Plato's Atomism in the *Timaeus*

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Aristoxenus of Tarentum, in a rather satirical anecdote, suggests that Plato wanted to collect the writings of Democritus and have them burned before he was stopped by two Pythagoreans who argued that this attempt would be futile since copies of the books were already widely available (DL, IX, 40). This story seems to point out a certain jealousy of Plato towards Democritus, a philosopher he never quotes in his dialogues. However, in the *Timaeus*, Plato describes how the corporeal entities of our universe are constituted by the combination of invisible basic particles. The resemblance between Plato's *Timaeus* and Leucippean-Democratian atomism was pointed out by Aristotle and seems to be based on the fact that both theories investigate the ultimate *stoicheia* from which the universe is composed.[1] More generally, it seems plausible that Plato's *Timaeus* should be understood as a critical dialogue with the *physiologoi*, especially Anaxagoras, Empedocles and the Atomists.[2] Two main characteristics must be kept in mind when comparing Plato's *Timaeus* with Presocratic cosmologies: first, in Timaeus' *eikôs mythos,* a divine craftsman, the Demiurge, looking to an intelligible model, builds the universe by imposing order to pre-existing chaotic *milieu*. Second, two complementary dimensions must be considered in order to provide a complete explanation of what the *cosmos* is, namely intellect (*nous*) and necessity (*ananke*). Timaeus' description of the constitution of the four elements in 53b-61c (fire, air, water, earth: FAWE) can only make sense if it is understood within the context of the whole dialogue in which the Demiurge persuades an unordered necessity by means of his intellect.[3] In this context, Plato will introduce a geometric atomism that aims to describe how the elements FAWE are themselves constituted by more basic

[1] *De Caelo* III 2, 300b16; III 8, 307a16; IV 5, 312b21, *De Gen. et Corr.* I 8, 325b30.
[2] See Taylor (1928) and Vlastos (2005), pp. 66-68.
[3] 48a2.

elements which he identifies with two basic triangles. In this way, both Plato and Democritus are committed to the idea that, as Vlastos notices, "the unobservables we postulate to account for properties of observables need not themselves possess those same properties".[4] In other words, neither philosopher commits the "fallacy of division" that is, attributing to the parts the properties of the whole, at least without providing any justification. However, unlike Democritus' atoms which are indivisible solids possessing an infinite multiformity, Plato's geometrical atoms consist of planes limited in number.[5] But before getting there, some contextualization has to be provided in order to be able to understand what kind of atomism Plato introduces in the *Timaeus*.

I will divide my investigation into two parts: first, in order to understand how a geometric atomistic view of reality emerges in the *Timaeus*, a close look will be given to the structure of Plato's story about the constitution of the universe. More precisely, the narration of the myth will be distinguished from its doctrinal content. Second, a description of Plato's geometric atomism will be offered by considering its specific context. To conclude, following the results of the two first parts, I will briefly address three puzzles: the origin of motion, the nature of the Receptacle and the relationship between Plato's geometric atomism and the Theory of Forms as it appears in the *Timaeus*.

1/ **Principles and events in the *Timaeus***

1.1 A myth and its principles

Plato's geometrical atomism appears in the second part of the *Timaeus* (53b-61c): the first part describes the works of intellect (29d-47e), the second the action of necessity (47e-69a) and the third the cooperation between intellect and necessity (69a-92c). These three parts are preceded by the introduction of premises on which all the cosmological discourse is founded (27d-29d).[6] In this context, a divine Demiurge (29d-30c), looking at an intelligible Model (30c-d), will constitute the

[4] Vlastos (2005), p. 68.
[5] Vlastos (2005), p. 70 and Cornford (1937), p. 210 who speaks of a « deliberate correction of Democritus' atomism ».
[6] Following Cornford (1937), p. 21, the axioms are "(1) The eternal is the intelligible; what comes to be is the sensible. Since the world is sensible, it must be a thing that comes to be. (2) Whatever comes to be must have a cause. Therefore, the world has a cause-a maker and father; but he is hard to find. (3) The work of any maker will be good only if he fashions it after an eternal model. The world is good; so its model must have been eternal. Finally, the conclusion is drawn: any account that can be given of the physical world can be no better than a 'likely story', because the world itself is only a 'likeness' of unchanging reality."

cosmos. Plato qualifies the discourse he is offering as a probable account (*eikôs mythos*[7]). Although this interpretation has been criticized[8], Timaeus seems to suggest that a discourse which will concern the universe and its origin can only reach the level of likelihood: this is a consequence of considering the *cosmos* an image of an intelligible Model. A discourse about the intelligible Model can be true, whereas an account about its sensible image will be, at most, plausible (29c-d). Consequently, Timaeus' story should not be read as a scientific account of the coming to be of the universe, but as the best possible discourse considering the human nature of the narrator (29d1). Furthermore, Timaeus, from 29d7, qualifies his discourse as a myth about the fashioning of the universe. This implies i) a specific temporality (from a non-*cosmos* at t1 to a fully constituted universe at t2), ii) characters (endorsing different roles: the Demiurge (Father 1), the Forms (Father 2[9]), the Receptacle (Mother) and the sensible Universe (Child)- 50d) and iii) a dramaturgy (the proper constitution of the universe). Should the reader take this story seriously? Was the universe *literally* fabricated by a divine craftsman? Or should the account be demythologized and translated into a more rational explanation of the ontological constituents of the universe?[10] Without either getting into the details of this difficult question, or deciding which alternative must be assumed, the following comment might suffice for my investigation. Plato himself leans towards a certain demythologization: the order of the events described by Timaeus does not actually follow the order of what *should* be the myth of the creation of the Universe if expressed in a strictly chronological progression. As a matter of fact, Timaeus insists that the story he is telling i) did not happen in the same order as the one he has chosen (34c) and ii) necessitates different points of departures (48a-b). That is: due to Timaeus' and the reader's human limits (34c3), the myth offered is, in fact, already somehow *demythologized*. The main division of the discourse between (1) the works of intellect (30a2-6) and (2) necessity (47e5-48a7) is actually a good exemplification of Plato's didactical intention: the story must describe the origin of the universe from two points of view which are not chronologically but ontologically differentiated.

