IIIβ: Metaphysics Λ1-6
IIIβ2: Λ6: From eternal motion to an ἀρχή that is pure ἐνέργεια

IIIβ2a: The strategy of Λ6 and the eternity of motion

Metaphysics Λ6 is closely continuous with Λ1-5. Picking up Λ4-5's discussion of the different causal routes from sensibles things up to their ἀρχαί, Λ6 pursues the only path that leads to a numerically single ἀρχή, individually eternal and numerically one despite its many species of effects. This ἀρχή will be a non-conspecific efficient cause, and, as Λ4-5 suggest, it will be a cause to the many sublunar species by being a cause to the heavenly bodies, since (as Λ4-5 claim without explanation) the sun and its motions are necessary for the generation of sublunar species. Λ6 is continuing the discussion of the ἀρχαί of sensible things, and, in arguing that the first moving ἀρχή is ἐνέργεια rather than δύναμις, it is applying the results of Θ8, as Λ1-5 have applied results of other parts of ZHΘ. Also, within the overall structure of Λ, Λ6 takes up Λ1's distinction between the three kinds of οὐσίαι, sensible perishable, sensible eternal, and unchanging non-sensible, and declares that the third type of οὐσία does exist, and that there is a causal chain leading up from sensible to non-sensible οὐσίαι. The first sentence of Λ6 announces, "since there were three [kinds of] οὐσίαι, two physical and one unmoved, about this last let it be said that there must be some eternal unmoved οὐσία" (1071b3-5), and initially Λ6 looks as if it will be a connected argument for this claim. But Aristotle is concerned not just to prove that this kind of οὐσία exists, but to describe what it is like and what kind of effects it has. In claiming that there is an eternally existing first cause of motion to the world, Aristotle is following Anaxagoras and Empedocles and Plato (both Timaeus and Laws), and he may not expect too much resistance from his audience. His main controversial claim, against Anaxagoras and Empedocles and Plato, is that this ἀρχή is not a δύναμις but an ἐνέργεια. By this Aristotle means not just that the ἀρχή was not "in the beginning" an unexercised δύναμις, or that the ἀρχή is eternally ἐνεργοῦσα, but also that its essence is ἐνέργεια: that is, the ἐνέργεια is not an accident predicated of an underlying οὐσία whose essence is δύναμις, but rather the οὐσία is ἐνεργοῦσα by its own essence. It is a corollary that the ἀρχή, since it has no δύναμις, cannot change, and also (since Λ2 has argued that matter is a δύναμις) that the ἀρχή is without matter; but these are merely corollaries, and although presumably Aristotle agrees with the Timaeus and disagrees with Anaxagoras on both points, what he emphasizes instead, against both Anaxagoras and the Timaeus, is that the ἀρχή is always acting in the same way to produce motion in the world. As we have already seen, this reconception of the efficient ἀρχή as essentially ἐνέργεια--the fruit of the argument of Θ--leads Aristotle to a rejection of any narrative leading from the ἀρχή to the world, and thus to a deep transformation of the very notion of an ἀρχή.

In discussing Λ6, I will concentrate on Aristotle's internal criticism of the νοῦς-cosmogony of Anaxagoras and the Timaeus, discussing his argument that the ἀρχή is ἐνέργεια, the consequent denial of any beginning to the ordered world, and the consequent problem of how generation and corruption can arise from an ἀρχή (or several ἀρχαί) whose effects are eternally constant. (Aristotle's answer involves the mediating role of the heavens, and also the plurality of heavenly motions, so I will say something about his treatment of the plurality of heavenly motions in Λ8, and in texts outside the Metaphysics, to explicate what he says about the issue at the end of Λ6.) I will not, in this section, address the issue of how an entirely actual, and thus unmoved, ἀρχή can move something; Aristotle's answer, "as an object of thought and desire," is not given until

