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Note to readers: This paper is an early chapter draft written for a planned edited volume on grounding and fundamentality in Plato and Aristotle. The thematic focus of the volume shapes the approach I take here in obvious ways. But the core sections of the paper can also be considered part of several loosely connected drafts, notes, etc. about different kinds of context-sensitive explanation in the Timaeus, *one of which emerges in this paper.*

Elemental properties and context-sensitive explanation in Plato's *Timaeus*

According to Plato's *Timaeus*, the four material elements earth, air, fire, and water occur in the form of regular three-dimensional figures now known as the Platonic solids; for example, fire particles are tetrahedra (triangular pyramids), while earth particles are cubes. Ordinary material objects and stuffs – the wine we drink, the oil we consume, or the metal pot and bonfire we use to heat it – are aggregates of such particles. In virtue of being tokens of specific types of Platonic solid, the elemental particles have intrinsic "geometric" properties, such as the number and shape of their faces or the angles between their faces.

On *Geometry First* views, the intrinsic geometric properties of elemental particles consistently determine and explain these particles' "physical" properties (e.g., weight and mobility) and causal powers (e.g., powers to cut or heat, or powers to compress). This paper shows why traditional *Geometry First* views require significant modifications and qualifications to remain interpretively viable, proposes a new account of the explanatory role of geometric properties, and argues that formulating certain interpretive claims about elemental properties in terms of the notion of grounding has real, if limited, interpretive utility.

The paper begins with some necessary preliminaries about the Timaean elements and their properties (§1) before outlining the *Geometry First* approach and its underlying motivations (§2). In §3, I turn to complications and constraints for traditional *Geometry First* views. For one, the geometric properties of elemental particles do not fully determine physical properties of particular

elemental particles (§3.1). Moreover, there is no function from specific geometric properties (e.g., the angular sharpness of fire particles) to specific causal powers to affect identical or different patients (e.g., powers to separate human flesh or other fire particles). Even when elemental particles share the same specific geometric property (e.g., angular sharpness) and comparable causal powers (e.g., powers to separate other bodies), this geometric property may be central to the determination and explanation of one causal power, but peripheral in the case of the other (§3.2).

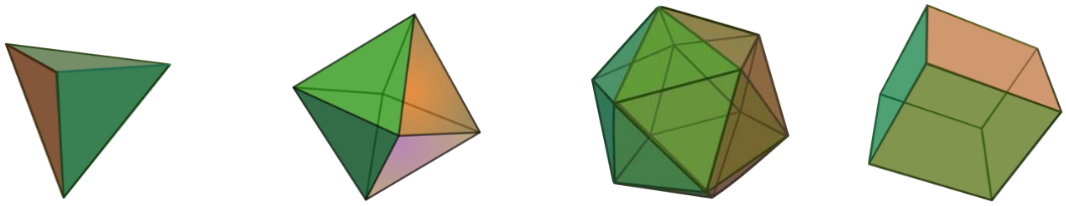
In light of these constraints, I propose a modified *Geometry First* account of causal powers that captures this context-sensitivity (§3.2). I then argue that the notion of grounding is interpretively useful for articulating the complex but ordered relations between different elemental properties more clearly (§4). To that end, §4.1 motivates and qualifies the applicability of the notion of grounding to interpretive claims about the relations between different elemental properties. Even though this notion cannot capture what is most distinctive about the Timaean picture, §4.2 then argues that formulating certain interpretive claims in terms of grounding – specifically, (merely) partial, non-vacuous grounding – helps articulate aspects of these relations that are easily missed.

1. Preliminaries: elemental particles and their properties[1]

In the *Timaeus*, particles of the four material elements are identified with four of the five three-dimensional regular polyhedra that are now known as the Platonic solids:[2]

[1] I read the Greek text printed in Burnet's 1902 OCT edition of the *Timaeus*. In what follows, translations are my own unless otherwise noted, and Stephanus numbers without dialogue abbreviates refer to the *Timaeus*.

[2] Each Platonic solid is *regular* in that it has equally sized and shaped faces, with equally sized angles between any two faces. The role of the dodecahedron, the fifth such solid, in the Timaean cosmos is somewhat mysterious; but we are told that the Timaean demiurge uses it 'for the whole universe' (55c4–6); cf. e.g. Kotrč 1981 and Paparazzo 2011 for interpretive proposals.



tetrahedron (fire) octahedron (air) icosahedron (water) cube (earth) [3]

More complex material stuffs and bodies such as minerals, wine, honey, plants, animals, and people are all constituted by aggregates and mixtures of elemental particles. There is a limited number of varieties within each element that correspond to differently sized elemental particles of the same kind; e.g., particles of two varieties of earth would come in the form of differently sized cubes (cf. 57c7-d3).[4] Aggregates and mixtures of such differently sized elemental particles in turn give rise to the indefinite material variety that we observe around us (57d3-5, with 58c-61c).[5] In brief, elemental particles constitute the material world as we know it.

As a result, Timaeus frequently appeals to elemental particles when discussing material change at higher levels of complexity. For example, a puddle of water freezing overnight and the motion of a rock thrown into the air can be described in terms of changes at the level of (aggregates of) elemental particles (cf. 59d-e; 79e-80a with 80c). More generally, explanations of phenomena as diverse as the formation of minerals, metals, and other material compounds (58d-61c),

[3] Images sourced from Wikimedia Commons (free to use); links: tetrahedron, octahedron, icosahedron, cube.

[4] In light of 57c7-d3, differences in the size of particles that belong to the same element are generally understood in terms of differences in the size of these particles' constituent faces and, consequently, in their overall surface area and/or volume. Commentators *do* disagree about how to understand the differences in the size of particles' constituent faces, but the details of that debate need not concern us here; cf. Cornford 1937, Brisson and Ofman 2021, and Schroeder 2023 for three different views.

[5] This two-level account of elemental variation is the most natural reading of the account of elemental variation at 57c8-d5 in conjunction with the extended discussion of specific elemental varieties at 58c-61c. For a more detailed reconstruction of 57c8-d5, see Schroeder 2023, 34-37. Cf. Cornford 1937, 231 and 246.

perception of sensible qualities (61c-68d), digestion, respiration, and circulation (77a-81c), and death from old age (81c-e) invoke material change at the level of elemental particles.

