. This goes a long way toward explaining his catastrophic views about humanity as a *massa perditiones*, a heap of depravity, in a state of moral death where even the newborn child carries the hereditary stigma of original

sin; where infants who die unbaptized share the fate of eternal damnation with the vast majority of mankind, pagan and Christian. For salvation is only possible through an act of Grace which God extends to individuals predestined to receive it by an apparently arbitrary selection; because 'fallen man cannot do anything well-pleasing to God'.[5] This terrible doctrine of predestination was taken up again in various forms at various ages by Cathars, Albigenses, Calvinists, and Jansenists, and was also to play a curious part in the theological struggles of Kepler and Galileo.

Again, there are countless redeeming aspects, ambiguities, and contradictions in Augustine's writings, such as his passionate pleading against the death penalty and judicial torture; his repeated affirmation that *Omnis natura, inquantum natura est, bonum est*;* it may even be said that 'Augustine was not an Augustinian'.[6] But these brighter elements were ignored by the generations after him, and the shadow he threw was dark and oppressive; it blotted out what little interest in nature, or inclination to science, still remained.

Since, in the Middle Ages, the churchmen became the successors to the philosophers of antiquity, and, in a manner of speaking, the Catholic Church took over from the Academy and the Lyceum, its attitude now determined the whole climate of culture and the course of learning. Hence the importance of Augustine, who was not only the most influential churchman of the earlier Middle Ages, the chief promoter of the Papacy as a supranational authority, and the originator of the rules of monastic life; but above all the living symbol of continuity between the vanished ancient, and the emerging new civilization. A modern Catholic philosopher justifiably said that Augustine was 'to a greater degree than any emperor or barbarian war-lord, a maker of history and a builder of the bridge which was to lead from the old world to the new'.[7]

2. *The Bridge to the City*

The tragedy lies in the selective nature of the traffic which passed across the bridge that Augustine built. At the tollgate

* All nature, in as much as it is nature, is good.

of the City of God, all vehicles carrying the treasures of ancient learning, beauty, and hope were turned back, for all pagan virtue is 'prostituted with the influence of obscene and filthy devils. . . .[8] Let Thales depart with his water, Anaximenes with the air, the Stoics with their fire, Epicurus with his atoms.'[9]

And depart they did. Only Plato and his disciples were allowed to pass the bridge and were welcomed, for they knew that knowledge cannot be obtained through the eyes of the body, and provided an allegorical supplement to Genesis, as it were: Adam, expelled from the Garden, was made to proceed straight to Plato's Cave, and to take up the existence of a chained troglodyte.

Most welcome of all was the Neoplatonists' contempt for all branches of science. From them Augustine 'derived the conviction, which he transmitted to the succeeding generations of many centuries, that the only type of knowledge to be desired was knowledge of God and the soul, and that no profit was to be had from investigating the realm of Nature'.[10]

A few quotations from the *Confessions* will illustrate more vividly the mental attitude toward knowledge at the opening of the Christian era. In the Tenth Book, which concludes his personal narrative, Augustine describes his state of mind twelve years after his conversion, and implores the help of God to overcome various forms of temptations which are still assailing him: the lust of the flesh, which he can resist when awake but not in sleep; the temptation to enjoy his food instead of taking it as a necessary medicine 'until the day when Thou wilt destroy both the belly and the meat'; the allurement of sweet scents, to which he is fairly immune; the pleasures of the ear derived from church music at the risk of being 'more moved by the singing than by the thing that is sung'; the lure to the eye of 'diverse forms of beauty, of brilliant and pleasing colours'; and, last but one, the temptation of 'knowing for knowing's sake':

> At this point I mention another form of temptation more various and dangerous. For over and above that lust of the flesh which lies in the delight of all our senses and pleasures – whose slaves are wasted unto destruction as they go far from You – there can also be in the mind itself, through those same bodily senses, a certain vain desire and curiosity, not of taking delights in the body, but of making experiments with the body's aid, and cloaked under the name of learning and knowledge. . . . Pleasure goes after objects that are beautiful to see, smell, taste, touch; but curiosity for the sake of experiment can go after quite contrary things, not in order to experience their unpleasantness, but through a mere itch to experience and find out. . . . Because of this disease of curiosity you have the various freaks shown in the theatres. Thus men proceed to investigate the phenomena of nature – the part of nature external to us – though the knowledge is of no value to them: for they wish to know simply for the sake of knowing. . . .
>
> In this immense forest of snares and perils, I have cut off and thrust from my heart many sins, as you have given me to do, O God of my salvation; yet when would I dare to say – with so many things of the sort buzzing about our daily life on every side – when dare I say that no such thing can draw me to look at it or through vain curiosity to desire it? Certainly the theatres no longer attract me, nor do I care to know the course of the stars. . . .[11]

