

Part I:

The Model of the Universe in the Timaeus

The aim of the *Timaeus* is multiple, comprising a cosmological model and simultaneously describing the origin of mankind and the constitution of an ideal city which is both the critical reverse of the Athens in which Plato lived and the model it should follow. It is therefore impossible to separate neatly in the *Timaeus* that which pertains to cosmology and that which is dependent on other areas of knowledge: mathematics, physics, chemistry, biology, medicine, psychology, sociology, politics and even religion. All this is tied together in one dense web. None of these areas of learning displays the real autonomy that they have been able to gain two millennia later. A reading of the *Timaeus* can therefore only avoid anachronism if it recognizes from the outset this lack of autonomy. Nonetheless, the *Timaeus* is a work on cosmology, since it advances a model of the physical universe; it is even the first such work to have reached us in its entirety. What is more, for the first time, a model of the universe is proposed that professes to be totally mathematical.

A further difficulty in the *Timaeus* ensues from the intertwining of mythical narrative and scientific approach, a problem indissociable from the status of a discourse on the origin of the sensible world. To recall the origin of the sensible world is to describe *the coming into being of sensible reality*, which, by definition so to speak, no human being can ever have experienced. The philosopher who commits himself to this undertaking is as unprepared as the poet, Hesiod for example, who, in the *Theogony*, must have recourse to the Muses. And Plato must first set forth his own fundamental epistemology.

The Date of Composition of the Timaeus and Its Dramatic Situation

The *Timaeus* appears to follow the *Republic*, or a dialogue resembling this discussion of Justice, and it is followed by the *Critias*, an unfinished dialogue meant to expand upon a *Hermocrates* that was never written. It is essentially a discussion between four characters: Socrates, Hermocrates, Critias, and Timaeus.

The project of this discussion as a whole, within which the *Timaeus* is embedded, is above all political and tackles this question: how can the Athenians be reformed? The answer: by reminding them of their history (which Hermocrates would have done), and by evoking a distant past (which Critias does) where the organization of their City conformed to the ideal described by Socrates in the *Republic*. To show that this ideal is realizable on earth, to found this political project in nature, it is necessary to go back to the origin of man and to the origin of the world, and to explain how man, this microcosm, finds his place within the macrocosm, the universe which is but the sensible image of an intelligible model. Plato puts into the mouth of Timaeus, a citizen of Locri (in southern Italy) the long monologue wherein this ambitious program is set forth in detail.

On what date is the discussion between Socrates, Hermocrates, Critias and Timaeus supposed to have taken place? If we leave aside the problem presented by the relationship between this discussion and the one recounted in the *Republic*, the action must be situated between 430 and 425 BC. Socrates would then have been forty to forty-five years old.

It seems that the *Timaeus* and the *Critias* were written by Plato ten or twelve years before his death, between 358 and 356 BC. Translated into Latin, at least in part, by Cicero (106-43 BC) and by C(h)alcidius (fourth cent. AD), commented by many Platonists, including Proclus (fifth cent. AD), the *Timaeus* has reached us through papyri and manuscripts, the oldest of which was produced in Constantinople and goes back to the end of the ninth century of our era (more than a millennium after Plato's death).

The First Twelve Axioms of the Cosmological Model Advanced in the *Timaeus*

Fundamental to our analysis in this book is the following assumption: the cosmological model advanced by Plato is a "scientific model," in the strong contemporary sense of the term. It thus ensues that this construction, this theoretical model of the universe, must be assembled as a formal axiomatic system: a set of primordial propositions – the axioms – must first be established, and all observable manifestations of

the universe must then in principle be deducible as theorems from these axioms.

To be sure, Plato may not have been perfectly conscious of the fact that he was constructing a model based on a list of axioms and that these axioms have no other justification than their epistemological consistency. But he accepted this idea: whoever finds a different set of axioms, whoever could advance another model or attempt a different explanation, is equally entitled to be listened to; and only the model best fitting the data, the model that “works best,” will be chosen.

... but if anyone should put the matter to the test and discover that it is not so, the prize is his with all good will. (*Timaeus* 54a-b)

... but another, looking to other considerations, will judge differently. (*Timaeus* 55d)

This truly modern feature of Plato's cosmology deserves to be emphasized.

Axiom T1

Reality is separated into two domains: the intelligible Forms (*eidos, idea*), pure, eternal, immutable and simple; and the complex sensible particulars, ever-changing (*kinetos*) in time.

This separation of reality into two domains corresponds to the distinction between being and becoming, between that which remains forever identical and that which never ceases becoming different, between that to which the predicate “true” can be attributed and that to which this predicate is refused.