Λ7, and I will discuss it in discussing Λ7 and Λ9 in IIIγ1 below. Likewise, in this section I will not discuss how Aristotle thinks he knows that the ἀρχή is νοῦς: he does not actually call it νοῦς until Λ7, although certainly Anaxagoras' and Plato's descriptions of νοῦς are important in the background of Λ6. Indeed, a frustrating feature of Λ6 is that it tends to assume a basic Anaxagorean/Platonic world-picture, and to give argument only where it disagrees with Anaxagoras or Plato; it does not give direct answers to questions that we outsiders might want to ask, e.g. "why must there be a single all-encompassing motion causally prior to all particular motions within the world?", or "why does the circular motion of the heavens require a moving cause other than the heavens themselves?". However, in some cases the answers can be supplied or reconstructed from Aristotle's physical works. As we have seen, because of the extreme abbreviation of Λ, often to fill out its arguments we have to turn to related passages, either from other books of the Metaphysics or from physical or even ethical works: in a fuller version of Λ, Aristotle would have either cited these other passages explicitly, or simply repeated in Λ the same considerations that he had developed in these other texts. For Λ6, the crucial texts from outside the Metaphysics will be Physics VIII and On Generation and Corruption II,9-11; for Λ7 and Λ9, the crucial texts will be from De Anima III, along with some ethical texts. In calling on these other texts to help interpret Λ6-10, we will be seeing how Aristotle's different treatises "converge at the top" to give a single theory of the ἀρχαί.

While Aristotle's theory of the ἀρχαί and their causal relations with physical things is most immediately a critical development of Plato's, and while he also (like Plato) develops themes from Anaxagoras and Empedocles, he also more surprisingly makes use of Democritus. Certainly Aristotle regards his own account of the ἀρχαί as being closer to those of the other three philosophers than to that of Democritus. As he reports it in Metaphysics A, Anaxagoras and Empedocles and Plato agree in positing a good-itself as an ἀρχή, which is for Anaxagoras and Empedocles (and also, though Aristotle does not say so, for the Timaeus) a source of motion, and for Plato elsewhere a formal cause; and one of the main aims of Λ, indeed of the whole Metaphysics, is to vindicate this claim that the good-itself is an ἀρχή, while rejecting the claim (made by Empedocles and at least sometimes Plato) of a contrary evil ἀρχή. Democritus, who has neither good nor evil ἀρχαί, and does not even pretend to give teleological explanations, seems at the furthest extreme from the position Aristotle will defend; indeed, Metaphysics A lists Democritus among philosophers who do not posit an ἀρχὴ κινήσεως at all, not just because Democritus has no moving causes distinct from his material causes, but also because he has nothing that begins motion, or causes there to be motion rather than rest (he just assumes that motion has always existed--atomic collisions merely redirect it). So too in the On Generation and Corruption Aristotle takes Democritus as the philosopher offering the very opposite explanations to his, both of coming-to-be and specifically of the inexhaustibility of coming-to-be. Nonetheless, Aristotle agrees with Democritus, against Anaxagoras and (with qualifications) Empedocles and the Timaeus, that there is eternally motion. (Empedocles thinks that motion has existed from the infinite past and will exist into the infinite future, but that there are also intervals of rest, under the total dominion of Love or of Strife [or so Aristotle says, Physics VIII,1 250b26-251a5]. The Timaeus thinks that there was always motion, since before the cosmos the receptacle and its contents were in disorderly motion, but that the cosmic motions due to the activity of νοῦς began at some finite past time. The Laws apparently does think that cosmic motion is eternal.) Aristotle thus feels free to use Democritean strategies of argument, against his own natural allies, to force them to admit eternal motion; Aristotle will then argue, with his allies and against Democritus, that there must be a cause for this motion, indeed a cause that resembles

the νοῦς of Anaxagoras and Plato, but corrected by being made essentially and eternally active, and so never merely δυνάμει.

The argument of Λ6 thus turns very heavily on the claim that motion is eternal. Aristotle argues for this claim, very briefly, in the first paragraph of Λ6, 1071b3-11 (this argument actually occupies only 1071b6-11). I will devote what may seem a disproportionate amount of space--the remainder of this subsection IIIβ2a, more than half of my discussion of Λ6--to unpacking the argument of these few lines (using clues from elsewhere in Aristotle's work), because so much rests on the conclusion and because Aristotle's argument here is not only sketchy but apparently fallacious. The problem is that it looks as if Aristotle is passing without argument from "there is always some motion" to "there is some motion that always exists." The second claim is much stronger, because, given the identity-conditions for motions that Aristotle has established in the Physics, it entails that some numerically single object must be moved, in the same (spatial or qualitative) direction and preferably at a uniform speed, for infinite time; as Aristotle goes on to infer at Λ6 1071b10-11, these conditions can be satisfied only by an eternal circular motion. This conclusion looks too strong to be supported by Aristotle's argument, and it is easy to suspect either that he is committing a formal fallacy, or else that, once he has shown that there is always some motion, he just tacitly assumes that it will be the empirically observed circular motion of the heavens. However, Aristotle does have a real argument in mind, and, by filling in some background from texts outside the Metaphysics, we can see why Aristotle would think that if there is always some motion--if, say, there is an eternal succession of motions--there would also have to be a single eternal motion to regulate this succession of motions. And this Aristotelian picture of how a single eternal motion would regulate a succession of motions (such as the successive generation of animals within an eternal species) is well worth exploring, because it gives the only causal link between the eternally constant activity of νοῦς and the world of generable and corruptible things.