Such change can take one of two forms. First, elemental particles that are composed out of the same kind of basic parts can intertransform. Timaeus constructs the elemental particles out of two kinds of basic triangle that constitute their faces: fire, air, and water particles have equilateral triangular faces that are constituted out of atomic, uniformly sized half-equilateral triangles (30º/60º/90º), while earth particles have square faces that are constituted out of atomic, uniformly sized right isosceles triangles (45º/45º/90º). Accordingly, particles of fire, air, and water can intertransform through the separation and combination of their constituent triangles, while earth particles can transform only into other earth particles (56d-e). Second, elemental particles can change their location without undergoing intertransformation. However, since the Timaean cosmos is a plenum, elemental particles must displace other particles in order to move while remaining intact (59a, 60c, 79b-c, 80c). Thus, both intertransformation and locomotion involve interactions between (aggregates of) elemental particles, where the nature of these interactions depends at least in part on various properties of the particles in question.

In this connection, it will be helpful to distinguish three kinds of properties of elemental particles.

(1) First, elemental particles have *geometric properties*. These are intrinsic properties that elemental particles have solely in virtue of their geometric structure and construction out of the basic triangles (cf. 53d-55c; 57c7-5). For example, the geometric properties of a tetrahedron include the number and shape of its faces and the consequent angles between these faces, which give rise to its pyramidal shape; and the number and kind of its constituent basic triangles, which give rise to its surface area.

(2) Elemental particles and their aggregates also have what we can call *physical properties*, such as weight and mobility. These properties are introduced as relative or comparative properties: elemental particles or aggregates are lighter/heavier and more mobile/less mobile than other elemental particles or aggregates (cf. 55e-56b; 62c-63e).

(3) Finally, elemental particles and their aggregates have *causal powers*, i.e. powers to affect other particles, aggregates, or composite bodies. For example, fire particles are often characterized as having the power to cut other bodies, whether individually or as part of an aggregate (cf., e.g., 58b, 60a, 65e-66a).

The relation between these different properties will become clearer in what follows.

2. The "Geometry First" approach

Consider a natural, perhaps familiar view of Timaean physics. On this view, interactions between elemental particles are determined by these particles' physical properties and causal powers, which in turn are determined by their intrinsic geometric properties. The physical properties and causal powers of elemental particles may not follow logically from their geometric properties, but that is not the point. What matters is that geometric properties do the relevant explanatory work: to explain an element's physical property or causal power, you need only look towards the geometric structure of the elemental particle(s) in question, since that is what determines their other properties.

Call this the "Geometry First" approach to the physical properties and causal powers of elemental particles. Many passages in the second part of the dialogue offer textual support for this approach,[6] and versions of it can be found already in Aristotle and Theophrastus.

[6] Cf. esp. 55d6-56b6 for physical properties, and 58d-68d for causal powers.

2.1. Example 1: The relative weight and mobility of elemental particles

Take the weight of a fire particle. When Timaeus assigns the tetrahedron to fire, the octahedron to air, and the icosahedron to water (56b3-6), he does so in part on the grounds that of these three, the tetrahedron is "the lightest (ἐλαφρότατον), being constituted out of the fewest of the same parts (ἐξ ὀλιγίστων … τῶν αὐτῶν μερῶν)" (56b1-2). Now, "the same parts" could refer either to 30/60/90 basic triangles or to the equilateral triangular faces that they constitute. Either way, it seems that fire particles are lighter than air and water particles in virtue of having fewer constituent triangles of the relevant sort; similar analyses would follow for the relative weight of air and fire particles, *mutatis mutandis*.

Aristotle takes this reading of 56b1-6 further and attributes to Plato a reductive account on which the number of constituent triangles determines the absolute weight of elemental particles (cf. *De Caelo* III.1, 299b31-300a1, and Code 2010 for discussion). But even if we think of weight as a relational property, it seems reasonable to conclude from 56b1-6 that the weight of fire, air, and water particles relative to one another is a function of the numbers of their constituent triangles.[7]

As it happens, Timaeus does not discuss the relative weight of cubes (i.e., earth particles) in this context.[8] But he does rank all four kinds of elemental particles in terms of their relative mobility (55d8-56b6): the cube is the least mobile of the four kinds because it has square faces composed out of 45/45/90 triangles, which are by nature more stable than the triangular faces of

[7] See also, e.g., Code 2010, 204; Cornford 1937, 222-223 n.4.

[8] As Code 2010, 206 notes, a conversion into a common measure such as overall surface area would be necessary for extending this account of relative weight to earth particles. But even if we understand the above account of the relative weight of fire, air, and water particles in terms of surface area, we have no way of comparing the surface area of such particles to the surface area of earth particles, because we are not given any indication of how the 45/45/90 basic triangles that constitute earth compare to the 30/60/90 basic triangles that constitute fire, air, and water in surface area. Cf. Archer-Hind 1888, 200.

tetrahedra, octahedra, and icosahedra that are composed out of 30/60/90 triangles (55e2-7; τοιοῦτον in e2 picks up ἀκινητοτάτη in e1). Of these remaining three, the tetrahedron is the most mobile (εὐκινητότατον) because it has the fewest triangular faces (cf. τὸ μὲν ἔχον ὀλιγίστας βάσεις, 56a6-7).[9] The octahedron and icosahedron take second and third place, respectively, in degrees of relative mobility (cf. 56a2-b6). Accordingly, it seems reasonable to conclude that the relative mobility of elemental particles (a physical property) is a function of the shape and number of the particles' faces (two geometric properties).

As we will see, the full account of the relative weight and mobility of elemental particles turns out to be more complicated.[10] But first, to feel the full force of the "Geometry First" approach, consider what is arguably its most illustrative example: Timaeus' explanation of fire's power to cut, separate, and heat other bodies in terms of the geometric properties common to all fire particles.

2.2. Example 2: Fire, "sharp angles", and the powers to cut and heat

We begin once more with the passage in which Timaeus assigns the four regular solids to the four elements. The fact that the tetrahedron has fewer triangular faces than the octahedron and icosahedron makes it "most able to cut (τμητικώτατον)" and "sharpest (ὀξύτατον)" of the three (56a6-b1). The natural reading of these remarks is that the comparatively fewer faces and

[9] The claim that the tetrahedron has the fewest faces (*baseis,* 56a6-7) may thus be distinct from the claim above that it has the fewest identical parts (*ex autōn merōn*, 56b1-2). Arguably, the number of *faces* highlights the acute angles of tetrahedra in a way that an appeal to constituent basic triangles would not. Moreover, many commentators find an appeal to the number of constituent basic triangles more plausible in the context of weight insofar as Timaeus' description of intertransformation suggests that conservation of matter is understood in terms of conservation of overall surface area (cf., e.g., Cornford 1937, 224 and 229; Vlastos 2005, 89–90). That said, it remains possible to read *ex autōn merōn* as referring to faces; for the purposes of this paper, nothing hinges on the point.

[10] Most (more or less) recent discussions reflect these complications in the case of weight; see discussion in §3.1 below.