In the Platonic system, the intelligible Forms, generally called “ideas,”¹ are postulated as metaphysical entities, indispensable for explaining the world perceived by the senses. There is no veritable reality in the permanent change of all that is in time, of all that is always becoming, of all that we moderns call “material.” Time is tied to change, but does not affect the eternal realities, which are timeless and changeless. As we can read in the *Timaeus*:

We must, then, in my judgment, first make this distinction: what is that which is always real and has no becoming, and what is that which is always becoming and is never real? That which is apprehensible by thought with a rational account is the thing that is always unchangeably real; whereas that which is the object of belief together with unreasoning sensation is the thing that becomes and passes away, but never has real being. (*Timaeus* 27d-28a)

Only the knowledge of intelligible Forms can really be said to be “true.” But finite, ephemeral and limited human beings cannot in this world attain such a knowledge. The knowledge of these divine entities is the exclusive privilege of the gods and of a small number of their friends (*Phaedrus* 278d). Knowledge whose object is the world of sensible particulars, which Plato qualifies as “opinion” (*doxa*), is an inferior type of knowledge, since it can at best attain only verisimilitude. Here lies the root of the epistemological problem Plato tries to solve in the *Timaeus*: *how to know truly the sensible world which is ever-changing, whereas true knowledge (episteme) can have as its objects only the intelligible Forms which moreover remain inaccessible to human beings?*

Axiom T2

The Good occupies a singular situation among the Forms.

The Good is one intelligible Form among others: Justice, Unity, Man, Animal, etc., but it plays a crucial role within the Platonic system, particularly in the *Timaeus*.² This Form confers upon the other intelligible Forms these distinctive features: beauty, harmony, order, simplicity. According to the cosmological model advanced by Plato, the other intelligible Forms then communicate these features to the sensible particulars.

Axiom T3

In the sensible world, all that becomes becomes as the result of a cause.

Causality only finds an application in the sensible world, since in the realm of intelligible Forms, which, following axiom T1, are eternal and immutable, there is no change, and, consequently, there is no cause-effect connection in the intelligible world. And in the sensible world, *changes* amount to the *relationships* between elementary components (cf. axiom T18 *infra*). These elementary components are eternal and immutable (cf. axiom T13 to T18 *infra*). But all change obeys causality, according to axiom T3. Any change of relationship will therefore always be the effect of another change of relationship, antecedent in rank or in time. By further postulating that inter-connections between changes, between relationships, can as far as possible be expressed mathematically (cf. axiom T12 *infra*), Plato constructs (invents, according to our terminology) a causally ordered mathematical universe.

The word "cause" (*aitia*), a term borrowed from the judicial vocabulary where it designated responsibility,³ is used to designate this chain of relationships.

Axiom T4

The sensible world is the result of the ordering effort of a god.

One of the causes of the sensible world is a god, also called "father," "maker" and "demiurge," this last term being the most frequently used. This god does not *create* the world; his action is limited to the partial *ordering* of a primordial chaotic substrate (cf. axiom T7).

Axiom T5

The demiurge is good (*agathos*).

The goodness of the demiurge imposes upon him a certain way of acting (cf. axiom T10).

*Axiom T6***The demiurge is not omnipotent.**

This god is not omnipotent, for two reasons posited as axioms. The intelligible Forms and the *khora*, the primordial stuff or the “spatial medium,” exist independently of him (axioms T1 & T7). 2) And the demiurge must face *anagke* (axiom T8) which always resists his ordering effort.⁴

The Platonic demiurge is a peculiar divinity; after his ordering effort, he retires from the universe (*Timaeus* 42e). This cosmological approach presents a radically “materialis” character. Mankind is left alone in a material, ever-changing world where divine intervention subsists only in the form of an imperfect, partial, mathematical order.

*Axiom T7***The demiurge orders a primordial stuff, the *khora*.**

Khora is at the same time that in which sensible particulars are found, i. e., space or place, and that of what they are made, i. e., something approximating matter. We translate *khora* as “spatial medium.”

Khora is a hybrid entity. It is eternal, it exists even before the demiurge introduces, insofar as this is possible, order into it. But all that is found “in” the *khora*, and all that is produced “from” it, the sensible world, is ever-changing.

Plato acknowledged the difficulty in conceiving this “spatial medium;” and he was probably aware of the fact that he could not find a solution to the space/matter relationship; a problem that had to wait until the twentieth century to be solved. In fact, Plato asserts that we can only manage to conceive the *khora* by a sort of “bastard reasoning.”

... *khora* is everlasting, not admitting destruction; providing a situation for all things that come into being, but itself apprehended without the senses by a sort of “bastard reasoning,” and hardly an object of belief.

This, indeed, is that which we look upon as in a dream and say that anything that is must needs be in some place and occupy some room, and that what is not somewhere in earth or heaven is nothing. (*Timaeus* 52b)

... *khora* is the receptacle and the nurse of all becoming. (*Timaeus* 49a)

These quotations show how the spatial medium is at the same time “that in which” and “that from which” the sensible world is made.

Axiom T8

A cause, called *anagke*, perpetually resists the order which the demiurge attempts to introduce in the world.

The term *anagke* in ancient Greek is generally translated as “necessity.” But the way Plato uses the term *anagke* in the *Timaeus* refers to a very different meaning from the one intuitively given to “necessity”: constraint regarded as a law prevailing through the material universe. Plato holds *anagke* to be a “cause,” but a negative one, qualified as an “errant cause (*planomene aitia*)” (*Timaeus* 48 a), since it represents a non-rational element permanently resisting the ordering effort of the demiurge (cf. axioms T9, T10, T11, T12).