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[7] 29b3-d3, 48c2-e1, 54a2-5, 56b3-c7, 57d4-6, 68b6-8, 68c7-d2.

[8] See Burnyeat (2008) and Brisson's answer (2012).

[9] See n. 17.

[10] For an account of the distinction between a literal and a didactic reading of the *Timaeus* see Pitteloud (2017), pp. 197-198. For the didactic reading see Cornford (1937), p. 26. Each of the two readings must deal with specific difficulties (for example, on the literal account: does a *time* exist before the creation of time (37c-38c)? What is the cause of motion (52d-53c) before the constitution of the World Soul? On the didactic account: what could be demythologized in Timaeus' discourse? Could the Demiurge be identified with the *nous* of the World Soul, or with the Model, or with the Form of Good?). See Cornford (1937) pp. 209-210 and Vlastos (2005).

It is directly after the second point of departure (2) that the description of the constitution of the four elements (FAWE) starts. However, right after the first beginning (1), Timaeus has already described the fabrication of the World Body by the Demiurge (31b-34a). In order to understand better the complexity in which Plato's geometric atomism appears, it might be relevant to distinguish between the cosmological principles (P) on which the whole discourse is built and which are introduced during the course of the myth, and the events (E) of the constitution of the universe in their chronological order. Let's start with a list of the principles (P) supposed by Timaeus:[11]

P1: The Universe is the combination of intellect (1) and necessity (2).
P2: The constituents (also called the three kinds) of the Universe are: a) the intelligible Model, b) the Receptacle and c) the sensible being, itself an image of the Model (48e-49a).
P3: The Receptacle is a neutral *milieu* in which the images (*mimêmata* 50c7) of the Forms of the Four Elements appear.
P4: The Receptacle possesses both a spatial (*in which*) and a constitutive (*of which*) dimension.[12]
P5: Since i) the *cosmos* must possess *intellect*, ii) the place of intellect is the soul and ii) for sensible entities a soul is united with a body, then the *cosmos* will be a living animal constituted by a body and a soul (30a-b).[13]
P6: The Model of the *cosmos* is the Form of the Living Creature, a Form which is all inclusive (which possesses all the intelligible species) (30c-d).[14]
P7: The *cosmos* is both an image (reflection) of the intelligible Model and a Demiurgic fabrication.[15]
P8: The *cosmos* is the best possible realization.[16]

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[11] Beyond these principles, the premises pointed out by Cornford (1937), see n. 6 above, must also be accepted. Furthermore, some metaphysical principles (like the hypothesis of Forms, see 51b-e) are admitted too. Obviously, each of these principles would require a great deal of discussion, which goes beyond the scope of this paper.
[12] The Receptacle (*hupodokhê*: 49a6, 51a5) is described as a mother (*mêtêr*: 50d3), a nurse (*trophos*: 88d6, *tithênê*: 49a6, 52d5, 88d6), a place (*khôra*: 52a8, 52b4, 52d3, 56a6, *topos*: 52a6, 52b4, 57c3, *edra*: 52b1, 53a6). It is described in ways that might make think of it as space *and* matter (Timaeus uses the metaphor of gold (50a5-b5), an impress or mould (50c2-3) and an odourless base of perfumed ointments (50e8-51a1)). Aristotle believes Plato mistakenly identified the two concepts (*Phys*. 4.2.209b11-12). For a discussion of Aristotle's criticisms of Plato's *khôra* and the relationship with his own *hulê,* see Brisson (2011). See also Harte (2006), pp. 247-264 and (2010).
[13] At least, for visible objects, *nous* must be found "within" a soul, which does not prevent the possibility for the Demiurge to be a pure transcendent *nous* (see Menn (1995)).
[14] On the different sorts of model, see O'Meara (2017), pp. 41-64.
[15] Both "images" are to be found in the *Timaeus*: the appearance of the *mimêmata* of the Forms of FAWE in the Receptacle is distinguished from the artisanal constitution of the *cosmos* by the Demiurge. In this way, the *cosmos* possesses two different kinds of *father*: the Demiurge (29e-30b) and the Model (50d3).
[16] This implies that the Demiurge must bestow some properties of the Model upon the *cosmos* (self-sufficiency, independence, indissolubility). See on that O'Meara (2017), pp. 60-64.

These are the principles which do not depend on any chronological ordering, and they justify why the universe is the way it is. However, Timaeus' discourse exposes the coming to be of the *cosmos* in a certain order. This order is not completely chronological, for it is based on the two points of view intellect (1) and necessity (2). It might be useful to try to re-construct the chronology of the universe[17], according to Plato's myth.

1.2/ The chronological events:

1.2.1/ The first event

The demiurge does not create the universe from nothing. He organizes all that is visible and finds a pre-existing disordered *milieu* (30a2-6), which implies that something already existed before the Demiurgic work. According to P2, P3 and P4, the disordered pre-cosmic state of the universe implies the existence of the Model (intelligible Forms), the Receptacle (milieu) and the images (*mimêmata*) of the Forms (becoming), *even before the Heaven came into being* (52d4).

E1: Before the beginning of the constitution of the ordered *cosmos*, there was a chaotic pre-cosmic state of affair.

This state of the affair is described in 52d-53c and represents a moment of the story *when a deity is absent from it* (53b3-4).[18] In that condition, all that exists, says Timaeus, can be found in a state of disorderedly motion. The text (52d4-53b5), which is rather obscure, depicts how the Receptacle was before the Demiurge's intervention and follows a long description of the "wandering cause" (which starts at 47e). This description aims to show what the state of the four elements FAWE was *before the generation of the Heaven* (48b3-4). This description implies the introduction of a third kind, the Receptacle, in addition to the Model (*paradeigma*) and the sensible copy (*mimêma*) of the Model (48e-49a). The new distinction between these three kinds involves a certain difficulty when it comes to refer to the sensible four elements, since they are the appearances of the intelligible Forms of

[17] For the present purpose, I will only reconstruct the story of the *cosmos* until the end of the Demiurge's work.