(consequently) more acute angles of the tetrahedron are responsible for fire's power to cut or separate other elemental particles (cf. 56e8-57a2). Aristotle makes explicit the intuitive connection between "sharpness", acute angles, and fire's causal powers when he says that Plato identifies fire particles with tetrahedra on the grounds that the tetrahedron "has the most acute/sharp angles, and burns and warms in virtue of its angles" (τὸ δὲ ὀξυγωνιώτατον, καίει δὲ καὶ θερμαίνει ταῖς γωνίαις)" (*De Caelo* III.8, 306b32-307a3).[11]

Timaeus' subsequent discussions of elemental interactions and perception seem to vindicate Aristotle's reading. Thermoception is an especially illustrate example. When we perceive heat, Timaeus says, "we notice how fire acts on our bodies by dividing and cutting them, for just about everyone perceives that the affection is something sharp" (61d6-e2).[12] After recalling the features that led him to assign the tetrahedron to fire at 55d-56b, he notes that "this and no other nature most of all separates and cuts our bodies into small bits" (62a2-3).[13] These remarks make it eminently plausible that "[f]ire is hot because its shape is such that it cuts bodies into small pieces" (Modrak 2006, 138).

This is *not* to say that when fire cuts us and we perceive heat, we feel the "sharp", acute angles of the tetrahedra themselves. Like other elemental particles, individual tetrahedra are too small to be perceived by us and so are only in principle perceptible; accordingly, we perceive only bulks or aggregates of such particles (56b7-c7).[14] But it can still be the case that, as Caston puts it,

[11] For the use of ὀξύς to describe acute angles, see LSJ s.v. A.

[12] 61e1-2: τὴν διάκρισιν καὶ τομὴν αὐτοῦ περὶ τὸ σῶμα ἡμῶν γιγνομένην ἐννοηθέντες· ὅτι μὲν γὰρ ὀξύ τι τὸ πάθος, πάντες σχεδὸν αἰσθανόμεθα.

[13] 62a2-3: ὅτι μάλιστα ἐκείνη καὶ οὐκ ἄλλη φύσις διακρίνουσα ἡμῶν κατὰ σμικρά τε τὰ σώματα κερματίζουσα.

[14] Timaeus makes the point in terms of vision, but it is uncontroversial that it generalizes.

"the searing quality of heat is due to the sharpness of the fire atoms responsible for it and the way they cut and penetrate our body" (Caston 2015, 39).[15]

In light of this account of thermoception, it seems reasonable to expect that geometric properties also explain other causal powers of elemental particles. In other words, one might reasonably expect that geometric properties do the explanatory work not just in the account of certain isolated causal powers (e.g., only fire's power to cut human flesh), but that they are responsible for particles' causal powers across the board in a relatively uniform manner.

For some interpreters, this expectation goes unfulfilled. Thus Aristotle and Theophrastus complain that on the Timaean account, only our perception of heat follows directly from the shape of the elemental particles, but not our perception of cold. In Theophrastus' words, "This is also strange: first, that he does not explain everything in a similar way, not even things in the same genus; for, having defined the hot by shape, he did not explain the cold in the same way" (*De sens.* 87; see also Aristotle, *De Caelo* III.8, 307b5-17).[16]

But many others have found the explanatory consistency and uniformity they expect, including in the context of perception.[17] For example, Modrak concludes that other perceptible characteristics are ultimately "a consequence of the shapes of the elemental bodies", with the result that "[t]he character of a simple perception of a proper object is fully determined by the physical interaction between the body of the percipient and external bodies" (138; cf. 141). Similarly, Caston writes that "[l]ike Democritus, all of [Plato's] accounts are based on the magnitudes and

[15] Cf. also, e.g., Kung 1985, 19-20; McCready-Flora 2018, 130.

[16] *De Sens.*87 (following the text in Diels' *Doxographi Graeci*): ἄτοπον δὲ καὶ τοῦτο. πρῶτον μὲν τὸ μὴ πάντα ὁμοίως ἀποδοῦναι, μηδὲ ὅσα τοῦ αὐτοῦ γένους. ὁρίσας γὰρ τὸ θερμὸν σχήματι τὸ ψυχρὸν οὐχ ὡσαύτως ἀπέδωκεν. For 'explain', 'give an account' as a translation of *apodidōmi* cf. LSJ s.v. A.11.

[17] Cf. Archer-Hind 1888, 226-7 and Taylor 1928, 432 for responses to Aristotle and Theophrastus on Timaeus' accounts of *hot* and *cold* in particular.

geometric structure of physical objects, together with the causal powers they have as a consequence, except that Plato appeals to the geometrical properties of elemental particles rather than molecular structures" (39).[18]

To summarize: Timaeus explains several physical properties and causal powers of elemental particles in terms of these particles' geometric properties. These examples motivate and support "Geometry First" views, according to which geometric properties consistently determine and explain the physical properties and causal powers of elemental particles. Even Aristotle and Theophrastus' objection betrays a default expectation of this sort: as they see it, Timaeus ought to explain comparable causal powers (viz., fire's power to heat and water's power to cool) as a direct consequence of comparable geometric properties (viz., fire's shape and water's shape), but fails to do so consistently.

Regardless of the merits of this particular objection, it seems reasonable to expect ordered relations between specific geometric properties and specific causal powers. For example, one might reasonably expect that the acute angles of fire particles are responsible for fire's power to cut or separate other bodies not only some of the time, but whenever fire particles have this power.[19] As Taylor puts it: "The fire divides a log of wood which it sets on fire exactly in the same way and for the same reason that it divides my flesh." (Taylor 1928, 432).

[18] Similarly, McCready-Flora 2018: "sensation-producing effects *follow from* elemental geometry" (129, emphasis added).

[19] Cf. Johansen 2020: "fire is structured so as to interact in an ordered way with the other basic bodies" (33-4); "[f]ire, for example, is made of sharp triangles which *necessarily* move fast and cut through other materials" (26, emphasis added).

3. Complications for the "Geometry First" approach

3.1. Changes in weight and mobility despite identical geometric properties

In section 2.1, I outlined an account of the relative weight and mobility of elemental particles as a function of these particles' geometric properties. This account comes under pressure from what is often called "like-to-like motion" of the elements. The four elements have their own regions within the Timaean cosmos, which itself is spherical; for example, fire's region is at the periphery of the cosmos, while earth's region is at the center of the cosmos (cf. 63b ff.). Elemental particles naturally gather in their own region (57c2-3, 58a4-7, 63b2-3, c6-8, d4-6), since "everything that is akin moves towards itself" (81a2–4). In this way, elemental particles engage in "like-to-like" motion towards their natural place in the cosmos. By extension, elemental particles resist motion away from their natural place. Thus, fire particles will naturally move towards the periphery of the cosmos but resist motion towards the cosmic center, while earth particles will naturally move towards the center but resist motion towards the periphery.