But he has not yet succeeded in plucking out of the human heart that sinful desire for knowledge.

He came perilously near to it, though.

3. *The Earth as a Tabernacle*

Compared with the other early Fathers, Augustine was still by far the most enlightened. Saint Lactantius, who lived in the century before him, set himself to demolish the notion of the rotundity of the earth, with resounding success. The third volume of his *Divine Institutions* is called 'On the False Wisdom of the Philosophers', and contains all the naïve arguments against the existence of the antipodes – people can't walk with their feet above their heads, rain and snow can't fall upwards – which, seven hundred years earlier, no educated person could have used without making a fool of himself. Saint Jerome, the translator of the Vulgate, fought a life-long battle against the temptation of reading the pagan classics, until he finally defeated 'the stupid wisdom of the philosophers': 'Lord, if ever again I possess worldly books, or if ever again I read such, I have denied Thee'.[12] Not until about the

end of the ninth century was the spherical shape of the earth, and the possible existence of the antipodes reinstated, fifteen hundred years after Pythagoras.

The cosmology of this period goes straight back to the Babylonians and Hebrews. Two main ideas dominate it: that the earth is shaped like the Holy Tabernacle, and that the firmament is enclosed by water. The latter idea was based on Genesis 1: 6, 7:

> And God said let there be a firmament in the midst of the waters, and let it divide the waters from the waters. And God made the firmament, and divided the waters which were under the firmament from the waters which were above the firmament.

From this, the notion was derived that the super-celestial waters were resting on top of the firmament, and that their purpose was – as Basil the Great* explained[13] – to protect the world against the celestial fire. His contemporary, Severianus, further explained, that the lower heaven consisted of crystalline or 'congealed' water, which prevented it from being set aflame by the sun and stars; and that it was kept cool by the liquid water on top of it, which, on the Last Day, God would use to extinguish all the lights.[14] Augustine, too, believed that Saturn was the coolest planet because it was closest to the upper waters. In answer to those who objected to the presence of heavy water on top of the heavens, he pointed out that there is liquid phlegm present in the heads of men too.[15] The further objection that the spherical surface of the firmament and its motion would cause the waters to slide down or be spilled, was met by several Fathers who explained that the heavenly vault may be round inside but flat on top; or contain grooves and vessels to hold the water in.[16]

At the same time the notion was spreading that the firmament is not round, but a tent or tabernacle. Severianus refers to Isaiah, XL: 22, that God 'stretches out the heavens as a curtain and spreadeth them out as a tent to dwell in',[17] and others follow suit. However, the Fathers and Doctors were not sufficiently interested in these worldly matters to go into detail.

* Fourth century A.D.

The first comprehensive cosmological system of the early Middle Ages, destined to replace the teachings of pagan astronomers from Pythagoras to Ptolemy, was the famous *Topographica Christiana* by the monk Cosmas. He lived in the sixth century, was born in Alexandria, and, as a merchant and seaman, had travelled wide and far through the known world, including Abyssinia, Ceylon, and Western India, which earned him the title *Indicopleustus*, the Indian traveller. He subsequently became a monk, and wrote his great work in a monastery on Sinai.

The first of its twelve books is entitled 'Against those who, while wishing to profess Christianity, think and imagine like the pagans that the heaven is spherical'. The Holy Tabernacle, described in Exodus, was rectangular and twice as long as it was wide; hence the earth has the same shape, placed lengthwise from East to West at the bottom of the universe. It is surrounded by the ocean – as the table of shew-bread is surrounded by its wavy border; and the ocean is surrounded by a second earth which was the seat of Paradise, and the home of man until Noah crossed the ocean, but is now uninhabited. From the edges of this deserted outer earth rise four vertical planes, which are the walls of the universe. Its roof is a half-cylinder which rests on the north and south walls, making the universe look like a Nissen hut or a Victorian travelling trunk with a curved lid.