Anagke is indeed an inherent property of the *khora* postulated in axiom T7. The effect of *anagke* is that, in the *khora*, before the demiurge's interventions, the four elements that are supposed to make up all of the sensible world (axiom T9) “behave without reason or measure (*alogos kai ametros*)” (*Timaeus* 53a). Nothing in the *Timaeus* allows us to know to what extent the demiurge, who is not omnipotent (axiom T6) has succeeded in imposing order on the universe. *Anagke* continues to manifest itself in the sensible world as an “errant cause,” after the demiurge retires from the world. As a result, a factor of complexity and disorder always subsists in the universe.

It is easy to shrug off *anagke* as a myth. However, to claim that the entire universe must submit to simple mathematical rules accessible to mankind is at least as mythical.

Axiom T9

Sensible particulars, including heavenly bodies, are made out of four elements only: fire, air, water and earth.

Here Plato follows the tradition inaugurated probably by Empedocles, and which was universally accepted until the birth of modern chemistry in the eighteenth century.

Axiom T10

All that a benevolent demiurge (axiom T5) endeavoring to introduce some order into the *khora* (axiom T4) can do is to use as his model a “perfect paradigm” and to attempt to bring it about that the result of his efforts be the best possible *copy* (*eikon*) of that model (axiom T6).

In the *Timaeus*, one can read:

Let us, then, state for what reason becoming and this universe were ordered by him who ordered them. He was good ... Desiring, then, that all things should be good and, so far as might be, nothing imperfect, the god took over all that is visible – not at rest, but in discordant and unordered motion – and brought it from disorder into order, since he judged that order was in every way the better. Now it was not, nor can it ever be, permitted that the work of the supremely good should be anything but that which is best. (*Timaeus* 29e-30b)

Now whenever the maker of anything looks to that which is always unchanging and uses a model of that description in fashioning the form and quality of his work, all that he thus accomplishes must be good.⁵ (*Timaeus* 28a-b)

Plato’s epistemology postulates that the knowledge leading to truth (*episteme*) can only be that knowledge whose objects are the intelligible

Forms. This knowledge remains inaccessible to human beings living in the sensible world. They can only know the partial order, that imprint of the divine, which the demiurge attempts, insofar as possible, to introduce into the world. By reason of axiom T1, reality has been separated into two unbridgeable domains; now the mathematical order imposed by the demiurge provides a means to fill this gap; it represents the epistemologically necessary participation of sensible particulars in the Forms.

... [in the *khora* before the demiurge's intervention], these things were in disorder and the demiurge introduced into them all every kind of measure in every respect in which it was possible for each one to be in harmonious proportion (*analoga kai summetra*) both with itself and with all the rest. For at first they were without any such proportion save by mere chance, nor was there anything deserving to be called by the names we now use – fire, water, and the rest... (*Timaeus* 69b-c)

It follows from the axioms postulated thus far, that the effort of the demiurge consists in transforming, as far as possible, a chaotic, spatio-material substratum into a construction ordered according to symmetry, an operation that, by itself, will enable the *naming* of the things of the sensible world. In order to do this, the demiurge takes as a model what Plato calls the “perfect paradigm,” the intelligible realm ruled by the Good. The universe, thus modeled, presents, as much as possible, beauty, symmetry, order, harmony, simplicity, etc.

Axiom T11

As a copy of a perfect paradigm, the sensible world made by the demiurge can be nothing other than a living thing whose body is made from the four elements (cf. axiom T9) and whose soul (*psukhe*) is endowed with reason (*nous*), (cf. axiom T12).

According to axiom T1, the sensible world undergoes perpetual change. And according to axiom T10, the demiurge introduces partial

order into this change. Now the major cosmological problem for ancient Greeks was to account for what is partially ordered in the sensible world: the engendering of man by man, the ordered succession of the seasons, and above all, the most regular movement that can be observed, that of the heavenly bodies. Plato explains these changes by assimilating the sensible world to a living being. The distinctive feature of a living being is the *autonomous* principle of *ordered* change and movement (*kinesis*). This autonomous source of order was called “soul (= *psukhe*)” by Plato, who here again gave a new meaning to an ancient word. Consequently, *if* any kind of scientific knowledge of the sensible world is to be obtained, that world must be presupposed to be equally endowed by an autonomous principle of ordered change and movement; it must be an ensouled (living) entity. Since the demiurge is good (axiom T5), he tries to endow the sensible world with the best possible soul, a soul blessed with reason (*nous*). And it is this soul endowed with reason that *directly* explains the regular, ordered and permanent, that is to say “rational,” movement of the heavenly bodies.

Taking thought, therefore, he [= the demiurge] found that, among things that are by nature visible, no work that is without reason will ever be better than one that has reason, when each is taken as a whole, and moreover that reason cannot be present in anything apart from soul. In virtue of this reasoning, when he ordered the universe, he fashioned reason within soul and soul within body, to the end that the work he accomplished might by nature be as excellent and perfect as possible. This, then, is how we must say ... that this world came to be, by the god’s providence in very truth a living creature with soul and reason. (*Timaeus* 30b-c)

Since the world possesses a rational soul, and since order, which is an aspect of the Good, is infinitely superior to disorder, the change that affects sensible particulars will be ordered there where the world soul imposes itself like a “mistress and governor.” (*Timaeus* 34c)

Plato postulates that perfect knowledge must have as its object perfect being, and since the sensible world is just a copy inferior to its model, because the demiurge is not omnipotent (axiom T6), he produces only a copy of a perfect paradigm (axiom T10). Therefore, the

knowledge of the universe framed by such a demiurge must remain imperfect, amounting at best to a verisimilar account, to an *eikos logos*.