The argument for the eternity of motion: Λ6 and Physics VIII

Aristotle argues for the eternity of motion, and thus for the eternity of some οὐσία as its ἀρχή, very briefly at the beginning of Λ6, and almost as briefly in the close parallel GC II,10 337a17-33, but at much greater length in Physics VIII. Λ6, from the beginning, says: "since there were three [kinds of] οὐσίαι, two physical and one unmoved, about this last let it be said that there must be some eternal unmoved οὐσία. For οὐσίαι are the first of beings, and if they are corruptible, all things are corruptible. But it is impossible for motion either to have come-to-be or to perish (for it always was), or time either. For there cannot be before and after if there is no time: and so motion is continuous, just as time is: for [time] is either the same thing as motion or else a πάθος of motion. And there is no [sc. eternally] continuous motion except motion in place, and of this [only] circular motion" (1071b3-11).[1]

To understand what Aristotle is doing here, we need to look at the much fuller treatment in Physics VIII. Physics VIII, like Λ6, starts from the fact of motion and uses it to demonstrate an eternal and unmoved cause of motion; here, as in Λ, Aristotle does not argue from the observed motion of the heavens, but proceeds more abstractly from motion as such, without explicitly relying on observation or cosmological theory on his way to the ἀρχή, although in both books he deduces an eternal circular motion along the way. The argument-structure of Physics VIII is complex and intricate: it is much more complex than what it is sometimes imagined to be,

[1]d deal with the logical question raised by Oehler

namely an infinite regress argument from the fact of motion to a first cause of motion which must itself be unmoved. Physics VIII,1-2 are an argument for the preliminary thesis that motion has always existed and will always exist; but the main thesis of the book is first stated in Physics VIII,3. Plato in the Sophist had asked whether all things are in motion, all at rest, or some in motion and some at rest; Plato argues that the last is true, since the Forms are eternally at rest and sensibles are eternally in motion. But there are more possibilities, and Aristotle poses the question more precisely: "necessarily either all things are always at rest, or all are always in motion, or some things are in motion and others are at rest; in this case either the ones that are moved are always moved and the ones that are at rest are always at rest, or all things are naturally capable both of motion and of rest, or there is a third possibility: it may be that some beings are always unmoved, and others are always moved, and others come to partake of both motion and rest; and this is what we must say" (Physics VIII,3 253a24-30).[2] Aristotle starts by arguing that ordinary sensible things are not eternally in motion, but alternate between motion and rest (a thing cannot always be becoming hot, or moving up, and if it alternates between becoming hot and becoming cold again, there must be a moment of rest in between). Then he sets out to show that there are also some things eternally in motion, and others eternally at rest (or rather, eternally unmoved, since rest is a privation and things not capable of motion are not at rest): instead of using Platonic dialectical arguments, he will argue physically, by pursuing the efficient cause of the ordinary things that alternate between motion and rest. But the causal argument that will bring ultimately bring us to eternally unmoved movers is not simply the regress argument from motion to a first unmoved mover. Aristotle in fact gives this argument in Physics VIII,4-5: he argues in VIII,5 that the first mover is unmoved, and not as Plato says self-moved: an animal is a self-moved mover, not because its soul is a self-moved mover, but because the soul moves its body while itself remaining unmoved, except that the soul can be said to be moved per accidens because the composite animal is moved. However, just this conclusion shows that the simple regress argument is too crude to reach an eternal unmoved mover. The regress might terminate in an unmoved mover like the soul of an animal, which is not eternal: for as the soul is moved per accidens when the animal is moved, so it is generated and corrupted per accidens when the animal is born and dies. Aristotle proposes to find an eternal unmoved mover by looking for the causes of the eternity of motion; just as, in the On Generation and Corruption, he had pursued the causes not simply of generation, but of the eternity or inexhaustibility of generation (question first raised GC I,3 317b33-318a25; recalled at Metaphysics Λ10 1075b16-17).