Like-to-like motion is a key principle that features in explanations of material changes across the *Timaeus*, including a revisionary account of direction and weight at 63b-e. On this account, none of the cosmic regions are by nature above or below, since the cosmos is spherical. Moreover, nothing is heavy or light without qualification; rather, things are heavy or light to the extent that they resist motion away from or towards their natural place.

T1. So in fact it is necessary that these [*sc*. things we call 'heavy', 'light', 'above', 'below'] are disposed differently in relation to one another because different masses of the kinds occupy places opposite to the others. For what is light in one region, or heavy or below or above, will be found to become and to be opposite or oblique or altogether different in its relations to what is light, heavy, below, or above in the opposite region. This one thing, however, must be kept in mind about all of them, that the journey of each towards its own kind makes

> the moving thing heavy and makes the region into which such a thing moves below, while the things opposed to these produce the opposite. (63d4-e7) [20]

In brief, the relative weight and mobility of elemental particles directly depend on their cosmic location and direction of movement.

Take the weight of three particles of fire, air, and water. (Alternatively, in line with the focus on perceptible aggregates of elemental particles at 62c-63e, consider three aggregates of such particles, one for each element.) Ex hypothesi, the geometric properties of these particles are the same regardless of their locomotion and cosmic location; yet the weight of the fire particle relative to that of the air and water particles depends on their location within the cosmos as a whole and on whether the three particles move towards or away from their respective natural places.

Similarly, consider the relative weight and mobility of a fire particle and an earth particle, or aggregates thereof. The principle of like-to-like motion leads us to conclude that fire particles are lighter and more mobile than earth particles at the center of the cosmos, but heavier and less mobile than earth particles at the cosmic periphery. In other words, the relative weight and mobility of these elemental particles do not supervene on their geometric properties, since there can be a change in the former without a change in the latter.

Evidently, this directional account of weight and mobility stands in tension with the earlier account of the relative weight and mobility as a function of elemental particles' geometric properties. Since the directional account is introduced in the context of a broader discussion of perception-producing affections, one might consider restricting it to the *perceived* weight and

[20] 63d4-e7: ταῦτ' οὖν δὴ διαφόρως ἔχειν αὐτὰ πρὸς αὐτὰ ἀνάγκη διὰ τὸ τὰ πλήθη τῶν γενῶν τόπον ἐναντίον ἄλλα ἄλλοις κατέχειν—τὸ γὰρ ἐν ἑτέρῳ κοῦφον ὂν τόπῳ τῷ κατὰ τὸν ἐναντίον τόπον ἐλαφρῷ καὶ τῷ βαρεῖ τὸ βαρὺ τῷ τε κάτω τὸ κάτω καὶ τὸ ἄνω τῷ ἄνω πάντ' ἐναντία καὶ πλάγια καὶ πάντως διάφορα πρὸς ἄλληλα ἀνευρεθήσεται γιγνόμενα καὶ ὄντα—τόδε γε μὴν ἕν τι διανοητέον περὶ πάντων αὐτῶν, ὡς ἡ μὲν πρὸς τὸ συγγενὲς ὁδὸς ἑκάστοις οὖσα βαρὺ μὲν τὸ φερόμενον ποιεῖ, τὸν δὲ τόπον εἰς ὃν τὸ τοιοῦτον φέρεται, κάτω, τὰ δὲ τούτοις ἔχοντα ὡς ἑτέρως θάτερα.

mobility of the elements.[21] However, the fact that like-to-like motion is central to explaining both perceptible and imperceptible interactions between elemental particles complicates such efforts. In other words, simply confining the scope of the directional account to the weight of perceptible aggregates in contrast to the "objective" weight of individual, imperceptible particles, as some have proposed, likely will not do by itself. Accordingly, some commentators dismiss the earlier, numerical account of weight,[22] while others have proposed solutions for reconciling the two apparently inconsistent accounts.[23]

But we need not go into the details of this scholarly debate here. What matters for present purposes is simply this: the geometric properties of particular elemental particles cannot do all the explanatory work in the case of physical properties like relative weight and mobility.[24] There is no clean function from a particle's geometric properties to its physical properties (and likewise for an aggregate of such particles).[25]

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[21] Cf. Cornford 1937, 265-266.

[22] Cherniss 1944, 165.

[23] O'Brien 1984, Code 2010. Cf. Kalderon (ms.), 193-196 for discussion.

[24] Of course, that is not to say that geometric properties are *irrelevant* to explaining the relative weight and mobility of any given elemental particle (cf. §4 below). My conclusion here is thus compatible with views on which the like-to-like motion of elemental particles – viz., the key player in the directional account of weight and mobility – is itself partly explained by these particles' geometric properties; see, e.g., Code 2010, 210-211.

[25] One might wonder about *relative size* in this context, which Timaeus mentions alongside relative weight and mobility in the assignment passage at 55d6-56b6. The size of an elemental particle relative to another elemental particle is at least conceptually distinct from any one of their geometric properties, unless we presuppose from the outset that all size claims are to be understood in terms of a specific geometric property that we find intuitive – e.g., polyhedral volume as opposed to surface area (see Vlastos 2005, 84-91). And even though commentators might disagree about *which* geometric property determines the relative size of elemental particles, most seem to think that *some* specific geometry property *does* fully determine particle size.

While a detailed discussion of elemental size exceeds the scope of this paper, let me briefly note an initial complication for this proposal, followed by a sketch of my own view. The assignment passage suggests that there is a clear ranking of fire, air, and water particles in terms of their relative size, with fire particles being the smallest and water particles being the biggest. However, many commentators think that this ranking no longer holds once Timaeus introduces differently sized varieties within each element (Cornford 1937, 222 n.3, Taylor 1928, 381; contrast Brisson & Ofman 2021, and cf. Schroeder 2023, 49 n.28). On my own view, size differences between particles that belong to the *same* elemental kind do correspond to differences in overall surface area and/or volume (see §1, n.4 above), but not all claims about the relative size of elemental particles can be understood in this way. In other work in progress, I argue that many claims about the relative size of particles belonging to *different* elemental kinds cannot be parsed as claims about the relative surface area or volume of the particles in question. In particular, I argue that in many

3.2. Geometric properties, causal powers, and context-sensitive explanation

Timaeus sometimes explains the power of fire particles to cut, separate, and heat other bodies in terms of their "sharp" or acute angles, and it is clear that this geometric property of tetrahedra does significant explanatory work in the account of thermoception and several elemental interactions, including non-perceptual ones (§2.2). But that still leaves open how exactly we should understand the relationship between fire's sharp angles and its power to cut. More generally, it leaves open what, if any, ordered relations between specific geometric properties and causal powers there are.

a) *No function from specific geometric properties to specific causal powers*

One qualification that any "Geometry First" approach to causal powers must accommodate is that specific geometric properties do not necessitate or guarantee specific causal powers, even if the (would-be) patient is held fixed. For example, while certain fire particles cut other bodies in virtue of their sharp angles, there are fire particles with equally sharp angles that do not have this power. Take daylight. Daylight is a variety of fire, and so particles of daylight are tetrahedra. Yet these particles come into contact with human flesh every day without cutting it – in fact, Timaeus explicitly characterizes daylight as a variety of fire that does *not* cut or burn (cf. 45b4-5: τοῦ πυρὸς ὅσον τὸ μὲν κάειν οὐκ ἔσχε, τὸ δὲ παρέχειν φῶς ἥμερον). In brief, particles of daylight have the same acute angles as all other fire particles but lack the power to cut human flesh.