Axiom T12

As the vehicle of reason, the world soul is mathematically structured.

In the cosmology of the *Timaeus*, this axiom holds the place of the key epistemological axiom, since it secures the *a priori* possibility for any human knowledge of the universe. In Plato's epistemology, real knowledge (*episteme*) has no other objects than the intelligible Forms; it thus remains beyond the reach of human beings. The verisimilar account (*eikos logos*) humanity can attain is thus dependent on this astonishing hypothesis: the characteristics that the Good dispenses to the intelligible Forms, such as beauty, symmetry, order, harmony, proportion, etc. can be expressed in mathematical terms. Given the state of mathematics in Plato's time, this hypothesis is truly amazing.

The scope of axiom T12 can only be understood if we refer to the role *symmetry* plays in Plato's cosmology. In ancient Greek, *summetros*, a word made up of *metron* "measure" as second term, means properly "with a common measure." If things have a common measure, they are called "commensurable;" otherwise they are incommensurable. A common measure allows proportion to appear. Thus things may be said to be in due proportion (*analogoi*); and if the proportion remains always the same, these things are symmetrical as such. If such ideas are accepted, "symmetrical" can become synonymous with "harmonious" and even more importantly with "ordered" (= *kosmetos*).

In its more general acceptance, symmetry describes those aspects of a thing that remain unchanged, if that thing is considered from different points of view, for example the left side and the right side of a face, or if that thing undergoes certain transformations, for example a parallel translation or a rotation around an axis (the circle and the sphere playing here a crucial role).

The essential aspect of symmetry is the following: some properties of a thing remain invariable throughout change, something remains "analogous," because proportion (= *analogia* in Greek, *ratio* in Latin) is

preserved. But only the intelligible Forms, sole objects of *episteme*, are, according to Plato, unchangeable, immutable and eternal. Plato's aim, in the *Timaeus*, is to propose a cosmology which secures a verisimilar account (*eikos logos*) of the universe, since a true account (*alethes logos*) of it is out of reach. In our ever-changing sensible world, a verisimilar account, a partial knowledge, is possible if and only if this world shares the immutability of the intelligible Forms, even if only partially. This Plato assumes as the key tenet of his cosmology. Consequently, the aim of cosmological inquiry is to uncover such invariable properties. Plato daringly extrapolates: these reflections of the divine are found in the world as symmetry, and symmetry can only be grasped mathematically. In this way, the entire program for science is outlined; it has not changed since.

Plato's extrapolation relied on an important discovery made in his time. The sound of a musical string instrument remains consonant when the lengths of the strings are changed, if the mathematical proportion (*analogia*) between the lengths of the strings remains unchanged. The Pythagoreans had discovered that what remains unchanged is a mathematical formula giving, in terms of integers, the proportion between the lengths of the strings.

One can thus predict that two different musical instruments, such as *A* and *C*, will identically produce a consonant harmonious music, if the lengths of their strings are in the correct mathematical proportion *B*. The participation of the sensible (material strings) in the intelligible (musical proportion) is thus mediated by mathematics. Plato will bestow this Janus-like characteristic of mathematics upon the world soul. Thereby mathematically expressible symmetry is promoted to the rank of the necessary *a priori* condition for any scientific knowledge of the sensible world. Plato puts forward one of the key tenets of contemporary physics, but the mythical language he employs has obscured this fact for centuries.

The World Soul in the *Timaeus*

The world soul is that entity which mathematically orders the universe, for it is destined by the demiurge to rule over the universe "as its mistress and governor." (*Timaeus* 34c) The mathematical order that

governs the universe is determined by two characteristics of the world soul. On one hand, it participates both in being and becoming; by this means, it appears as the mediating agent between the eternal Forms and a sensible world that never ceases changing (axiom T1). Furthermore, the world soul exhibits a mathematical structure; and a mathematical order becomes manifest only there where the soul rules. In the Platonic system, the soul in general, and the world soul in particular, are the causes of ordered movement (axiom T11). In a universe governed by a mathematically structured soul, all change is necessarily governed, as far as possible, by mathematical precepts. Following this, that which at first seemed to exceed all possibility of rational analysis – reality exclusively perceived by the senses foreign to reason, and which never ceases changing – becomes amenable to a verisimilar account.

The demiurge achieves his objective as follows. In the first place, he introduces a soul into the world's body, which, being a copy of a perfect original, is endowed with the most perfect form, and thus presents the aspect of a gigantic sphere, the sphere being the most symmetrical figure. Moreover, to avoid infinite regress, the world soul must be autonomous, that is, it must be the cause of its own movements. As a result, the soul is a complex construction displaying two remarkable features: its movements are circular, circular movement being the most symmetrical movement, and they obey the laws of musical harmony, because musical harmony can be considered an aspect of the Good (cf. the "music of the heavenly spheres"). As well as being circular, the movements of the world soul maintain permanently a constant speed, a property which gives them the most perfect symmetry. Since immutability means perfection, this permanence and regularity, which are ultimately of a mathematical nature, allow the sensible world, where all movements are governed by the movement of the world soul, to partake, to a certain extent, in the eternity and the stability of the intelligible.