However, the floor, that is the earth, is not flat but slants from north-west to south-east – for it is written in Ecclesiastes 1: 5 that 'the sun goes *down*, and hasteth to his place where he arose'. Accordingly, rivers like the Euphrates and Tigris which flow southward, have a faster current than the Nile which flows 'uphill'; and ships sail faster toward the south and east than those which must 'climb' to the north and west; the latter are therefore called 'lingerers'. The stars are carried round the space under the roof of the universe by angels, and are hidden when they pass behind the uptilted northern part of the earth, which is topped by a huge conical mountain. This mountain also hides the sun at night, the sun being much smaller than the earth.

Cosmas himself was not a high ecclesiastical authority, but his ideas are all derived from the Fathers of the preceding two centuries. There were more enlightened men among them, such as Isidore of Seville (sixth to seventh century) and the Venerable Bede (seventh to eighth century). Yet Cosmas' *Topographica Christiana* is typical of the general view of the universe prevailing during the early Middle Ages. Long after the spherical shape of the earth was reinstated, and indeed up to the fourteenth century, maps were still produced representing the earth either as rectangular, after the shape of the Tabernacle, or as a circular disc with Jerusalem as its centre, because Isaiah had spoken of the 'circuit of the earth' and Ezekiel had stated that 'God had set Jerusalem in the midst of the nations and countries'. A third type of map made the earth oval-shaped, as a compromise between the tabernacle and circuitous view; the Far East was usually occupied by Paradise.

Once again we are impelled to ask ourselves: Did they really believe in all this? And again the answer must be both yes and no – depending on which compartment of the split mind was involved. For the Middle Ages were the era of the split mind *par excellence*; I shall return to the subject at the end of this chapter.

4. *The Earth is Round Again*

The first medieval churchman to state unequivocally that the earth is a sphere, was the English monk Bede, who rediscovered Pliny, as it were, and often quoted him verbatim; yet he still clung to the notion of the super-celestial waters and denied that there were people living in the antipodal regions; for those regions being inaccessible on account of the vast ocean, its supposed inhabitants could neither have descended from Adam, nor be redeemed by Christ.

A few years after Bede's death, a curious incident took place. A certain Irish ecclesiastic by name of Fergil or Virgil, who lived as an abbot at Salzburg, became involved in a quarrel with his superior, Boniface, who denounced Virgil to Pope Zacharias on the grounds that the Irishman taught the existence 'of another world and other people under the earth' – meaning the antipodes. The Pope replied that Boniface should call a council and expel Virgil from the Church for his scandalous teaching. But nothing happened – except that Virgil in due time became Bishop of Salzburg and held that see till his death. The episode reminds one of the futile denunciation of Aristarchus by Cleanthes; it seems to indicate that even in this period of benightedness, orthodoxy in matters of natural philosophy (as distinct from matters theological) was maintained less by threats than by inner compulsion. At least I am not aware of any recorded instance of a cleric or layman being indicted for heresy in this heresy-ridden age because of his cosmological views.

This danger was further diminished when, in A.D 999, Gerbert, the most accomplished classical scholar, geometer, musician and astronomer of his age, ascended the papal throne as Sylvester II. He died four years later, but the impression that the 'magician Pope' made on the world was so powerful that he soon became a legend. Though he was an exceptional individual, far in advance of his age, his papacy, at the symbolical date A.D. 1000, nevertheless marks the end of the darkest period of the Middle Ages, and a gradual change of attitude toward the pagan science of antiquity. From now onward, the spherical shape of the earth, and its position in the centre of space, surrounded by the spheres of the planets, became again respectable. What is more, several manuscripts from approximately the same period show that the 'Aegyptian' system of Herakleides (where Mercury and Venus are satellites of the sun) had been rediscovered, and that elaborate drawings of the planetary orbits were circulating among the initiates. But they did not make any noticeable impression on the dominant philosophy of the age.