Even so, we can still ask whether there are ordered relations between specific geometric properties and specific causal powers whenever elemental particles *do* have such powers. For

explanations of *inter*-elemental interactions, relative size functions as a proxy for other elemental properties (e.g., angular sharpness, relative mobility, …). Since I cannot defend this reading here, I rely only on *intra*-elemental size comparisons in the paper.

example, is it the case that whenever fire particles have the power to cut other bodies, they have this power *primarily* in virtue of their acute angles?

The answer to that question turns out to be "not quite". A good example here is Timaeus' explanation of seeing the colour *white*. Colour vision involves what is often called the "visual ray", which is a homogenous body that is formed from particles of daylight and particles of an internal fire that streams out of our eyes, which is "sibling (ἀδελφόν)" to daylight (45b6-d3). Coloured objects in the world emit colour-flames that interact with the visual ray, and when the resulting affections of the visual ray are passed on to the soul, we see different colours (67d-e; 45c-d & 64a-c). For example, white objects emit white colour-flames that separate the visual ray, which results in our seeing white, while black objects emit black colour-flames that compact the visual ray, which results in seeing black.

Let's focus on the powers of the particles that constitute white and black colour-flames.[26] Since white and black colour-flames are *both* varieties of fire, their particles have equally sharp angles. Yet only particles of white colour-flames can separate the visual ray; particles of black colour-flames not only lack this power, but actually have the opposite power of *compacting* it.[27]

[26] Both coloured objects and the particles that constitute their colour-flames have powers to separate the visual ray. The colours we see are coextensive with the powers of coloured objects to affect the visual ray by means of their colour-flames, not with the powers of individual particles. (Recall, too, that individual particles are too small to be perceived by us; 56b7-c7). But all that matters for our purposes is that particles of different colour-flames also have powers separate and compact the visual ray, not just the coloured objects that emit them; and these are my focus here.

[27] The fact that different varieties of fire can have opposite powers of separating and compacting may influence how we understand the status of the elements as *sunaitia* ('auxiliary/contributory causes') in contrast to real *aitia* in the *Timaeus*, perhaps especially when compared to material conditions as 'mere necessary conditions' in the *Phaedo* (cf. *Phd.*96a ff.). For example, Johansen (2020, 26-9, 33) argues that material conditions in the *Timaeus* are promoted to *sunaitia* because they cannot be used to bring about opposite results, in contrast to the mere necessary conditions of the *Phaedo*. It is not clear to me that cases like non-burning daylight and compacting colour-flames must conflict with Johansen's claim, but they certainly demand further elaboration or qualification. Questions about the *aitia/sunaitia* distinction in the *Timaeus* are closely connected to the dialogue's broader causal-explanatory framework of reason-and-necessity. Addressing these questions lies outside the scope of this paper, but see §4.1. below on grounding and causation for the purposes of this paper, and ch.### in this volume for a focused discussion of causation in the *Timaeus*.

Moreover, white colour-flames separate the visual ray in virtue of their fire particles *being smaller than* the fire particles that constitute the visual ray, where such differences in size must here correspond to differences in overall surface area and/or volume (cf. 67d-e).[28] The acute angles of these particles are not mentioned here. So it is not the case that whenever fire particles *do* have the power to cut other bodies, they have this power primarily in virtue of their acute angles.

To summarize: specific geometric properties do not necessitate, guarantee, or fully determine specific causal powers. Having a specific geometric property (e.g., fire's acute angles) is not sufficient for having a specific causal power (e.g., the power to separate other particles), even if we hold fixed the patient or individuate powers in terms of patients (e.g., the power to separate the visual ray). More generally, then, specific causal powers do not "follow from" specific geometric properties, except perhaps in some qualified sense yet to be determined.

b) *Geometric properties and context-sensitive explanation*

Arguably, we should not be surprised by this result. According to Timaeus, change requires non-uniformity and inequality between an agent and a patient:

T2. Motion will never be within uniformity. For it is difficult, or rather impossible, for that which will be moved to be without that which will move it, or that which will move without that which will be moved; but there is no motion when these are absent, and it is impossible that these should ever be uniform. Thus let us posit that on each occasion rest is in uniformity and motion is in non-uniformity; and the cause of the nature of the non-uniform, in turn, is inequality. (57e2-58a1)[29]

[28] On size, cf. §1, n.4 and esp. §3.1, n.25 above.

[29] 57e2-58a1: ἐν μὲν ὁμαλότητι μηδέποτε ἐθέλειν κίνησιν ἐνεῖναι. τὸ γὰρ κινησόμενον ἄνευ τοῦ κινήσοντος ἢ τὸ κινῆσον ἄνευ τοῦ κινησομένου χαλεπόν, μᾶλλον δὲ ἀδύνατον, εἶναι· κίνησις δὲ οὐκ ἔστιν τούτων ἀπόντων, ταῦτα δὲ ὁμαλὰ εἶναί ποτε ἀδύνατον. οὕτω δὴ στάσιν μὲν ἐν ὁμαλότητι, κίνησιν δὲ εἰς ἀνωμαλότητα ἀεὶ τιθῶμεν· αἰτία δὲ ἀνισότης αὖ τῆς ἀνωμάλου φύσεως.

An agent's causal power to affect a patient presupposes non-uniformity and inequality between the agent and the patient. Since the particles of both white colour-flame (the agent) and particles of the visual ray (the patient) are tetrahedra, they have equally acute angles, and so any causal powers of the agent to affect the patient cannot be primarily determined by, and explained in terms of, this shared feature. Thus, even if fire's acute angles are primarily responsible for its power to cut other bodies in inter-elemental changes, the same cannot be true in intra-elemental changes.