[18] This moment could either be a proper stage of the development of the universe (on the literal reading) or a thought experiment of what would be the world without demiurgic order (on the didactic reading). As the Forms are already reflected in the Receptacle, it might be safe to conclude that the intelligible realities are only necessary, but not sufficient, conditions for the ordering of the *cosmos*. On this question, see Vlastos (2005), Cherniss (1954), Brisson (1994), p. 298 and Cornford (1937), pp. 198-210.

the Four Elements (whose existence is justified in 51b-52a) in the Receptacle : this difficulty (49c7-50b5) concerns the fact that *only* the Model and the Receptacle possess the permanence which allows them to be designated with the demonstrative "this" (*touto*).[19] The phenomenal appearances of the Forms of the Four Elements are deprived of stability as they are constantly entering and leaving the Receptacle. Consequently, the sensible appearance of fire, for example, in the pre-cosmic chaos, should not be called *this fire* but "suchlike" (*toiouto*) fire.[20] In this context, the Receptacle is described as a *milieu* in which the images of the Forms of the four elements appear and disappear.[21] Timaeus affirms that the Receptacle *must be always called the same* (50b6-7) and concludes that:

> it (the Receptacle) appears to have different qualities at different times; while the things that pass in and out are to be called copies of the eternal things, impressions taken from them in a strange manner that is hard to express: we will follow it up on another occasion.[22]

After having introduced two other analogies[23], Timaeus asserts that even though the Receptacle *partakes of the intelligible in some obscure way and is very hard to apprehend* (51a6-b2)[24], it is an essential entity which needs to be supposed in order to guaranty the existence of the sensible as an image of the intelligible (52c-d). This fairly long reasoning leads to the description of the pre-cosmic chaos, a description (52d4-53b5) which implies that before the Demiurge initiates his work, the images of four elements already existed and appear in the Receptacle. These images are called traces (*ichnê*) of the elements. They are not yet configured by the Demiurge (by means of shapes and numbers) and they appear as affections (*pathê*) with powers (*dunameis*) that are neither alike nor evenly balanced, without proportion and measure (*alogôs kai ametrôs*). Nevertheless, says Timaeus, they are visible,

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[19] A « much misread passage » according to Cherniss (1954(b)). See on that Brisson (2011), pp. 4-7 and Pitteloud (2017), pp. 286-290.

[20] It has been suggested that the appearances of the Forms in the Receptacle could be understood as *tropes*. See Buckels (2018).

[21] The analogy with gold (50a5-b5) is introduced to help understand this point: we should imagine someone who never ceases forming different shapes (triangle, square, …) from some gold substrate. It would be absurd, in order to refer to one of these shapes, to use the demonstrative "this", since at the very moment we would do so, the form would have already been transformed into another one. Only the gold substrate could be designated with the demonstrative "this" as it is what remains through the transformations. For the comparison between the Receptacle and a kind of matter or medium, see Harte (2006) pp. 255-256.

[22] 50c3-6. On the *"another occasion"* (*eis authis*), scholars don't agree if this promise has been fulfilled or not by Timaeus. If it has, does it refer to the pre-demiurgic appearance of the Forms into the Receptacle as described in 52c-d (which does not seem to be a real explanation) or to the imposition by the Demiurge of geometrical shapes to the elements (53c4). On that see O'Meara (2017), p. 60.

[23] See n. 14.

[24] The Receptacle seems to be apprehended without the senses by a sort of abstraction, called a *bastard reasoning* (52b2).

although no living creature has been yet constituted and could actually look at them!

One might wonder how these forms (*morphia)* would appear in the Receptacle *if someone could* look at them? As traces, those pre-elements could either be, not yet, or no longer, images of the elements.[25] If it is true that strictly speaking those are traces "*of the elements*, not of the models of the elements"[26], it nevertheless seems that the setting of the pre-cosmic chaos just after the description of the four elements which are called images (*mimêmata)* of the Forms of FAWE (especially in 52c), strongly suggests that the *traces* should be identified with the *images* of the Forms. Those traces are said to be without proportion and measure (69b5), and when Timaeus returns to talk about them in 69b, he claims that they should not even be called elements (69b7).

Furthermore, these traces are to be found in a disorderly motion.[27] How can this motion be understood? First, Plato seems to describe a mechanical motion caused by powers that are not evenly balanced, because there is no principle of measure and proportion to be found yet. This causes a shaking of the Receptacle and all its contents (the traces). The Receptacle is said in turn to shake the pre-elements. Later in his discourse, when Timaeus gives a description of motion and rest in the universe, at 57d-58c, he insists on the fact that a necessary condition for motion is inequality: inequality, according to Timaeus, implies heterogeneity, and heterogeneity is itself necessary in order for motion to occurs : no motion could ever occurs in in a state of complete homogeneity.[28] This description, contrary to what is said at 52d4-53b5, presupposes that the four elements have already been geometrized by the Demiurge. However, in both cases, the motions described are *chaotic and unordered* since the World Soul, which is the principle of all *ordered* motions, has not yet been united with the World Body. In the case of the pre-cosmic chaos, the pre-elements are neither alike nor evenly balanced (52e2): this diversity seems to be somehow what causes the motion of the Receptacle which, in turn, will shake and move the irregular traces. The pre-elements,

[25] For a suggestion that the term *ichnon* does not refer to the relation between a particular and a Form see O'Meara (2017), pp. 60-61. For an occurrence of this term in Plato, and the difference between the heuristic and causal aspect of a trace, see Harte (2010), n. 6 p. 133.
[26] O'Meara (2017), p. 60.
[27] This is a vexed issue: as the World Soul has not been fashioned yet, it seems that some motions are not caused by the soul. Timaeus' discourse seems to differentiate between two kinds of motion: an irrational-unordered motion which takes place in the Receptacle and a rational-ordered one which is caused by the World Soul. Both are also distinguished by the presence or absence of the god (53b3-4). This of course can be understood in a literal or didactic sense. In both cases, the existence of the chaotic motions in the Receptacle must be justified. If one believes that *all motions* are caused by the soul in Plato's philosophy, then one of two following options will emerge: i) the hypothesis of a pre-cosmic irrational soul or ii) an irrational part of the World Soul (as Cornford (1937) defended on pp. 209-210).
[28] See 58a1. Unfortunately, Timaeus does not explain much this idea. It seems to imply that motion involves alterity which can only occurs when it is associated with heterogeneity (inequality, dissimilarly and difference appear to be somehow related in this complex question).