The Substance of the World Soul

The description of the world soul takes the form of a mythical narrative recording what the demiurge does. The intervention of the demiurge does not however violate the postulate formulated in the

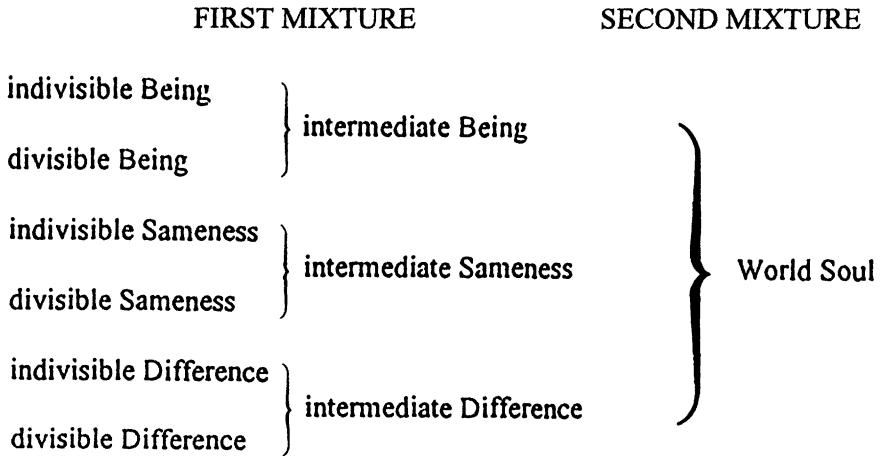
Phaedrus (245c-246a) concerning the ungenerated character of all principles, because this intervention does not imply an origin in time. It reveals two things: the soul is ontologically dependent upon the intelligible Forms, and furthermore is a reality intermediate between intelligible Forms and sensible particulars.

To compose the most fundamental entity of his cosmology, Plato makes use of the three most general notions in his metaphysical system: Being, Sameness and Difference. All reality comprises these constituent elements as described in the *Sophist* (254d-259b). All reality "is," the first requirement in metaphysics. Considered in its relationship with all that it "is not," this Being maintains its identity, which brings about the second fundamental concept, Sameness. But this Being only maintains its identity, because it is different from all that is not itself, because it is Different from all the rest (a horse *is*, it is a *horse* and it is *nothing else*, for example, a cat).

Furthermore, as the world soul must play the role of mediating agent between the sensible and the intelligible, its constituent elements are situated in it on an intermediary level between indivisibility, which characterizes the intelligible, and the divisibility, which characterizes the sensible. This is what the demiurge tries to bring about in performing these mixtures:

Between the indivisible Being that is ever in the same state and the divisible Being that becomes in bodies (axiom T1), he compounded a third form of Being composed of both. Again, in the case of Sameness and in that of Difference, he also on the same principle made a compound intermediate between that kind of them which is indivisible and the kind that is divisible in bodies. Then, taking the three, he blended them all into a unity, forcing the nature of Difference, hard as it was to mingle, into union with Sameness, and mixing them together with Being. (*Timaeus* 35a-b)

In this difficult passage, illustrated in the following diagram, Plato expresses two ideas: i) the soul comprises the same constituent elements as any other reality: Being, Sameness, Difference; and ii) it is an intermediary reality between the intelligible and the sensible.



From these mixtures, a concoction results which Timaeus describes as a mass of metal. Solidified, this mass of metal serves the demiurge as material for constructing the armillary sphere which displays the motor function of the world soul, on which all the movements of the universe, including those of the planets and the fixed stars, depend.

The Mathematical Structure of the World Soul

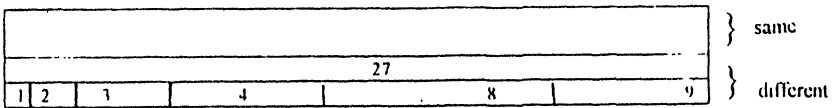
The world soul is framed as an armillary sphere, since, although it is supposed to be the *principle* of movement of the heavenly bodies as well as the *principle* of changes within the whole universe, its primordial purpose is to account precisely for the observed movements of the heavenly bodies, and allow a mathematical description of astronomical phenomena.

The movements of the heavenly bodies seem to present two characteristics: *permanence* and *regularity*, characteristics known from the remotest antiquity and which led mankind to regard these bodies as divine beings, as opposed to the hypercomplex sublunary realities,

subject to movements apparently devoid of all regularity. To account for these two characteristics, Plato formulates two postulates, flowing from axioms T10, T11 and T12. 1) Movements of the heavenly bodies are circular, thus they are *permanent*; 2) Movements of the heavenly bodies obey the laws of the various types of the mathematical proportions known at the time; thus, in spite of appearances, they are perfectly *regular*, i.e., mathematical.