Physics VIII,1-2, and their very brief parallel Metaphysics Λ6 1071b6-10, supply arguments for the premiss that motion is eternal (as Aristotle says, "this will be important not only for the study of nature but also for the discipline concerning the first ἀρχή", Physics VIII,1 251a6-8). Two arguments are particularly important. First, for one thing to move another (e.g. to heat it), the agent must be so disposed as to produce that motion, the patient must be so disposed as to undergo the motion, and the agent and patient must be together; and whenever these conditions are satisfied, the motion will occur. So "if there was not always motion, it is clear that [its patient and agent] were [previously] not so disposed that the one was able to be moved and the other to move; rather, one or the other of them must have changed [from the previous condition to the condition in which they do produce the motion]: for this must happen even with relatives, e.g. if having not been double it is now double, one or the other must have changed, if not both. So there will be some change prior to the first" (Physics VIII,1 251b5-10). In effect, this is an

[2]parallel at the end of Metaphysics Γ, Γ8 1012b22-31, probably cited in Iβ2

argument from the principle of sufficient reason: if everything has been in the same condition from eternity until time t (or indeed from a finite time s until t), there can be no sufficient reason why motion should begin at t and not before. Indeed, Aristotle says as much further on, in a passage arguing specifically against Anaxagoras: "to be at rest for an infinite time, and then at some point to be moved, and that there is no difference in this [to explain] why now rather than before, and that this has no proportion [of the time of the motion to the previous infinite time], is not the work of nature" (252a14-16). This seems to be Aristotle's main argument in Physics VIII,1, and seems to be abbreviated in Λ6's "it is impossible for motion either to have come-to-be or to perish (for it always was)" (Λ6 1071b6-7).[3] But there is also a second important argument: "how will there be before and after if there is no time, or time if there is no motion? For if time is either the number of motion or [is itself] some kind of motion, then if there is always time, motion too must be eternal" (Physics VIII,1 251b10-13, parallels Λ6 1071b7-10, GC II,10 337a22-5). Aristotle goes on to give the reason why time cannot begin or end, namely that its beginning or end would be a moment [a "now"], and that every moment is both the beginning and the end of some (interval of) time, so that there would also be time before the supposed beginning, or after the supposed end (251b19-26). But, he says, the conclusion that time has no beginning or end is almost uncontroversial: "about time, everyone, with one exception, seems to be in agreement: they say it is ingenerable. And by means of this Democritus shows that it is impossible for all things to have come-to-be, since time is ingenerable. But Plato alone generates it: for he says [in the Timaeus] that it is simultaneous with the heaven, and that the heaven came-to-be" (251b14-19).

This passage gives evidence of Aristotle's use of Democritus in arguing for the eternity of motion. Metaphysics Λ6, while not citing Democritus in the arguments for the eternity of motion, does cite him (or rather Leucippus) as rightly agreeing with the conclusion (1071b31-3). But the Physics text just quoted does cite Democritus for the argument from the eternity of time, given both in Physics VIII,1 and in Metaphysics Λ6. And it is also very likely that the argument from the principle of sufficient reason against a first motion is also Democritean, since the one real verbatim fragment of Leucippus, cited "from the περὶ νοῦ" says "nothing comes-to-be at random [μάτην], but everything for a reason [ἐκ λόγου] and by necessity" (DK B2, from Stobaeus). There is no reason to think that Leucippus wrote more than one book, later called the Μέγας διάκοσμος to distinguish it from Democritus' Μικρὸς διάκοσμος: the περὶ νοῦ would be a section of that book, presumably a section criticizing Anaxagoras; we are told elsewhere that Democritus criticized Anaxagoras, and specifically that he "tears apart [Anaxagoras' doctrines] about the διακόσμησις and about νοῦς" (Diogenes Laertius IX,34, from Favorinus). Leucippus' fragment looks like it is arguing against Anaxagoras that there is no reason why νοῦς should start causing motion at an arbitrary moment--the same argument Aristotle makes against Anaxagoras at Physics VIII,1 252a10-19. It thus seems likely that both of the main arguments of Physics VIII,1 and Metaphysics Λ6 for the eternity of motion are developed out of arguments that Democritus (or Leucippus) had made against Anaxagoras; Aristotle is extending them against anyone else who thinks that cosmic motion arose from a previous state of rest.