Timaeus says, due to their similar affections, will be attracted towards each other and occupy different regions. This seems to imply that each of the four kinds of pre-elements (that is pre-fire, pre-air, pre-water and pre-earth) will agglutinate and occupy a place in the Receptacle. The reader must thus imagine a chaos, where pre-elements are without *proportion or measure* (53a8), and yet a kind of pre-order appears since each kind of the pre-element will occupy a different region. The passage at 57d-58c completes this picture: now the elements have been properly constructed by the Demiurge and a spherical shape has been given the *cosmos*. Still, a chaotic motion will also appear in the case of the geometrized elements: *inequality* between the shapes given to the elements by the Demiurge will cause a chaotic motion which will be followed by a natural tendency for the like to be grouped with the like (fire with fire, air with air etc.). This should lead to a state of complete rest by the formation of four homogeneous masses, as it appeared in 52d4-53b5.[29] Consequently, inequality is a necessary but not sufficient condition for motion for a *cosmos* which is not yet ensouled. This is probably why Timaeus adds that *a limit* must be given to the World Body (58a-c) in order to prevent motion to stop. Let us now examine the next chronological events as they should be reconstructed.

1.2.2/ The following events

After E1, the demiurgic work begins, based on P5, P6, P7 and P8. His reasoning implies that the *cosmos* will be one living creature with a body and soul in order to be the best possible realization.[30] Let's qualify briefly the event in a chronological order:

E2: The Demiurge constitutes the World Soul

Contrary to the order of Timaeus's discourse, it is clear that the World Soul was fashioned before the World Body since the soul is ontologically prior to the body.[31] The World Soul is an intermediary between the intelligible and the sensible made out of sensible and intelligible Being, Sameness and Difference (35a-b).[32] The World Soul possesses a mathematical structure (35b-36b) and is responsible for the motions of the planets (36b-d and 37c40d) in the Universe.[33] It also

[29] I will come back to that motion in the next part.
[30] In 31a-b, the Demiurge seems to think that since the model is unique, and in order to bestow more perfection upon the image, the world must also be unique.
[31] 34c435a1.
[32] All these claims should be discussed and contextualized. See Pitteloud (2019).
[33] The World Soul is divided according harmonic intervals which by means of inequality maintains its unity since the nature of Difference is hard to mingle (35a7-8). See Cornford (1937), pp. 66-72.

possesses a cognitive function (36e-37c) and can consequently access the sensible and the intelligible.

E3: The Demiurge geometrizes the traces of the four elements and constitutes the elements in order to justify their reciprocal transmutation, the different grades of corpuscles, the variety of each elements and the mechanism of sensations (53b-69a). This is what is called "Plato's atomism" and will be described in the next section.

E4: The Demiurge constitutes the World Body (31b-34a).

From the four geometrized elements, the Demiurge fashions the World Body. Since i) what comes to be must be bodily, and so visible and tangible, and nothing can be visible without fire or tangible without earth, ii) two things alone cannot be satisfactorily united without a third then:

> *for there must be some bond between them drawing them together. And of all bonds the best is that which makes itself and the terms it connects a unity in the fullest sense; and it is of the nature of a continued geometrical proportion to effect this most perfectly.*[34]

Geometrical proportion implies only three terms (A/B=B/C), however as the *cosmos* is a three-dimensional solid, two middle terms are necessary in order to reach more unity (35a6).[35] This is Timaeus' justification of postulating air and water *between* fire and earth.[36] As the World-Body contains the whole of all the four primary elements (32c-33b)[37], and is self-sufficient and everlasting, it is then the best possible realization.[38] Furthermore, it is a sphere, without organs or limbs, rotating on its axis (33b-34a).

E5: The Demiurge unites the World Body and the World Soul

The union of the Body and Soul of the Universe is described in the following way:

> *And in the centre he set a soul and caused it to extend throughout the whole and further wrapped its body round with soul on the outside; and so he established one world alone, round and revolving in a circle, solitary but able by reason of its excellence to bear itself company, needing no other acquaintance or friend but sufficient to itself.*[39]

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[34] 31c1-4. That is: the best bond between three things is through geometrical proportion: for example, for the numbers 2, 4 and 8, it gives: 2/4=4/8, 8/4=4/2, 4/8=2/4, 4/2=8/4.
[35] See Brisson (1994), n. 136 p. 232 and Cornford (1937), pp. 46-52.
[36] The proportion resulted is: as fire is to air, so is air to water, and as air is to water, so is water to earth.
[37] As all particles geometrized will be used, there is nothing left outside the World-Body. As the four elements appear in the Receptacle, which is identified with space, there is no place beyond the limit of the World-Body, which constitute the whole universe.
[38] Since the Model is all-inclusive (it contains the four species). See Cornford (1937), p. 52.
[39] 34b3-8. For a comparison between this description and Empedocles' cosmogony, see O'Brien (2003).

E6: The Demiurge instructs the young gods to continue his work and retires.

When it comes to creating the inhabitants of the *cosmos*, as the universe must be as complete as possible, the Demiurge decides that it must contains the four following species: the heavenly gods; winged things whose path is in the air; all that dwells in the water; all that goes on foot on the dry land.[40] (39e-40). The Demiurge constitutes the heavenly gods and, from the mixture made in order to fashion the World-Soul, he constructs the immortal part of human souls, asking the young gods to take care of the rest of the creation (mortal parts of human soul, human bodies and the rest of the species), giving them precise instruction how to do so (41a-d). After that discourse, the Demiurge retires (42e5) and lets his helpers continue the constitution of the *cosmos*.