T3. Whenever one of the other kinds is caught in fire and is cut by the sharpness of its angles and in relation to its edges, it stops being cut once combined into the nature of [fire]. **For each kind that is alike and the same as itself is not able either to bring about any change in or to be affected in any way by what is like it in the same respects.** (56e8-57a5)[30]

Accordingly, the account of colour vision correlates different powers to affect the visual ray with *differently sized* colour-flame particles instead of appealing to the acute angles of only some such particles (67d-e): particles of white colour-flame have the power to separate particles of the visual ray in virtue of being smaller than them.

However, the principle that the causal powers of elemental particles are determined by non-uniformity and inequality between particles is too general to offer concrete guidance for explaining any given causal power. Fire particles that burn human flesh differ from the earth and water particles that constitute flesh in all kinds of ways, not just with respect to their angles.

Yet it seems clear that the same geometric property (fire's acute angles) can be central in the explanation of one causal power (the power to separate human flesh) and peripheral, though not irrelevant, in the explanation of a similar causal power (the power to separate the visual ray).

[30] 56e8-57a5: ὅταν ἐν πυρὶ λαμβανόμενον τῶν ἄλλων ὑπ' αὐτοῦ τι γένος τῇ τῶν γωνιῶν καὶ κατὰ τὰς πλευρὰς ὀξύτητι τέμνηται, συστὰν μὲν εἰς τὴν ἐκείνου φύσιν πέπαυται τεμνόμενον— τὸ γὰρ ὅμοιον καὶ ταὐτὸν αὑτῷ γένος ἕκαστον οὔτε τινὰ μεταβολὴν ἐμποιῆσαι δυνατὸν οὔτε τι παθεῖν ὑπὸ τοῦ κατὰ ταὐτὰ ὁμοίως τε ἔχοντος.

These differences in explanatory relevance are not random, but reflect different roles of the same geometric property in determining similar causal powers.

To start articulating these differences, we may distinguish between essential and variable geometric properties of each elemental kind. Essential geometric properties are necessary for a particle to be a token of a given type of Platonic solid (e.g., tetrahedron) and belong to the corresponding element (e.g., fire), such as the shape and number of its faces and the consequent angles between any two faces. By contrast, variable geometric properties are not necessary for type membership, such as surface area and volume. On behalf of the *Geometry First* view, we can now propose the following:

> Whenever fire particles have the power to cut and separate certain bodies in inter-elemental interactions, this power is primarily due to their essential geometric properties (e.g., acute angles). Whenever fire particles have the power to cut and separate certain bodies in intra-elemental interactions, this power is primarily due to their variable geometric properties (e.g., surface area or volume).
>
> More generally, whenever elemental particles have a specific causal power in inter-elemental interactions, this power is primarily due to their essential geometric properties; whenever elemental particles have a specific causal power in intra-elemental interactions, this power is primarily due to their variable geometric properties.

It is worth emphasizing here that we cannot infer the existence of similar causal powers across different interactions. For example, (1) we cannot infer from the fact that certain fire particles have the power to cut other bodies in inter-elemental changes that they also have the power to cut other bodies in intra-elemental changes, even if we adjust the explanatorily central geometric property in each case. When I look at my white cup, the particles of the cup's white colour-flame separate my visual ray in virtue of their smaller size. But if I touch the white cup, the particles of white colour-flame no more separate my earthy hand in virtue of their essential geometric properties (acute angles, etc.) than particles of non-cutting daylight do.

Similarly, (2) we cannot infer from the fact that certain fire particles can separate *some* non-fiery particles that they have the power to cut other, *very similar* non-fiery particles. For example, we all have an internal fire in our belly that is responsible for digestion, which cuts incoming food stuffs into spare parts that can be distributed to areas in need of repair around the body (78e–79a, 80d–81c; cf. 77a-c). But we have no reason to think that this digestive fire *also* cuts up our internal organs, even though these are constituted out of the same kinds of elemental particles as the food that we eat. In other words, digestive fire seems to affect only some of the many, equally non-fiery would-be patients that it encounters.

The modified *Geometry First* proposal does not yet give us a complete story of what determines, on each occasion, the causal powers of elemental particles. But it accommodates the complications discussed so far, and it preserves some ordered relations between specific geometric properties and specific causal powers of elemental particles.[31]

3.3. Taking stock

The findings of this section can be summarized as follows:

- The geometric properties of particular elemental particles do not fully determine these particles' physical properties, and so cannot do all the explanatory work in such cases. (§3.1)

[31] This outcome is consistent with Timaeus' remarks about thermoception at 61e-62a. In that passage, Timaeus recalls the assignment passage by characterizing a *variety* of properties – specifically, "the fineness of fire's edges, the sharpness of its angles, the minuteness of its parts, and the swiftness of its motion" (61e2-3) – as properties "in virtue of *all* of which [fire], being excessive/violent and cutting in sharpness, cuts what it encounters on each occasion on which it cuts (οἷς πᾶσι σφοδρὸν ὂν καὶ τομὸν ὀξέως τὸ προστυχὸν ἀεὶ τέμνει)" (61e4-62a1). In other words, there is no singular focus on the sharpness of tetrahedral angles, and Timaeus' claim need not be the claim that fire *always* cuts what it encounters. If we take *aei* in 61e4 in the sense of 'on each occasion' rather than 'always', then his claim is that fire cuts in virtue of its properties x, y and z, taken together, on each occasion on which it cuts what it encounters, *rather than* the claim that fire cuts *whatever* it encounters (as on the Zeyl 2000 translation). Note that on this reading, the "swiftness of its motion" plausibly varies depending on fire's cosmic location and the distribution of other matter around it.

- There is no function from specific geometric properties to specific causal powers, even when the would-be patient is held fixed. For example, Timaeus invokes the acute angles of fire particles to explain their power to cut other elemental particles or aggregates. Yet there are fire particles that do not have any causal powers of cutting or separating whatsoever, despite having equally acute angles, and some even have seemingly opposite powers of compacting other bodies. (§3.2)
- The kind of explanatory work that is done by specific geometric properties of elemental particles is context-sensitive: the same geometric property may be central to the explanation of one causal power (e.g., fire's power to separate ice or human flesh) but peripheral in the explanation of another, similar causal power (e.g., fire's power to separate the visual ray). These context-sensitive differences in explanatory relevance reflect the underlying metaphysical relations in each case: the same geometric property may be primarily responsible for one causal power, but not for another, similar causal power. (§3.2)

4. The interpretive utility of grounding claims in our interpretation of elemental properties

How does all this relate to the notion of grounding? This section will *not* consider whether Plato, in the *Timaeus*, operates with any particular notion of grounding found in contemporary analytic metaphysics. Instead, I want to ask whether the notion of grounding has any interpretive utility to us as interpreters of the *Timaeus,* specifically with respect to elemental properties. This goes beyond asking whether we can formulate interpretive claims about elemental properties in terms of grounding without distorting the account developed in §§1-3. The question is rather: what, if any, interpretive claims that use the notion of grounding might illuminate the relationship between elemental particles and their properties in Plato's *Timaeus*?