Aristotle's strategy is to use Democritus against Anaxagoras (and Empedocles, and the Timaeus if we disregard the disorderly motion), but then to turn against Democritus by drawing

[3]note on the Physics VIII,1 argument against motion perishing. this argt seems much more dubious (suppose the last motion is something that is X becoming Y, and X is mobile and Y is not). but Aristotle is much less interested in this case than in the beginning of motion case. and no one had ever maintained that motion was beginningless but not endless

the further inference that if there is an eternal motion, there is something eternally causing this motion. Democritus or Leucippus are criticized by name on this issue in both Physics VIII,1 and Λ6, although in different ways. In Physics VIII,1, Aristotle has complained that Empedocles gives no explanation why love and strife should regularly alternate, ruling for equal periods, beyond saying that they have always done so; "and in general, it is not right to suppose that this is a sufficient ἀρχή [i.e. a stopping-point of explanation], that something always is or always happens in this way; this is what Democritus traces back the causes of natural [phenomena] to, that it happened in this way before also; but he would not see fit to seek a [further] ἀρχή of what always is. This is right in some cases, but not in all. For the triangle always has angles equal to two right angles, but nonetheless there is a further cause of this eternal [truth]; but of [genuine] ἀρχαί, which are eternal, there is no further cause" (252a32-b5; parallel GA II,6 742b17-743a1). Here presumably Aristotle has in mind specifically that Democritus says there has always been motion, without saying why there has always been motion; but Aristotle does not make this explicit, and frames the criticism as a more general methodological point. In Λ6 he is more explicit. He has been arguing, against "the theologians [here Orpheus] who generate [all things] out of night … [and] the physicists [who] say 'all things were together'" (1071b27-8), that the world could not have come-to-be out of mere δύναμις, since only a cause in ἐνέργεια will move it. He then says, "this is why some people posit eternal ἐνέργεια, like Leucippus and Plato: for they say there is always motion. But they do not say what motion or on account of what, nor the cause of [its moving] in this way or that.[4] For nothing is moved at random [ὡς ἔτυχε]; rather, there must always be some [sc. cause: δεῖ τι ἀεὶ ὑπάρχειν], just as now too [something is moved] in one way by nature, in another by violence [βίᾳ] or by νοῦς or by something else. So which of these is first?--it makes an enormous difference" (1071b31-7). So, where Democritus gives no answer, Aristotle will try to specify what the first motion is (it is the rotation of the heavens) and what its cause is (νοῦς, not nature or force), thus returning us to something much more like Anaxagoras or Plato, except with νοῦς producing motion eternally.

Democritus will, of course, reply that he too agrees that every motion has a moving cause, and that he has posited no motion without a cause: atom A is now in motion, and its motion was caused by its previous collision with atom B. Aristotle says that the first motion must be eternal, and he demands to know its cause, but Democritus denies that there was any first motion, and he denies that there is any motion that is eternal: there is just an eternal succession of finite motions, each caused by an earlier motion. Does Aristotle have an argument that there is a single eternal motion, so that we can infer to a single eternal moving cause?

On a quick reading of Λ6, it looks as if Aristotle simply passes fallaciously from "there is always some motion" to "there is some motion that always exists." In the very quick argument in the first paragraph of Λ6--"it is impossible for motion either to have come-to-be or to perish (for it always was), or time either. For there cannot be before and after if there is no time: and so motion is continuous, just as time is: for [time] is either the same thing as motion or else a πάθος of motion. And there is no [sc. eternally] continuous motion except motion in place, and of this [only] circular motion" (1071b6-11)--the first sentence supports only the weaker thesis, but the last sentence depends on the stronger thesis. But it is not credible that Aristotle did not notice the difference between the two assertions. For he says in Physics VIII,7, "it is necessary that motion

[4](note repeated from IIIα1): translating Jaeger's emendation, without much confidence. Diels' emendation, adopted by Ross, seems about equally plausible. the sense isn't much different. (also note from there): when he says "Plato" here, he seems to be thinking of the disorderly motion of the Timaeus, since the criticism he gives would not apply to the Laws; but he then goes on to give another criticism which does apply to the Laws.