2/ **Triangles as Atoms**

E3 aims to expound the composition and transmutation of FAWE.[41] This will be undertaken through a description of the Demiurge's geometrization of the traces of the four elements. The account, which assumes that the four elements are not the ultimate and simplest constituents of the World–Body, will admit the following premises: i) FAWE are bodies and ii) bodies have depth, iii) depth must be bounded by surface, iv) every surface, which is rectilinear, is composed of triangles (53c). This implies that the most basic components of FAWE are triangles. Two triangles are chosen:

> *Now all triangles are derived from two, each having one right angle and the other angles acute. Of these triangles, one has on either side the half of a right angle, the division of which is determined by equal sides; the other has unequal parts of a right angle allotted to unequal sides.*[42]

For a reason which is not disclosed, Plato chooses, as the two ultimate types of *basic components* which constitute the four elements, two kinds of triangles, namely the right-angled isosceles and the right-angled scalene. However, these two kinds of triangle are not the ultimate *principles* of

[40] Each of them corresponds to one of the four elements.
[41] For a detailed account of the process of mathematization of the traces, see Cornford (1937), pp. 210-239, Opsomer (2012), Artmann & Shäfer (1993) and Pohle (1971).
[42] 53c8-d4.

reality, as Timaeus immediately adds:

> *This we assume as the first beginning of fire and of the other bodies, following the account which combines likelihood with necessity; the principles yet more remote than these are known to Heaven and to such men as Heaven favours.*[43]

The text suggests that the introduction of the two triangles is a sufficient condition (53e8) to explain what is the *nature* of the most perfect (53e8) four types of body, and how their construction from these triangles can explain their transmutation. Timaeus points out that there is only one sort of isosceles triangles, whereas the scalene triangles are of an endless number. The criterion adopted in order to determine which scalene triangle will be chosen is the following: it must be the most beautiful (54a3). Although Timaeus leaves open the possibility that a friend (45a5) could find a better kind of triangle and contradict his theory (54b1-2), he indicates that, for him, the two best triangles are the following: the half-square isosceles and the half-equilateral scalene, which has the greater side triple in square of the lesser (Figure 1).[44]

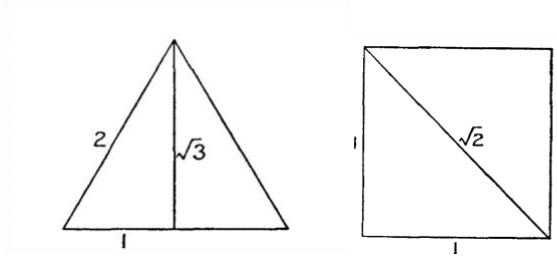


Figure 1

From these two basic triangles, the Demiurge will constitute more complexes plane surfaces in order to construct five different solids. It might have been expected that two exemplars of each basic triangle would be sufficient for the construction of a square and an equilateral triangle (as in figure 1), however the Demiurge will opt for another combination (Figure 2):

[43] 53d4-7. What are those ultimate principles? Lines? Points? Numbers? The One? For an overview of the different possibilities, see Karfik (2007), n. 138, p. 149.
[44] Figures are taken from: (1) Cornford (1937); (2) Artmann & Shäfer; (3) Friedlander (1964-1975), Vol. 1; (4) Cornford (1937).

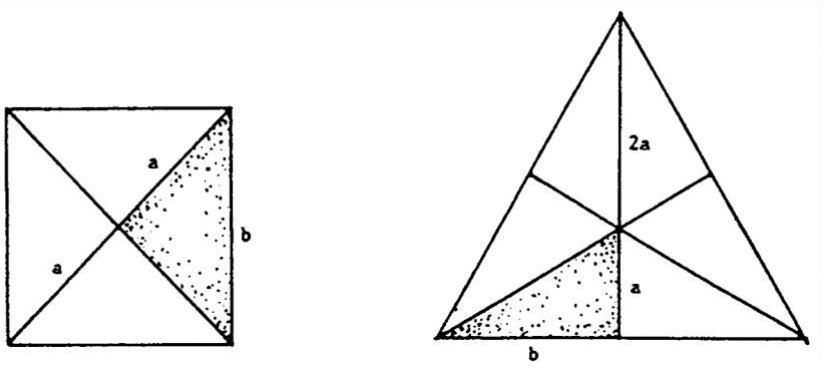
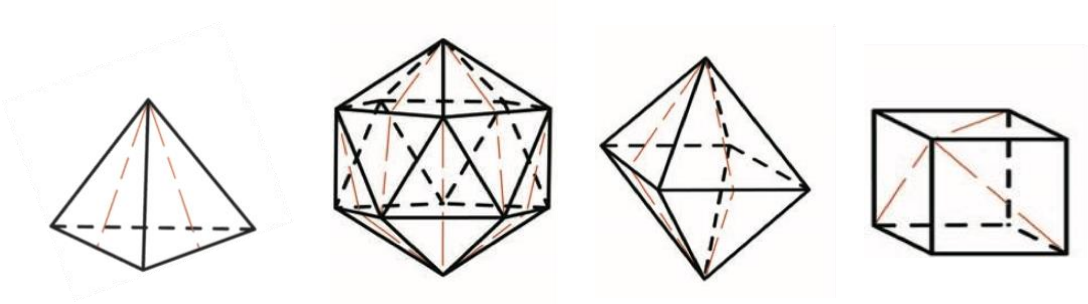


Figure 2

Respectively, 4 isosceles and 6 scalene triangles will be put together in order to constitute a square and an equilateral triangle. Those two plane surfaces will then be combined in order to obtain 4 regular solids: from the square, the demiurge will build the cube, and from the equilateral triangle, he will build the pyramid (tetrahedron), the octahedron, the icosahedron (figure 3). Each of these four solids will be then assigned to a primary body (55d-56c).



tetrahedron (fire) octahedron (air) icosahedron (water) cube (earth)

Figure 3

This is, to say the least, a very elegant way to describe the nature of the four elements. As one enters into the details of this account, some puzzles will arise and, as Plato did not develop all the aspects and consequences of his theory, the reader must try to answer the difficulties involved. For the present purpose, I wish to make a few comments.