Thus by the eleventh century A.D., a view of the universe had been achieved roughly corresponding to that of the fifth century B.C. It had taken the Greeks some two hundred and fifty years to progress from Pythagoras to Aristarchus' heliocentric system; it took Europe more than twice that time to achieve the corresponding progress from Gerbert to Copernicus. The Greeks, once they had recognized that the earth was a ball

floating in space, had almost at once set that ball in motion; the Middle Ages hastily froze it into immobility at the centre of a rigid cosmic hierarchy. It was not the logic of science, not rational thought that determined the shape of the next development, but a mythological concept which symbolized the needs of the age: the tabernacular universe was succeeded by the universe of the Golden Chain.

2 The Walled-in Universe

1. *The Scale of Being*

It was a walled-in universe like a walled-in medieval town. In the centre lies the earth, dark, heavy, and corrupt, surrounded by the concentric spheres of the moon, sun, planets, and stars in an ascending order of perfection, up to the sphere of the *primum mobile*, and beyond that the Empyrean dwelling of God.

But in the hierarchy of values, which is attached to this hierarchy in space, the original simple division into sub-lunary and supra-lunary regions has now yielded to an infinite number of sub-divisions. The original, basic difference between coarse, earthly mutability and ethereal permanence is maintained; but both regions are sub-divided in such a manner that the result is a continuous ladder, or graded scale, which stretches from God down to the lowliest form of existence. In a passage, frequently quoted throughout the Middle Ages, Macrobius sums up the idea:

> Since, from the Supreme God Mind arises, and from Mind, Soul, and since this in turn creates all subsequent things and fills them all with life ... and since all things follow in continuous succession, degenerating in sequence to the very bottom of the series, the attentive observer will discover a connexion of parts, from the Supreme God down to the last dregs of things, mutually linked together and without a break. And this is Homer's golden chain, which God, he says, bade hang down from heaven to earth.[1]

Macrobius echoes the Neoplatonist 'theory of emanations' which goes back to Plato's *Timaeus*. The One, the Most Perfect Being 'cannot remain shut up in itself'; it must 'overflow' and create the World of Ideas, which in turn creates a copy or image of itself in the Universal Soul, which generates 'the sentient and vegetative creatures' – and so on in a descending

series, to the 'last dregs of things'. It is still a process of degeneration by descent, the very opposite of the evolutionary idea; but since every created being is ultimately an emanation of God, partaking of His essence in a measure diminishing with distance, the soul will always strive upward, to its source.

The emanation-theory was put into a more specifically Christian shape in *The Celestial Hierarchy* and *The Ecclesiastical Hierarchy* by the second most influential among the Neoplatonists, known as the pseudo-Dionysius. He lived probably in the fifth century, and perpetrated the most successful pious hoax in religious history by pretending that the author of his works was Dionysius Areopagite, the Athenian mentioned in Acts XVII: 34, as a convert of St Paul's. He was translated into Latin in the ninth century by John the Scot, and from then on exerted an immense influence on medieval thought. It was he who provided the upper reaches of the ladder with a fixed hierarchy of angels, which afterwards were attached to the star-spheres to keep them in motion: the Seraphim turning the Primum Mobile,[2] the Cherubim the sphere of the fixed stars, the Thrones the sphere of Saturn; the Dominations, Virtues, and Powers the spheres of Jupiter, Mars, and the sun; the Principalities and Archangels the spheres of Venus and Mercury, while the lower Angels look after the moon.[3]

If the upper half of the ladder was Platonic in origin, the lower rungs were provided by Aristotelian biology, which was rediscovered around A.D. 1200. Particularly important became his 'principle of continuity' between apparently divided realms of nature:

> Nature passes so gradually from the inanimate to the animate that their continuity renders the boundary between them indistinguishable; and there is a middle kind that belongs to both orders. For plants come immediately after inanimate things; and plants differ from one another in the degree in which they appear to participate in life. For the class taken as a whole seems, in comparison with other bodies, to be clearly animate; but compared with animals to be inanimate. And the transition from plants to animals is continuous; for one might question whether some marine forms are animals or plants, since many of them are attached to the rock and perish if they are separated from it.[4]