The demiurge, whose actions are described in terms generally applied to a blacksmith, laminates the mass resulting from the mixture described above, and transforms it into a sheet. He begins by cutting this sheet lengthwise into two bands, which he somewhat paradoxically calls the band of the “Same” and the band of the “Different” even though these two bands are composed of the same mixture of Being, Same and Different. This operation accounts for the observed dissimilarity between fixed stars and planets. Next, the band of the Different is divided by the demiurge into seven sections to explain the movement of the “planets” known at that time. The apparently erratic (*planetes*) movement of the planets probably explains the name Different given to this band, to oppose it to the band of the Same which represents the apparently regular movement of the fixed stars.

Figure 1.1



This first operation is not sufficient. It has allowed the formation of two bands. But these bands must then be bent to become those circles on which the heavenly bodies will move with the *permanence* provided by the perfect symmetry of the circle.

The *regularity* of the heavenly bodies' movement must still be accounted for: this is where proportion comes into play.⁶

The band of the "Different" is therefore divided into seven parts, according to the following series of integers: 1, 2, 3, 4, 9, 8, 27. It may be observed that this series corresponds to a double geometrical progression expressed in powers of 2 and 3 respectively:

$$\begin{array}{cccc} 2^0 & 2^1 & 2^2 & 2^3 \\ 3^0 & 3^1 & 3^2 & 3^3 \end{array}$$

But the mathematical explanation goes much further.

These seven numbers represent, as we will see further on, the orbital radius of each of the seven planets that gravitate around the earth. The earth remains immobile in the center, and the number 1 corresponds to the distance from Earth to Moon. Between these seven numbers, two series of proportional means are now inserted.

1) harmonic means

$$(x - a)/(b - x) = a/b; \text{ or } x = 2ab/(a + b)$$

2) arithmetical means

$$(x - a) = (b - x) \text{ or } x = (a + b)/2$$

Which produces:

1) resulting from the insertion of the harmonic and arithmetical proportional means in the first geometrical progression:

		harmonic means	arithmetical means
a=1	b=2	4/3	3/2
a=2	b=4	8/3	3
a=4	b=8	16/3	6

that is to say: 1, 4/3, 3/2, 2, 8/3, 3, 4, 16/3, 6, 8

2) and as results of the insertion of the harmonic and arithmetical proportional means in the second geometrical progression:

		harmonic means	arithmetical means
a=1	b=3	3/2	2
a=3	b=9	9/2	6
a=9	b=27	27/2	18

that is to say: 1, 3/2, 2, 3, 9/2, 6, 9, 27/2, 18, 27

Furthermore, if we consider this double series of results, we notice that, between the harmonic and arithmetical proportional means in each of the two geometrical progressions given at the outset, there exist only three types of interval: 4/3, 9/8, 3/2.

$$\begin{array}{cccccccccccc} 1 & 4/3 & 3/2 & 2 & 8/3 & 3 & 4 & 16/3 & 6 & 8 \\ \underbrace{\hspace{1.5em}}_{4/3} & \underbrace{\hspace{1.5em}}_{9/8} & \underbrace{\hspace{1.5em}}_{4/3} & \underbrace{\hspace{1.5em}}_{4/3} & \underbrace{\hspace{1.5em}}_{9/8} & \underbrace{\hspace{1.5em}}_{4/3} & \underbrace{\hspace{1.5em}}_{4/3} & \underbrace{\hspace{1.5em}}_{9/8} & \underbrace{\hspace{1.5em}}_{4/3} \end{array}$$

$$\begin{array}{cccccccccccc} 1 & 3/2 & 2 & 3 & 9/2 & 6 & 9 & 27/2 & 18 & 27 \\ \underbrace{\hspace{1.5em}}_{3/2} & \underbrace{\hspace{1.5em}}_{4/3} & \underbrace{\hspace{1.5em}}_{3/2} & \underbrace{\hspace{1.5em}}_{3/2} & \underbrace{\hspace{1.5em}}_{4/3} & \underbrace{\hspace{1.5em}}_{3/2} & \underbrace{\hspace{1.5em}}_{3/2} & \underbrace{\hspace{1.5em}}_{4/3} & \underbrace{\hspace{1.5em}}_{3/2} \end{array}$$

These three types of interval correspond to the musical relationships already known in Plato's time: the fourth: 4/3, the fifth 3/2 and the tone 9/8. To obtain a musically harmonious arrangement, all that had to be found was the octave 2/1 that fills the interval between the fourth (4/3) and the fifth (3/2) and the *leimma* (= in ancient Greek, "that which remains") 256/243 that fills the interval remaining between the two tones (9/8). Hence this table:

a	1	9/8	81/64	4/3	3/2	27/16	243/128	2
2a	2	9/4	81/32	8/3	3	27/8	243/64	4
4a	4	9/2	81/16	16/3	6	27/4	243/32	8
8a	8	9	81/8	32/3	12	27/2	243/16	16
16a	16	18	81/4	64/3	24	27		
		9/8 9/8		256/243		9/8 9/8		256/243
		4/3				4/3		
		4/3				3/2		
		2/1						

Considered only from a musical point of view, the mathematical construction of the world soul would therefore comprise 4 octaves, a fifth and a tone:

$$2/1 \cdot 2/1 \cdot 2/1 \cdot 2/1 \cdot 3/2 \cdot 9/8 = 27$$

However, it should be observed that Plato's intention was not to produce a theory of the type of music that the heavenly bodies might emit.