1/ Plato's attempt to build up the four regular solids by means of putting together two basic

triangles might seem like "a child puzzle"[45] or a "Legoland"[46], forcing mathematics into physics (which appeared to have caused Aristotle a great deal of stress (*De Caelo* 299a6-9 and *Physics* VI, 1)). The ultimate motive of this account is soon revealed. In 56c-57d and 58c-61c, Plato shows how the transformation of the elements will occur between them according to three premises: i) because they are made from two different basic triangles, isosceles for earth, scalene for fire, air and water, only transformations between those three later elements will occur. Earth cannot be transformed into any other element and reciprocally[47]; ii) the four regular solids (and their respective parts) are not, as such, visible because of their smallness (56c1), however, when a certain number of the solids is aggregated, the masses constituted by them can be seen; iii) the transformation between the elements can be easily calculated since it depends on the number of basic triangles. Accordingly, we have:

Fire	4 equilateral triangles	24 scalene triangles
Air	8 equilateral triangles	48 scalene triangles
Water	20 equilateral triangles	120 scalene triangles
Earth	6 squares	24 isosceles triangles

Consequently, the transformation between fire, air and water, is established according the following proportions:

1 particle of fire = 4 equilateral triangles (e.t.)

2 particles of fire = 2 x 4 e.t. = 1 particle of air = 8 e.t.

1 particle of fire + 2 particles of air = 4 e.t. + 2 x 8 e.t. = 1 particle of water = 20 e.t.

2 ½ particles of fire = 2 ½ x 8 e.t. = 1 particle of water = 20 e.t.

[45] Cornford (1937), p. 213.
[46] O'Meara (2017), p. 75.
[47] Plato does not justify why this is the case. Either it is a limit of the mathematical account which lead to a displeasing consequence, or it could be the case that Plato believes that empirical experience shows that earth cannot be changed into any other elements. See Vlastos (2005), pp. 78-86. Again, Aristotle got displeased by this (*De Caelo* 360a1-7).

2/ If for Democritus, atoms are *solid* particles of minimum size and definite shape (characterized by an *infinite* variety of figures), Plato's atomism implies that the basic constituents of the World-Body can be reduced to *four figures* which are constituted by *two* types of triangle. In this way, Plato's atoms are not three but two-dimensional entities which can be reduced to two basic shapes. This geometrical atomism was designed to improved or correct Democritus materialism.[48] Giving precise structure and configuration to his atoms will allow Plato to support the idea that their respective nature is not due to chance but, on the contrary, is a direct consequence of the work of *nous*. Intelligibility, given through mathematization, implies here economy and simplicity.

3/ Unfortunately, Plato's account of the two fundamental triangles is incomplete and various problems arise which are not addressed in the text. Indeed, when commenting on the choice of scalene and isosceles triangles, Timaeus affirms that a proper justification of his choice would take too much time (54b1). Still, why does he specifically choose those two triangles as the most beautiful? Within Timaeus' geometrical account, no specific size is given to the sides of the two basic triangles (only the two proportions for their sides of, respectively 1, 2, $\sqrt{3}$ and 1, 1, $\sqrt{2}$). One interesting property of the two basic triangles is that they can be indefinitely subdivided into parts of the same type as themselves:

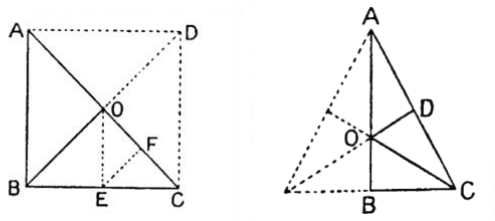


Figure 4

With these premises, the reader is left to attempt to answer the following questions: first, why does the Demiurge choose triangles and not the faces of the solids as basic constituents? Second, why those specific kinds of triangles? Third, why building up the faces of the solids with four (for the

[48] Vlastos (2005), p. 70: "On the Democritean theory an atom of fire, for example, could never change its shape or size in any way whatever—hence never change into an atom of air or of water. And this is precisely the sort of change Plato wants to insure. He wants corpuscles which will be susceptible of two types of radical transformation". That is i) a transformation between the elements and ii) between varieties of each of the primary elements. See also Cornford (1937), p. 210.

square) and six (for the equilateral) triangles when two of each of them would have sufficed (see figure 2)?[49] Various lines of enquires have been pursued to answer those questions. It must be noted that the choice of the two specific triangles allowing a division *ad infinitum* into the *exact same kind* of triangle implies that not only regularity but also symmetry is preserved.[50] That is indeed exactly what the presence of the god should assure in the traces (69b5: *analoga kai summetra*). This of course does not explain *why* the surfaces of the solids are divided into four and six triangles.[51] It has to be observed that P7 and P8 seem to imply that, in E2, E3 and E4, the same strategy is adopted: looking for the most beautiful bond, allowing for the stable construction made by the Demiurge (either of the World Soul, or the World Body or the four elements) to be the best possible realization. Shapes are consequently chosen (circle for the World Soul and triangles – the simplest rectilinear figures – for FAWE), and with the use of numbers (*arithmôn*), the Demiurge will establish the relevant proportion (arithmetic, harmonic and geometric) in order to maintain *unity* in his work. Note that, as the relationship between the sensible particulars and the intelligible Forms are that of *deficient* pluralities (particulars) towards a perfect unity (a Form,), the demiurgic work *recreates* the same relationship between *unequal* and *plural* parts (the triangles) towards *unity* (from the one found in one particle of an element to the one of the unique universe). In this way, both the Forms and demiurgic mathematics act like two sorts of glue, one metaphysical and one physical. This allows beauty (up to a certain point) to emerge from disordered multiplicity (the one of E1.)