First, however, we must establish the appropriateness of formulating claims about Timaean elemental properties in terms of grounding at all.

4.1. Preliminaries on the notion of grounding and its applicability to the Timaean elements:

Contemporary work on grounding often begins from the thought that grounding is a kind of determination or explanation that *contrasts with* causation. However variously grounding is understood, it is taken to be a sort of constitutive explanation or determination.[32] We say that x grounds y when y obtains in virtue of x, on account of x, or because of x, where these expressions do not denote a causal relation, but x somehow non-causally explains, produces, or brings about y.[33] For now, I will adopt the view that grounding is a kind of non-causal determination that backs grounding explanations.[34]

When Timaeus appeals to geometric properties to explain the physical properties or causal powers of elemental particles, his explanations seem to reflect some such non-causal sort of determination. Yet it is far from apparent that Plato would contrast this kind of determination or the explanations that appeal to it with causation or causal explanations as such. Rather, these explanations seem to belong together with other sorts of explanations as part of the overall account of why the world is the way it is and what determines what (considerations of space preclude a full

[32] Cf. Bliss and Trogdon 2021: "a form of constitutive (as opposed to causal or probabilistic) determination or explanation". Correia and Schnieder 2012, 1, take it to be "a particular sort of non-causal priority".

[33] Cf. Brenner et al. 2021, §2; Bliss and Trogdon 2021, §1.1; Correia and Schnieder 2012, 5, 7; Raven 2015, 324-5.

[34] In the contemporary debate, this thesis is sometimes called "separatism" about grounding, in contrast to "unionism" (Raven 2015, 326). Separatism distinguishes between grounding and grounding explanations, such that grounding is a kind of determination that underwrites grounding explanations. By contrast, *unionism* identifies grounding and grounding explanation: "to be grounded just is to be metaphysically explained in a distinctive way" (Brenner et al. 2021, §3).

treatment of causation and explanation in the *Timaeus*, but see Johansen 2020 for a brief overview).[35]

One might distinguish claims *about* grounding from claims *of* grounding,[36] and suppose that while Plato makes few or none of the former, he frequently engages in the latter. Yet even this much might be misleading insofar as it suggests that Plato sharply contrasts such claims with causal explanations; from Plato's perspective, geometric properties' determination of elemental causal powers might have more in common with fire causing the separation of other elements, wine causing a person to perceive sweetness, or the demiurge causing the heavenly bodies to come to be than contemporary contrasts between grounding and causation allow (cf. also T2 and T3 above). In particular, it seems no less appropriate to describe the causal relations in terms of one thing obtaining because of, in virtue of, or on account of another than to describe cases of grounding in those ways. Admittedly, these expressions may pick out different sorts of determination or explanation in different cases, but that seems no less true of the contemporary language of grounding, which can cover cases of functional realization, mereological realization, set formation, composition, truthmaking, determinate-determinable relations, and more besides.[37] From a Platonic (or, more generally, pre-modern) perspective, it might seem odd to group all of these relations on one side and cases of causation on another, and the attractiveness of this categorization may be a product of the subsequent history of the concept of causation in modern philosophy.[38]

[35] Cf. also chapters ### in this volume.

[36] Bliss and Trogdon 2021, §1.5 draw this distinction.

[37] These examples come from Bliss and Trogdon 2021; for similar lists of illustrative cases, see Raven 2015, 322-323 and Correia and Schnieder 2012, 1.

[38] See Schmaltz 2014.

Setting this complication aside, however, it seems warranted to say that geometric properties play a central role in determining physical properties and causal powers, and this determination is at least broadly of the sort that many contemporary philosophers talk about in the language of grounding. We might thus speak of elemental properties grounding other elemental properties or causal powers. E.g., an elemental property φ may ground another elemental property ψ, in which case ψ would be grounded in φ. Claims of this form reflect the general applicability of the notion of grounding.[39]

Some contemporary philosophers think that "grounding induces necessary connections" between the ground and the grounded.[40] Call this *necessitarianism* about grounding.[41] In terms of elemental properties, this would mean that if φ grounds ψ, then as a matter of metaphysical necessity, elemental particle P has ψ if it has φ. However, as we have seen, there is no such necessary connection between specific geometric properties and specific physical properties or causal powers (§3).

We can avoid the issue by distinguishing between *full grounding* and (*merely*) *partial grounding*, such that ψ is (merely) partially grounded in φ iff ψ is fully grounded in φ and other properties.[42] Characterizing specific geometric properties as (*merely*) *partial grounds* of physical

[39] Formulating interpretive claims directly in terms of elemental properties grounding, and being grounded by, other properties is the most natural in light of the phrasing of various Timaean explanations. This approach contrasts, e.g., with formulating these interpretive claims in terms of facts or propositions about elemental properties grounding other such facts or propositions, which would be more in line with the common contemporary view that grounding is a relation between facts or propositions. That said, translating the relevant claims about properties into claims about facts or propositions would not necessarily affect the overall argument of this section, which after all concerns the interpretive utility of formulating interpretive claims in terms of grounding rather than the question of whether or not Plato/Timaeus operated with a modern conception of grounding. By the same token, interpretive claims formulated in terms of facts grounding other facts need not be misleading in ways one might fear – e.g., they would not saddle Plato/Timaeus with a commitment to the existence of facts.

[40] Correia and Schnieder 2012, 20.

[41] Cf. Correia and Schnieder 2012, 20-21; Bliss and Trogdon 2021, §4.1.

[42] This is also the strategy employed by necessitarians faced with putative counter-examples. I here add '(merely)' to prevent terminological ambiguity: while some participants in the contemporary debate simply contrast full grounding

properties or causal powers does not misrepresent the relations between different kinds of elemental properties discussed in §3. Thus, the fact that specific geometric properties do not necessitate or guarantee specific physical properties or causal powers need not speak against the general applicability of the notion of grounding, but rather brings out the importance of distinguishing between full and (merely) partial grounding.

Overall, then, it seems appropriate to apply the modern notion of grounding to elemental properties and causal powers, where grounding is a kind of constitutive determination relation whose instances are tracked in grounding explanations. With that in mind, let us turn to the question of whether formulating interpretive claims in terms of grounding illuminates and enriches our understanding of the metaphysics of elemental particles and their properties.[43]

4.2. The interpretive utility of certain kinds of grounding claims about elemental properties

The notion of grounding can enrich our interpretation of the Timaean elements and their properties in at least two ways.