The 'principle of continuity' made it not only possible to arrange all living beings into a hierarchy according to criteria such as 'degrees of perfection', 'powers of soul' or 'realization of potentialities' (which, of course, were never exactly defined). It also made it possible to connect the two halves of the chain – the sub-lunary and the celestial – into a single, continuous one, without denying the essential difference between them. The connecting link was found, by St Thomas Aquinas, in the dual nature of man. In the continuity of all that exists, 'the lowest member of the higher genus is always found to border upon the higher member of the lower genus'; this is true of the zoophytes, which are half plant, half animal, and it is equally true of man, who

> has in equal degree the characters of both classes, since he attains to the lowest member of the class above bodies, namely, the human soul, which is at the bottom of the series of intellectual beings – and is said, therefore, to be the horizon and boundary line of things corporeal and incorporeal.[5]

The chain, thus unified, now reached from God's throne down to the meanest worm. It was further extended downward through the hierarchy of the four elements into inanimate nature. Where no obvious clues could be found to determine an object's 'degree of excellence', astrology and alchemy provided the answer by establishing 'correspondences' and 'influences', so that each planet became associated with a day of the week, a metal, a colour, a stone, a plant, defining their rank in the hierarchy. A further downward extension led into the conic cavity in the earth, around whose narrowing slopes the nine hierarchies of devils were arranged in circles, duplicating the nine heavenly spheres; Lucifer, occupying the apex of the cone in the precise centre of the earth, marked the bitter end of the chain.

The medieval universe, as a modern scholar remarked, is thus not really geocentric, but 'diabolocentric'.[6] Its centre, once the Hearth of Zeus, is now occupied by Hell. In spite of the

continuous nature of the chain, the earth, compared to the incorruptible heavens, still occupies the lowest place, described by Montaigne as 'the filth and mire of the world, the worst, lowest, most lifeless part of the universe, the bottom storey of the house'.[7] In a similar vein his contemporary, Spenser, bemoans the sway of the Goddess Mutability over the earth, which makes him

> Loathe this state of life so tickle
> And love of things so vain to cast away;
> Whose flow'ring pride, so fading and so fickle, –
> Short time shall soon cut down with his consuming sickle.[8]

The extraordinary power of this medieval vision of the universe is illustrated by the fact that it had the same, undiminished hold on the imagination of the Elizabethan poets at the turn of the sixteenth century as it had on Dante's at the turn of the thirteenth; and it is still echoed, in a famous passage by Pope, in the eighteenth. The concluding half of the quotation provides a clue to the understanding of the great stability of the system:

> Vast chain of being! which from God began,
> Nature's aethereal, human, angel, man,
> Beast, bird, fish, insect . . .
> . . . from Infinite to thee,
> From thee to nothing. – On superior pow'rs
> Were we to press, inferior might on ours;
> Or in the full creation leave a void,
> Where, one step broken, the great scale's destroy'd;
> From Nature's chain whatever link you strike,
> Tenth, or ten thousandth, breaks the chain alike.[9]

The consequence of such a break would be disintegration of the cosmic order. The same moral, the same warning of the catastrophic consequences of any change, however small, in the rigid, graded hierarchy, of any disturbance in the fixed order of things, returns, as a leitmotif, in Ulysses's speech in *Troilus and Cressida* and in countless other places. The secret of the medieval universe is that it is static, immune against change; that every item in the cosmic inventory has its permanent

place and rank assigned to it on a rung of the ladder. It reminds one of the pecking hierarchy in a henyard. There is no evolution of biological species, and no social progress; no traffic moves up or down the ladder. Man may aspire to a higher life or condemn himself to an even lower one; but he will only move up or down the ladder after his death; while he is in this world, his preordained rank and place cannot be altered. Thus blessed immutability is made to prevail even in the lowly world of mutability and corruption. The social order is part of the chain, the part which connects the hierarchy of angels with the hierarchy of animal, vegetable, and mineral. To quote another Elizabethan, Raleigh – in straight prose for a change:

> Shall we therefore value honour and riches at nothing and neglect them as unnecessary and vain? Certainly not. For that infinite wisdom of God, which hath distinguished his angels by degrees, which hath given greater and less light and beauty to heavenly bodies, which hath made differences between beasts and birds, created the eagle and the fly, the cedar and the shrub, and among stones given the fairest tincture to the ruby and the quickest light to the diamond, hath also ordained kings, dukes or leaders of the people, magistrates, judges, and other degrees among men.[10]

Not only Kings and Barons, Knights and Squires, have their fixed place in the cosmic hierarchy; the Chain of Being runs even through the kitchen.