should exist continuously [συνεχῶς], and it would exist continuously either if it is continuous [συνεχής] or if it is successive [ἐφεξῆς]" (260b19-21; Aristotle adds that the continuous is better than the successive, and that we should suppose the better, if it is possible--an argument which would not impress Democritus). For there to be a numerically single motion, it must be continuous (Physics V,4 228a20-22), and this requires not only that the motion takes place in a continuous time, but also that it is the same thing that is moved throughout that time, and that it is moved throughout that time toward the same thing (e.g. in the same spatial direction, or toward greater heat): if the time is continuous, but the motions are in different directions, or are performed by different objects in relay, the motion will be merely successive and not continuous or numerically one (so Physics V,4 227b3-228b10; 228b15-229a3 adds that a motion is also more one if it is uniform, e.g. in speed). In Aristotle's terms, Democritus believes that motion exists "continuously," i.e. through an infinite continuous time, but that motion is not eternally continuous but only successive: there is no one motion that has always existed, since the present motion of atom A is not continuous with the previous motion of atom B that collided with A, or with the previous motion of atom A in a different direction. What Aristotle needs for the argument of Λ6 is that there is an eternal continuous motion, and he is assuming this already by the end of the first paragraph 1071b3-11;[5] but he cannot believe that the Democritean argument that "it is impossible for motion to have come-to-be" is enough to establish this conclusion.

The argument about time suggests a way of beginning to bridge the gap. Everyone agrees that time is continuous, and Aristotle suggests inferring that "motion is continuous, just as time is: for [time] is either the same thing as motion or else a πάθος of motion." He cannot mean that, because some time is continuous, any motion that occupies that extent of time must also be continuous; the idea is rather that, if there is continuous time, that time must be, or be dependent on, some special motion, and that special motion must be continuous. The premiss would be conceded, for instance, by Plato, who in the Timaeus identifies time with the regular motions of the heavens. If it can be shown that time is pre-eternal, it would follow that some continuous motion is also pre-eternal.

This is an attractive idea, and it is probably what Aristotle has in mind at the beginning of Λ6, but it also has obvious difficulties. Although Plato will agree that time is, or depends on, a uniform continuous motion, it is not obvious why Democritus or anyone else would have to accept this conclusion. Worse, it looks as if Aristotle is equivocating on two senses of "time." To make it plausible that time depends on a uniform continuous motion, we must take "time" to mean regular time, time that can be used as a standard for measuring durations, so that we can objectively compare the length of time taken by an earlier event and the length of time taken by a later event; this is the sense of "time" in which the Timaeus can say that the demiurge produces time simultaneously with producing the ordered cosmos. But Aristotle's argument that time is pre-eternal depends on saying that "there cannot be before and after if there is no time," and this seems to be true only on a broader sense of time, a not necessarily regular or measurable time.

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[5]the reason why the motion must be locomotion, and specifically rotation, is that motions in quality or quantity and rectilinear locomotions cannot be eternally continuous; since such motions cannot proceed infinitely far in any one direction, they would have to change direction, and thus be merely successive (Aristotle is relying here on arguments from Physics VIII,7-8). note also that if Aristotle was allowing "motion is eternal" to be verified by a motion performed by many successive objects in relay, there would be no ground for inferring, as he does, that because motion is an accident of some οὐσία, an eternal motion implies an eternal οὐσία; it could be an accident of many different οὐσίαι in succession (this equally whether we take the inference to be from motion to the οὐσία which is its subject [as Oehler, "Der Beweis für den Unbewegten Beweger," in his Der Unbewegte Beweger des Aristoteles, claiming to follow Alexander, Quaestiones I,1] or from motion to the οὐσία which is its efficient cause)

There must have been before and after even in the disorderly motions before the ordered cosmos, and while Plato can concede that there must have been "time" in a broad sense, he can still maintain that time in the strict sense was produced by the demiurge and has not always existed; and while perhaps even time in the broad sense depends on there being some motion or other, it is only time in the strict sense that depends on a single continuous motion.

What Aristotle needs is an argument that the infinite succession of past motions implies that time in the strict sense, and thus a single continuous motion, has also existed from infinity. And while he may not have such an argument fully worked out, I think he has at least a rough strategy for arguing in this way; but we have to look outside the present passage to find it.