3/ **Three puzzles**

One important result from the geometrization of the four elements is that it allows a theory which explains the transformation of the elements on the basis of the diversity of shapes, combinations,

[49] For some answers to those specific questions, see Harte (2006) 239-254.

[50] Symmetry can be defined in different ways: i) due proportion, ii) bilateral correspondence with regards to a reference, and iii) our present-day mathematical definition. On those distinctions and for a rejection of our present-day conception of symmetry in the *Timaeus*, see Paparazzo (2015a).

[51] Cornford (1937), pp. 230-239, argues that this issue is related with the question of the grades of the primary bodies. 57c-d seems to imply that there are different varieties of the four elements, and this is due to the different size of the (microscopic) particles composed by triangles. That is, the sizes of the scalene and isosceles triangles are unique as 56b2 suggests. What varies in size (as affirmed in 57d1-2) are the two surfaces (square and equilateral triangle) constituted by these two triangles, and these variations depend on the number of basic triangles which constitutes them. This allows to explain the transformation of the elements of different grades between them (although the exact proportions for these transformations are not to be found in the text). The choice to introduce surfaces with four and six triangles is meant to indicate, according to Cornford, the possibilities of different grades constructed by basic triangles of the same size. Thus, the two surfaces of figure 4 will constitute corpuscles of intermediary types (neither the smallest nor the biggest). On this issue, see (1971), Brisson (2001), pp. 302-306, Artmann & Shäfer (1993), O'Meara (2017), pp. 74-75 and Paparazzo (2015b).

and transformations of one body into another (61c). As the universe is spherically limited and the quantity of the four elements is determined (E3)[52], the reader is left with a complete picture of how materiality is conceived of in the *Timaeus*: from basic scalene and isosceles triangles (A) complex surfaces (equilateral triangles and squares) are derived (B), which in turn constitute the elementary polyhedara (C). Those polyehedara are invisible corpuscles which, when combined in sufficient number, form the four elements (D). Finally, those elements are mixed themselves by juxtaposition and form Plato's particulars (E).[53] From A to E, it appears likely that visible qualities supervene on mathematical quantities.[54] Three difficulties should be addressed in conclusion: a) what is the source of the motion *of* the triangles, b) what is the relationship between the triangles and the Receptacle and c) what are the implication of geometric atomism for the Theory of Forms?

As for the first difficulty, 56b7-c6 suggests that the qualitative changes between the elements are inherently related to their local changes.[55] The complete picture might be the following: i) in E1, the traces, which are affections (*pathê*) with powers (*dunameis*), are found in a state of motion in the Receptacle.[56] Consequently, Timaeus states that the traces move the Receptacle and are in return moved by it; ii) this would come to a stop according to the natural attraction of the like for the like, in the form of four regions characterized by the four pre-elements sorts ; iii) in E3, the geometrizing of the traces into the forms of two basics triangles opens the possibility of transformation of the elements, that is, it injects even more heterogeneity (based on the inequality of shapes between the solids constructed from the triangles) which will counterbalance the attraction of the like for the like and allow motions of elements *between* the four regions (the process of transformation will constantly modify the tendency of the elements to form four regions as described in E1) ; iv) E4 specifies that the elements are in a limited number within a limited space (the sphere of the World Body) which will prevent the mechanical motions described in i-iii to ever cease; and finally v) these mechanical motions will be ordered when the World Soul is united to the World Body in E5.

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[52] Plato neither indicates the size of the sides of the two basic triangles, nor the exact quantity of the four elements. What is given are the respective proportions involved. Nothing seems to suggest that it is possible to work out the details of one proportion from the other.

[53] It appears that the relationship between A and B, and B and C is of parts/whole. The relation between C and D seems to be of identity (a certain number of identical particles becomes visible) and the one between D and E of juxtaposition. See for a complete analysis, Opsomer (2012), pp. 148-155.

[54] See Opsomer (2012), pp. 155-157, for a list of Aristotle's criticisms.

[55] "Moreover, in the course of suffering this treatment, they are all interchanging their regions. For while the main masses of the several kinds are stationed apart, each in its own place, owing to the motion of the Recipient, the portions which at any time are becoming unlike themselves and like other kinds are borne by the shaking towards the place of those others to which they become like".

[56] See above on pp. 8-9 for an explanation of the cause of these motions within the Receptacle. Cornford (1937), pp. 228-230, defends that the motions of the traces are due to "blind irrational impulse in the soul that animates the body of the world."

Consequently, even if motion is described in the *Timaeus*, as going from an unordered state (E1) to an ordered one (E5), it must be noted that the unordered motion (from i to iv) already implies the work of intellect (the geometrization in E3 and the fashioning of the World Body in E4) in order to subsist. Without the action of the Demiurge, chaotic motion, although it is described as having its source in itself, would cease to be.

Must, then, the Receptacle be reduced to a spatial *milieu* in which free-floating triangles could be found during the cycle of elementary transformation? In that case, what would the triangles be made of? Would they, *qua* geometrical two-dimensional shapes, be filled with some matter? As suggested above[57], Plato is extremely careful when discussing the Receptacle within his *eikôs muthos*. Let's recall the teachings of the gold analogy (50a5-b5): the Demiurge modified the Receptacle and gave it the shape of the two basic triangles. Moreover, in 58a7, the existence of void is excluded. However, since the transformations between the different grades of elements occur *in* the Receptacle, it appears necessary to suppose small interstices (58b5) between the polyhedra formed by the triangles.[58] If indeed, inequality and heterogeneity must be supposed to guaranty motion and change, then it is impossible to suppose that the whole World Body should form a compact solid mass. It might be possible to conclude from that that the Receptacle must be considered as a kind of matter-space: let's imagine that the Receptacle is a sort of undetermined gold substrata: it must not be so solid that it would prevent any kind of motion between the forms imposed on it and, as such, it might be compared to a sort of thick, stable fluid.[59] From this fluid are formed the different shapes of the regular solids, and between these solids, remain interstices which could be filled by solids of smaller grades. Obviously, as the division into smaller grades of particles is limited, the minimal size of the interstices will also be limited. In any case, the Receptacle must fill a double role: one of a substrata guarantying the existence a) of the traces as images of the Forms reflecting in it (in E1) and b) of the solids made out of basic triangles constituted *of* it (in E3)[60] ; and one of a space in the very specific sense of a *milieu* in which a') the traces and b') the regular

[57] See above pp. 6-7. Timaeus of Locri's interpretation considers the basic triangles to be compound of (Aristotelian) form and matter. See Ulacco and Opsomer (2014).