Borrowing the idea of the "harmony of the spheres" perhaps from the Pythagoreans, Plato extrapolates. Knowing that musical harmony is governed by mathematical laws, he postulates that heavenly bodies, whose movements present the permanence and regularity that mathematical means provide in music, are also governed by such laws: the sort of mathematics that "works" so well in music, music which means harmony by antonomasy, should "work" just as well in astronomy.

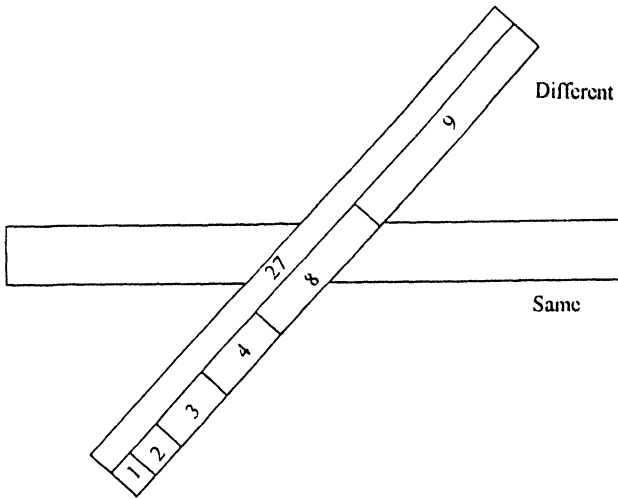
The Role of the World Soul

The stakes are important, since the role of the world soul is to explain the how and why of the ordered movement of the sensible world. The more the world soul is governed by rigorous mathematical laws, the more the movements affecting the sublunar sensible world will be

ordered. As the above-described proportions apply to a series of integers that represent the orbital radius of each of the seven planets surrounding the earth, these proportions affect not only the arrangement of the heavenly bodies, but also, and above all, the speed of their revolution, since Plato believes that the speed of the revolution of a body varies in function of the length of the radius of the circle it describes. This permanence and this regularity are transmitted, in various degrees, by the heavenly bodies to sensible things, as will be shown.

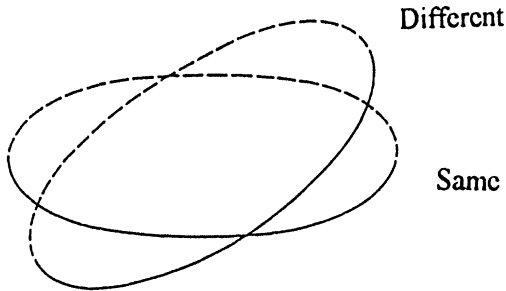
Let us go back to the working demiurge. After having cut the metal sheet described above, the demiurge crosses the two resulting bands making them coincide in their middle, as in the figure of the Greek letter X:

Figure 1.2



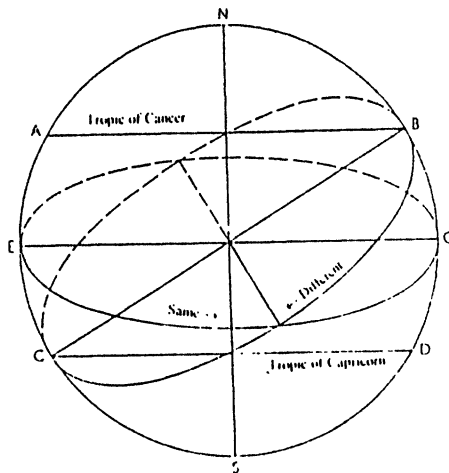
Next he bends these two bands and joins their extremities, thus forming two circles:

Figure 1.3



On the first circle, the circle of the "Same," move the fixed stars; the whole sphere of which the sensible world consists follows this movement, from east to west. On the circle of the "Different," move the seven "planets": Moon, Sun, Mercury, Venus, Mars, Jupiter, Saturn.⁷

Figure 1.4



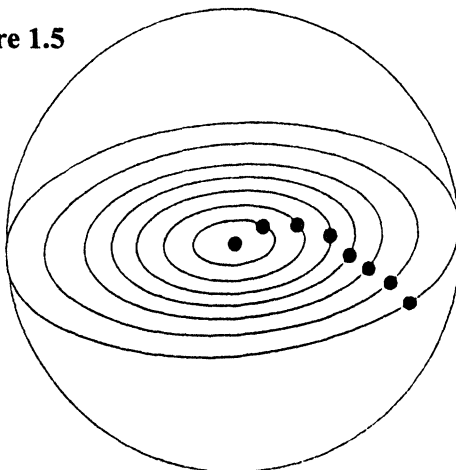
Comments

- AB is the Tropic of Cancer
- CD is the Tropic of Capricorn
- The movement of the “Same” is the movement of the world’s sphere, going from left (= the east) to the right (= the west) on the equatorial plane (= EF).
- The Zodiac can be represented by a large band where the twelve signs are ordered, forming a ring that shares its center with Ecliptic (BC), and whose circumference follows the sphere’s envelope.

The world body thus consists of an immense sphere that contains all sensible reality and beyond which there is nothing. This explains the perpetuity of the sensible world, for nothing can come from the outside to disturb or destroy it. Moreover, we must imagine that the fixed stars are in some way fastened to the internal surface of this sphere and moved with it; this explains why the movement of the fixed stars and that of the sphere that comprises the world body are identical.