> Who is to take the chief cook's place in case he is absent: the spit-master or the soup-master? Why do the bread-bearers and cup-bearers form the first and second ranks, above carvers and cooks? – Because they are in charge of bread and wine, to which the sanctity of the sacrament gives a holy character.[11]

The Middle Ages had an even greater horror of change, and desire for permanence than the age of Plato, whose philosophy they carried to obsessional extremes. Christianity had saved Europe from a relapse into barbarism; but the catastrophic conditions of the age, its climate of despair, prevented it from evolving a balanced, integrated, evolutionary view of the universe and of man's role in it. The recurrent, panic expecta-

tions of the End of the World, the outbreaks of dancing and flagellating manias, were symptoms of mass hysteria,

brought on by terror and despair, in populations oppressed, famished, and wretched to a degree almost unimaginable today. To the miseries of constant war, political and social disintegration, there was added the dreadful affliction of inescapable, mysterious, and deadly disease. Mankind stood helpless as though trapped in a world of terror and peril against which there was no defence.[12]

It was against this background that the vision of the walled universe was taken over from the Platonists as a protection against the Black Death of Change – rigid, static, hierarchic, petrified. The Babylonian oyster-world, which lay three and four thousand years back, was full of dynamism and imagination compared with this pedantically graded universe, wrapped in cellophane spheres, and kept by God in the deep-freeze locker to hide its eternal shame. Yet the alternative was even worse:

> . . . when the planets
> In evil mixture to disorder wander,
> What plagues and what portents, what mutiny,
> What raging of the sea, shaking of earth,
> Commotion in the winds, frights, changes, horrors,
> Divert and crack, rend and deracinate
> The unity and married calm of states
> Quite from their fixture . . .
> Take but degree away, untune that string,
> And hark, what discord follows. Each thing meets
> In mere oppugnancy. The bounded waters
> Should lift their bosoms higher than the shores
> And make a sop of all this solid globe.[13]

2. *The Age of Double-Think*

I have said that the Herakleidian system, in which the two inner planets circle the sun, and not the earth, had been rediscovered toward the end of the first millennium. But it would be more correct to say that heliocentricism had never been quite forgotten, even at the time of the tabernacular universe. I have

already quoted (pp. 71–2), among others, Macrobius to that effect. Now Macrobius, Chalcidius, and Martianus Capella, three encyclopaedic compilers of the period of Roman decadence (all three of the fourth-fifth century A.D.), were, together with Pliny, the main sources on natural science available till the Greek revival; and they all propounded the system of Herakleides.[14] It was again taken up by John the Scot in the ninth century, who made not only the inner planets, but all of them except distant Saturn, satellites of the sun; and from then onward, Herakleides remains firmly established on the medieval scene.[15] In the words of the best authority on the subject: 'the majority of the men who, from the ninth to the twelfth century, have written on astronomy, and whose books are preserved, were acquainted with and adopted the planetary theory designed by Herakleides of Pontus.'[16]

And yet at the same time, cosmology had reverted to a naïve and primitive form of geocentrism – with concentric crystal spheres determining the order of the planets and the accompanying hierarchy of angels. The highly ingenious systems of Aristotle's fifty-five spheres, of Ptolemy's forty epicycles were forgotten, and the complex machinery was reduced to ten revolving spheres – a kind of poor man's Aristotle which had nothing whatever in common with any of the observed motions in the sky. The Alexandrian astronomers had at least tried to save the phenomena; the medieval philosophers disregarded them.