The first is rather general: the notion of (merely) partial grounding allows us to capture the spirit of *Geometry First* views while avoiding the complications discussed in §3. We know that the geometric properties of particular elemental particles cannot fully ground their physical properties and causal powers. For example, the geometric properties of a fire particle do not fully determine its weight and mobility relative to other elemental particles, and so one cannot give a fully adequate explanation of these physical properties in terms of its geometric properties (§3.1); the same is true

with partial grounding (cf. Correia and Schnieder 2012, 21), others distinguish between merely partial grounds and partial grounds, where the latter but not the former can be full grounds (cf. Bliss and Trogdon 2021, §1.3).

[43] We can set aside further questions about the regimentation of grounding claims and related issues (e.g., granularity) that shape contemporary debates but are orthogonal to our central question here. Cf. Correia and Schnieder 2012, 10-19.

in the case of its causal powers (§3.2). Accordingly, the charitable reading of *Geometry First* views in the literature is that even their strongest claims about specific geometric properties of elemental particles determining these particles' causal powers stop short of anything like claims about full grounding, since such an analysis would be quite mistaken.[44]

Unlike full grounding, (merely) partial grounding is pretty cheap: the claim that the geometric properties of elemental particles are (merely) partial grounds of all physical properties and causal powers of these particles would seem to be true across the board. By extension, the notion of merely partial grounding helps us articulate the fact that there is some explanatory role for geometric properties in even the most muddied cases; for example, the geometric properties of fire particles partially ground their weight and mobility both when these particles are relatively light and mobile (e.g., fire at the cosmic center) and when they are relatively heavy and immobile (e.g., fire at the cosmic periphery). In this way, the notion of merely partial grounding helps capture the general spirit of the *Geometry First* views. This brings us to a second, related interpretive contribution of formulating certain interpretive claims in terms of grounding.

More substantively, the notion of *non-vacuous* grounding can help capture that the nature and identity of geometric properties matters even when such properties are peripheral in explanations of certain causal powers.

Now, we have already seen that specific geometric properties of elemental particles are (merely) partial grounds of these particles' causal powers regardless of explanatory context; e.g.,

[44] Some claims in *Geometry First* interpretations can suggest the view that the relevant geometric properties are sufficient for a fully adequate explanation of the causal power in question. Recall, e.g., the claim that the character of a perception is "a consequence of the elemental shapes causing it" (Modrak 2006, 141), or the claim that "sensation-producing effects *follow from* elemental geometry", such that thermoception-producing effects could be said to follow from "the size and shape of fiery vertices" (McCready-Flora 2018, 129, 130; emphasis added). But many proponents of such claims would almost certainly agree that a fully adequate explanation should at the very least include the elemental constitution of the patient (cf. Modrak, 136; McCready-Flora, 127). Perhaps they would also be willing to include other factors, such as cosmic location and like-to-like motion.

the geometric property of having acute angles is common to all fire particles, and this property is a (merely) partial ground of fire particles' power to cut other bodies whenever they have this power. This is true regardless of whether the causal power in question is *primarily* determined by this geometric property, and so regardless of whether the geometric property is central or peripheral to the explanation (as in the cases of, respectively, certain fire particles' power to separate human flesh and certain fire particles' power to separate the visual ray).

However, even when a geometric property φ is peripheral to the explanation of a causal power ψ, it nevertheless grounds the power in question *non-vacuously* – that is, (i) φ grounds ψ, and (ii) the nature and identity of φ matters for the determination of ψ.[45] For example, even though the property of having acute angles is peripheral in Timaeus' explanation of white colour-flame's power to separate the visual ray, this does *not* mean that the identity and nature of this geometric property is irrelevant. To the contrary: the power of particles of white colour-flame to separate particles of the visual ray is primarily determined by their relatively smaller size precisely because the property of having acute angles is common to all particles involved and so cannot be primarily responsible for any of their causal powers to affect each other.

In this way, formulating interpretive claims in terms of (merely) partial non-vacuous grounding helps articulate the role of specific geometric properties in the determination of specific physical properties and causal powers even when these geometric properties are explanatorily peripheral.

[45] See Bliss and Trogdon 2021, §2.3 on the distinction between vacuous and non-vacuous grounding (formulated in terms of facts and a conception of grounding as a kind of explanation): "Roughly speaking, [P], [P'], … vacuously grounds [Q] when the former grounds the latter, yet the identity and nature of the constituents of [P], [P'], … aren't explanatorily relevant to [Q] obtaining. Perhaps [The truck is red] is a vacuous ground for [Some fact or other obtains] – while the former grounds the latter, it seems that the identity and nature of the truck and the property of being red don't contribute to explaining why [Some fact or other] obtains." The distinction is proposed by Woods 2018.

Nonetheless, such claims do not capture what is most distinctive about the Timaean picture – viz., that the role of geometric properties in determining and explaining other elemental properties is context-sensitive. Fire particles' property of having sharp angles is a merely partial, non-vacuous ground of fire's causal powers regardless of explanatory context. Accordingly, the notion of non-vacuous, merely partial grounding can only supplement the interpretive framework in §3. Still, it helps articulate a part of the picture that is easily missed: the nature and identity of explanatorily peripheral geometric properties nevertheless plays an important role in the determination of the causal powers in question.

5. Conclusion

According to *Geometry First* views of the *Timaeus*, the geometric properties of elemental particles determine and explain their physical properties and causal powers (§2). To remain interpretively viable, such views must accommodate several qualifications and constraints: first, physical properties of particular elemental particles may change even when their geometric properties do not (§3.1); second, there is no function from specific geometric properties of elemental particles to specific causal powers to affect identical or different patients (§3.2); and finally, the same geometric property may be primarily responsible for one causal power and central in the explanation of that power, but not primarily responsible for another, similar causal power (§3.2).

Despite the context-sensitive role of geometric properties, there is nevertheless order in the relations between different kinds of elemental properties. A modified *Geometry First* view about causal powers can capture these complex but ordered relations in part by distinguishing between essential and variable geometric properties (§3.2). Articulating relations between elemental properties in terms of the notion of *grounding* can also be interpretively fruitful. For one, the notion

of grounding allows us to capture the spirit of traditional *Geometry First* views of the physical properties and causal powers of elemental particles while avoiding various complications for such views (cf. §3). More significantly, the notion of grounding can enrich even modified the *Geometry First* views that recognize the context-sensitivity of Timaean explanations. In particular, the notion of (merely) partial, non-vacuous grounding helps articulate the role of specific geometric properties in determining specific causal powers even when these geometric properties are peripheral in Timaeus' explanations of these powers (cf. §4.2). By the same token, however, the notion of grounding cannot capture what is most distinctive about the Timaean picture of elemental properties – viz., the context-sensitive role of specific geometric properties in determining and explaining other elemental properties.

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