Why an infinite succession of motions requires a single eternal motion: Physics VIII,6

While Aristotle seems to be thinking through roughly the same strategy of argument in a number of texts, the clearest development is in Physics VIII,6. Aristotle has argued in VIII,1-2 that motion is eternal, in the sense that there has always been some motion or other. He has also argued, in VIII,4-5, that every motion is ultimately produced by an unmoved mover, although not necessarily by an eternal unmoved mover, or by a mover that is not moved even per accidens. If he can bridge the gap from showing that there has always been some motion to showing that a single continuous motion has always existed, then the unmoved mover of that motion will also be eternal (it will take some further fine-tuning to show that it is not moved even per accidens). He argues:

> Since motion must always exist and never cease, there must be some eternal thing, whether one or many, that first produces motion; and the first mover is unmoved. Now whether every unmoved mover is eternal is beside the point; but it will be clear, if we investigate as follows, that there must be something, unmoved and immune to all change whether per se or per accidens, but moving something else. Let it be possible, if you like, for some things that they at one time are, and at another time are not, without coming-to-be or passing-away (for it is perhaps necessary that if something without parts is at one time and is not at another time, that everything like this is-at-one-time-and-is-not-at-another-time without [ever being in process of] changing). And it is also possible that among unmoved moving ἀρχαί, some are at one time and are not at another time; but this is not possible for all of them. For while everything that moves itself must have magnitude, if nothing without parts is moved [as was proved in Physics VI,4], there is no necessity by this argument for the mover [to have magnitude; and therefore, although self-movers (animals), if not eternal, must come-to-be and pass away, their unmoved moving constituents (souls) can be non-eternal without coming-to-be and passing-away, coming-to-be per accidens when the composite comes-to-be]. But the cause of the fact that some things [= some self-movers?] come-to-be and others pass away, and that this happens continuously, is not any of the things that are unmoved but do not always exist; nor are these the causes of these, and something else of those.[6] For neither each of them, nor all of them together, is the cause of [this happening] always and continuously: for this fact is

[6]accepting Ross' text without enthusiasm. give some discussion. note the closeness of the phrasing to a few lines below, this of this and something else of that. (check the textual footnote in Manuwald, Studien …, p.46 n142)

> eternal and necessary; and all [the non-eternal unmoved things together] are infinite, and do not all exist together. So it is clear that, even if thousands of unmoved movers and many self-movers pass away and others come-to-be to replace them, and this is an unmoved mover of this, and something else is an unmoved mover of that, nonetheless there is something which surrounds [περιέχει] [them all], and this is over and above each of them [παρ᾽ ἕκαστον], and is a cause of the fact that some of them are and others are not and of continuous change [i.e. of the fact that the self-movers, and thereby their unmoved moving constituents, continuously come-to-be and pass away]: this is a cause of motion to these [self-moved movers, or their unmoved moving constituents], and they to other things. (258b10-259a6)

The argument must go roughly as follows. Assuming that Aristotle is right that every chain of moving causes leads back to an unmoved mover (and neither to an infinite regress nor to an indecomposable self-moved mover), then since there has been motion from infinite time, there must also have been unmoved movers from infinite time.[7] If no one unmoved mover has existed from infinite time, there must have been a succession of them going back to infinite time. These non-eternal unmoved movers will come-to-be and pass away per accidens when their composite self-movers come-to-be and pass away, which they must have been doing in a succession going back to infinite time. These assumptions may be enough to explain each individual event: each motion will be traced back to a mover and ultimately to an unmoved mover; the per accidens coming-to-be of the unmoved mover will be traced back to the coming-to-be of the composite self-mover; and this in turn will have a moving cause traceable back to a previous unmoved mover--concretely, the per accidens coming-to-be of a soul, or the per se coming-to-be of an animal, will be traced back to the soul of the animal's father. However, Aristotle claims that there is another explanandum which these causes are not sufficient to explain, namely the continuity of the coming-to-be of animals within each species (that is, the fact that this coming-to-be happens συνεχῶς, though it is successive and not a single συνεχής motion). This is part of the explanandum of the On Generation and Corruption, the inexhaustibility of generation in general, although here the question especially concerns animals.[8] It is obvious that no one non-eternal unmoved mover is the cause of this eternal effect. But Aristotle also says, less obviously, that all the non-eternal unmoved movers together cannot be the cause of this effect, one such mover causing one instance of coming-to-be and another mover causing another: concretely, my father's soul causes my coming-to-be, and your father's soul causes yours. Aristotle says that the reason these causes do not suffice is that they "are infinite, and do not all exist together," the point being presumably that therefore they cannot come together to coordinate a single determinate effect. But in what sense is the continuity of generation a single determinate effect, over and above the particular generations of particular animals, that would need to be coordinated?