After these manipulations, the demiurge moves on to the final operation, which consists in dividing the interior circle six times (*Timaeus* 36 d) in order to obtain seven unequal circles corresponding to the orbits of the following planets: Moon, Sun, Mercury, Venus, Mars, Jupiter, Saturn, the Earth remaining immobile at the center of the sensible world (*Timaeus* 40b-c).

Figure 1.5



from the center:

Earth
 Moon
 Sun
 Mercury
 Venus
 Mars
 Jupiter
 Saturn

The resulting construction is fitted by the demiurge into the sphere which encompasses the sensible world, making sure that their respective centers correspond perfectly (*Timaeus* 36d-e, cf. 34b).

By so doing, the demiurge endows the sensible world with a principle that accounts for all ordered movements, whether they be of a physical (astronomy) or a psychical nature (knowledge). Indeed, by means of the circle of the "Same," the world soul establishes direct contact with the world of intelligible forms, and, with the circle of the "Different," it is put in contact with the sensible world. Since it is a living thing endowed with reason, the sensible world can autonomously order its own movements (i.e., changes), in a "rational" way.

Thus, in the *Timaeus* (38c-39e), Plato endeavors to put forward a complete astronomical system based exclusively on circular movement, a system that remained viable until Kepler.⁸

Corollary: The Definition of Time

The movement of the heavenly bodies permits Plato to establish several standards for the measure of time. The movement of the circle of the Same brings about the alternation of day and night. The movement of the Moon produces the monthly sequence, and that of the Sun, the yearly sequence. But Plato is even more daring. He hypothesizes a temporal duration measured by the revolution of the five other planets, and a "great year" corresponding to the return of all the heavenly bodies to their initial position (*Timaeus* 39c-e).

Since in the world of Becoming, only images exist, time, which is the measure of Becoming must present two characteristics: it is 1) an image, but 2) an image ordered by numbers. As it is directly associated with the unceasing change of the sensible world, time becomes an object of knowledge only if a resemblance is found between it and an intelligible Form, a resemblance that can be expressed with the help of a mathematical relationship of the type:

eternity/unity = time/the diversity of numbers.

Hence this famous definition: "When he [the demiurge] ordered the heaven, he made, of eternity that abides in unity, an everlasting likeness moving according to number, that to which we have given the name 'time.'" (*Timaeus* 37d) Time is therefore indistinguishable from the

world soul, for it is engendered by the movements of all the circles of the world soul; it is also indistinguishable from the world body, for the standards of temporal measurement are provided by the revolutions of the heavenly bodies. It follows that the sensible world can not be engendered in time since it itself engenders time. Sensible world and time co-exist;⁹ there can be no time before the sensible world.

Plato's Theory of Matter and the Cosmological Axioms¹⁰

An astronomical system is developed in the cosmology of the *Timaeus*. Plato's aim is to explain *everything*, including the underlying microscopic world and the complex world of human experience; hence the need to take into consideration not only physical phenomena but also biological and psychological phenomena. Consequently, a theory of matter must be advanced, implying new axioms.

Let us begin by recalling an above-mentioned axiom.

Axiom T9

Sensible particulars, including heavenly bodies, are made up of four elements only: fire, air, water and earth.

Greek physics was based upon this axiom. Plato wants to describe the origin of these elements, and moreover their mathematical origin. In so doing, he is aware of being truly original:

... what I [= *Timaeus*] must now attempt to explain to you is the distinct formation of each [of the elements] and their origin. The account will be unfamiliar; but you [= Socrates, Hermocrates, Critias] are schooled in those branches of learning which my explanations require [i.e., mathematics], and so will follow me. (*Timaeus* 53b-c)

The astonishing modernity of this endeavor has not gone unnoticed. In an article published in 1955, Werner Heisenberg compares modern particle physics with the theory of elementary material components laid out in the *Timaeus*:

In what follows, the particular form of the philosophy of nature propounded by Plato in the *Timaeus* shall be considered, with special emphasis on a characteristic trait of this approach which resurfaces in modern atomic physics, in the theory of elementary particles, and which there plays an important role. The mathematical forms by which we nowadays represent the elementary particles ... are more complex than the geometric forms postulated by the Greeks. But essentially, in both cases these forms originate in certain simple mathematical basic requisites. And one must not forget that on this point the program of modern physics has yet to be completed. The similarity between Plato's ideas and modern atomic physics appears furthermore in a different context. Should one inquire in Plato's [philosophy], what is the content of his [geometric] forms, out of what stuff they are ultimately made, one gets this answer: out of mathematics.

Heisenberg continues:

In the final analysis, in both cases, the notion of matter is essentially a mathematical concept. The most fundamental kernel of all that is material is for us, as well as for Plato, a [mathematical] form, and not some material content.¹¹

Heisenberg clearly saw the amazing similarity between Plato's theory of matter and its contemporary counterpart, and this on a fundamental axiomatic level. Indeed, the theory of matter in the *Timaeus* is based on the following axioms.

Axiom T13

The entire universe can be reduced to discrete, elementary components.