But a complete disregard for reality would make life impossible; and thus the split mind must evolve two different codes of thought for its two separate compartments: one conforming to theory, the other to cope with fact. Up to the end of the first millennium and beyond, the rectangular and oval, tabernacle-inspired maps were piously copied out by the monks; they provided a kind of Sunday idea of the shape of the earth according to the patristic interpretation of Scripture. But coexisting with these was an entirely different kind of map of amazing accuracy, the so-called Portolano charts, for practical use among Mediterranean seamen. The shapes of countries and seas on the two types of maps are as unrelated to each

other as the medieval idea of the cosmos and the observed events in the sky.[17]

The same split can be traced through the most heterogeneous fields of medieval thought and behaviour. Since it is against man's nature to go on blushing because he has a body and a brain, a thirst for beauty and an appetite for experience, the frustrated half took its revenge through extremes of coarseness and obscenity. The disembodied, ethereal love of the troubadour or serving knight for his lady, coexist with the brutal publicity given to the wedding bed, which makes marriages resemble public executions. The fair lady is compared to the Goddess of Virtue, but is made to wear a cast-iron chastity belt on her sub-lunary sphere. Nuns must wear shirts even in the privacy of their baths, because, though nobody else, God can see them. When the mind is split, both halves are debased: earthly love sinks to the animal level, the mystic union with God acquires an erotic ambiguity. Confronted with the Old Testament, the theologians save the phenomena in the Song of Songs by declaring that the King is Christ, the Shulamite the Church, and that the praise for various parts of her anatomy refers to corresponding excellences in the edifice that St Peter built.

Medieval historians must also live by double-think. The cosmology of the age explained away the disorder in the skies by ordered motions in perfect circles; the chroniclers, faced with worse disorder, had recourse to the notion of perfect chivalry as the moving force of History. It became to them

> ... a sort of magic key by the aid of which they explained to themselves the motives of politics and of history. ... What they saw about them looked primarily mere violence and confusion. ... Yet they required a form for their political conceptions and here the idea of chivalry came in. ... By this traditional fiction they succeeded in explaining to themselves, as well as they could, the motives and the course of history, which was thus reduced to a spectacle of the honour of princes and the virtue of knights, to a noble game with edifying and heroic rules.[18]

The same dichotomy is carried into social behaviour. A grotesque and rigid etiquette governs every activity, designed

to freeze life in the image of the heavenly clockwork, whose crystal spheres turn on themselves yet always remain in the same place. Humble refusals to take precedence in passing through a door take up a quarter of an hour, yet bloody feuds are fought for that same right of precedence. The ladies at Court pass their time poisoning each other with words and philtres, yet etiquette

> not only prescribes which ladies may hold each other by the hand, but also which lady is entitled to encourage others to this mark of intimacy by beckoning them. ... The passionate and violent soul of the age, always vacillating between tearful piety and frigid cruelty, between respect and insolence, between despondency and wantonness, could not dispense with the severest rules and the strictest formalism. All emotions required a rigid system of conventional forms, for without them passion and ferocity would have made havoc of life.[19]

There are mental disorders whose victims feel compelled to walk on the centres of flagstones, avoiding the edges, or to count the matches in the box before going to sleep, as a protective ritual against their fears. The dramatic outbursts of mass-hysteria during the Middle Ages tend to divert our attention from the less spectacular, but chronic and insoluble mental conflicts which underlie them. Medieval life in its typical aspects resembles a compulsive ritual designed to provide protection against the all-pervading potato-blight of sin, guilt, and anguish; yet it was unable to provide it so long as God and Nature, Creator and Creation, Faith and Reason, were split apart. The symbolic prologue to the Middle Ages is Origen cutting off his private parts *ad gloriam dei*; and the epilogue is provided by the parched voices of the schoolmen: Did the first man have a navel? Why did Adam eat an apple and not a pear? What is the sex of the angels, and how many can dance on the point of a pin? If a cannibal and all his ancestors have lived on human flesh so that every part of his body belongs to somebody else and will be claimed by its owner on the day of resurrection, how can the cannibal be resurrected to face his judgement? This last problem was earnestly discussed by Aquinas.

When the mind is split, departments of it which should complete each other, develop autonomously by inbreeding, as it were, insulated from reality. Such is medieval theology, cut off from the balancing influence of the study of nature; such is medieval cosmology, cut off from physics; such is medieval physics, cut off from mathematics. The purpose of the digressions in this chapter, which seem to have led us so far away from our topic, is to show that the cosmology of a given age is not the result of a unilinear, 'scientific' development, but rather the most striking, imaginative symbol of its mentality – the projection of its conflict, prejudices, and specific ways of double-think on to the graceful sky.