[58] Such interstices represent *space* for smaller particles of elements. Note that interstices should not appear between particles of earth, since the combinations of cube cannot allow it. As Cornford (1937) rightly points out, n. 1, p. 245: "It is not explained where earth comes into the scheme. There is nothing to show what sizes the earth cubes have, as compared with the other bodies. Cubes can be packed so as to leave no interstices; yet at 60e we hear that interstices between earth cubes are so large that fire or air particles can slip into them without disturbance."

[59] See Brisson (2001), n. 456, p. 257 for a similar analogy.

[60] 52c2-5. « (…), whereas for an image, since not even the very principle on which it has come into being belongs to the image itself but it is the ever-moving semblance of something else, it is proper that it should come to be in something else, clinging in some sort to existence on pain of being nothing at all (…)".

solids can move and change their positions given to the existence of small interstices.

Timaeus' account of geometric atomism finally seems to bear interesting consequences for the theory of Forms. More especially, it should be asked what is the relationship between E1 and E3 when it comes to understand the participation of the sensible to the intelligible? This, of course, is related to the question of the more *remote principles* (57d7) beyond the two basic triangles: are they intelligible Forms? If so, what kinds of Forms? Could they be the Forms of the Four Elements (FAWE)? Or does Plato suppose the existence of Forms of Triangles? As noticed, the text remains silent on this matter. Perhaps, a few thoughts, to conclude, could be proposed. Some of the difficulties here are related to the question of the Demiurge: if he merely is a literally tool, a symbol of the intellective work in the universe, it seems possible to somehow identify E1 and E3, without having to distinguish two *degrees* of participation. This would also imply conceiving the traces of the elements as indeterminate anticipations of sensible participation.[61] However, E1 and E3 seem to be distinguished by Timaeus, not only chronologically, but also conceptually. The description of the traces is explicitly associated with the nature of the sensible as an image of the intelligible model (52c2-5), and the Demiurge geometrizes this sensible image in E3. Another possible reading[62] of Timaeus' account seems to imply a distinction between two *moments* of participation. Even if the pre-participation of E1 might appear problematic[63], it appears not completely possible to do away with two types of imitation: a) the mirroring of the images of the Forms of the Four Elements in the Receptacle and b) the mathematization of these traces by the Demiurge in order for them to acquire a greater degree of perfection.[64] In case of *a,* the model of the traces are the Forms of the

[61] See O'Meara (2017), p. 62: "Of course there remains the mystery of what the pre-demiurgic "traces" of the elements might be. Here Timaeus gives us little help. We might suppose that the traces are indeterminate, confused *je ne sais quoi* which the demiurge will work up and give determination and shape. Later, at 69b6, it seems that the pre-elements might have shared to some extent, by chance (*tuchê)*, in the order which the Demiurge will give them, by anticipation, as it were. (…) In this case, the trace would be an adumbration, a chance anticipation of, not something produced by, that of which it is a trace. (…). Another possibility, which I think is far less likely, would be that the traces had been produced by elements, then these elements would have existed earlier than the traces, sometime in the past. The word "trace" can also have this sense, the sense of something left from a past era, a memory."

[62] A reading that does not need to be literal in any case.

[63] All the order of the sensible must come from the work of *nous*, however, this work cannot start from *nothing*, since in that case nothing would exist to be worked upon. The traces appear to point out an imperfect pre-demiurgic order. This pre-order must somehow be a first degree of order, for if it were not, it would be *a* nothing. See Vlastos (1939), p. 77. The text is indeed explicit on this fact: the Demiurge does not initiate his work in E3 on a completely indeterminate *milieu* but bestow mathematical order upon the images of the four elements.

[64] As O'Meara notices (2017), on p. 59, n. 61: "The reverse of such a sequence is described in the *Republic*, where an artisan (demiurge) makes a couch, according to "idea" of a couch (596b), and then a painter makes an image, an appearance, of the couch, as if in a mirror (596ce)."

Four Elements which must be found in the intelligible Model.[65] In the case of *b,* it is less clear what the model that the Demiurge looks at in order to mathematize the pre-elements is. As the result of this work generates basic triangles, it might be likely that this model is of a mathematical kind. This does not necessary imply the existence of Forms of triangles. What seems plausible is that, in the *Timaeus*, Plato differentiates two kinds of likeness: i) the one which comes for the appearance and disappearance of the images of the Forms in the Receptacle and which allows to explain the ontological difference between a model and its images, as well as the imperfection of the latter in relation to the former and ii) the one which justifies a greater resemblance between the sensible and the intelligible in terms of mathematical properties and which explains *how* the images possess a *likeness* of the model.[66] This, as a matter of fact, does imply, in my view, a *revised* version of the Theory of Forms which should specify how participation takes place as the geometrization of imperfect traces in the Receptacle. If this is correct, then Plato's atomism, although founded on the same distinction between micro and macro properties, should clearly be distinguished from any kind of materialistic atomism. In that case, Plato's atomism could well be an essential characteristic of his Theory of Forms.

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[65] The model is described as containing the four-living species. At no point, the text suggests that it must contain the Form of the Four Elements. However, as each specie is linked to a region of the world which in turn is associated with an element, it might be possible to suppose that the Forms of the elements can somehow be found within the Model.

[66] It has to be noted that it is not a physical resemblance: as 61d-62a indicates, this is the piercingness of the sharp angles of the pyramids which constitute fire particles that explains the pain feeling it causes. On that see Morrow (1968), pp. 26-27.

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