Before we try to formulate more precisely what Aristotle's explanandum is here, it will help to say more about his explanans. He speaks of something that "surrounds" [περιέχει], and is a cause to generable things of their generation and corruption and especially of its continuity.

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[7] may need discussion of what kind of infinite regress principles Aristotle accepts; why couldn't Democritus deny that there are any unmoved movers at all, even ones moved per accidens? or perhaps this doesn't matter; the Physics VIII,6 argt might be applicable against him even so

[8] in fact GC I,3, in discussing the causes of the inexhaustibility of generation, refers pretty clearly to the present passage of Physics VIII,6 for an account of the efficient cause of this inexhaustibility, at 318a3-5

While the argument, here as throughout Physics VIII, is supposed to work in the abstract without needing empirical support, clearly the empirical περιέχον which he thinks fits this description is the heaven, or the heavenly motions, or perhaps specifically the motions of the sun. While the father or his soul is obviously part of the explanation for the generation of an animal (and this was the part stressed in Λ3, in arguing that there is no need for separate forms), here in Physics VIII,6 Aristotle is claiming that there is a further efficient cause needed to explain some aspect of the explanandum; and this corresponds to what he says in Λ5, that among the causes of a human being are not only the material elements and the form but "also something else which is external, like the father, and beyond these the sun and the oblique circle" (1071a14-16), that as he says elsewhere "a human being is generated by a human being and by the sun" (Physics II,2 194b13). If we can infer from some aspect of the generation of a sublunar animal species to something like the ecliptic motion of the sun as its cause, we will have a single eternal motion which exists simultaneously with all the successive members of the species; and this motion will proceed either directly or indirectly from an unmoved mover, which must be eternal. But what is the sun's motion supposed to contribute, and what licences the inference from the sublunar effects to the celestial cause?

Some information about the causes of the continuity or inexhaustibility of coming-to-be, and about the role of the heavenly bodies and their motions, comes from the On Generation and Corruption. This work does not have much to say about animals in particular, but the generation of animals (and plants) is a part of, and is conditioned by, the generation of sublunar things in general, and On Generation and Corruption II assigns causes both for the generation of the four sublunar elements out of each other, and for the generation of composites out of the elements. One reason why sublunar generation needs celestial causes emerges from an aporia which Aristotle cites in GC II,10, "why, since the [four sublunar elementary] bodies are each moved toward their own appropriate place, the bodies have not in infinite time become separated" (337a8-10). Indeed, if there were no outside influences affecting the sublunar world, each of the four elements would eventually collect in its own natural place, the compounds that prevent each element from returning to its natural place would break up,[9] the world would reach a steady state of total separation, and generation and mixture would cease. The world would thus resemble Empedocles' reign of total Strife. Or, in another pre-Socratic comparison which was certainly on Aristotle's mind, a κυκεών separates if it is not stirred. Since in fact generation is eternal, there must be something outside the sublunar world and stirring it up. Now at this level of generality, Aristotle agrees with Anaximander and Democritus, who think that generation, of worlds and of things within them, is inexhaustible because there is an infinite and inexhaustible reservoir of matter in constant motion surrounding our world, and repeatedly breaking in to add matter and motion to our world.[10] When Aristotle speaks in Physics VIII,6 of "something which surrounds

[9]compare De Philosophia Frag. 20 Rose[3] and DA II,4 416a6-9 on the difficulty of holding compounds together

[10]As Aristotle says, one argument for an infinite ἀρχή was that "only in this way would coming-to-be and passing-away not be exhausted, [namely] if that from which the thing that comes-to-be is taken is infinite" (Physics III,4 203b18-20; cp. GC I,3 318a16-20). This strategy of argument is attributed to Anaximander by Aetius (DK Anaximander A14), but it was maintained and made more precise by the atomists. Simplicius says that Leucippus and Democritus "plausibly undertake to deliver all substances and all their affections, by what agency each comes-to-be and how, if there are infinitely many ἀρχαί; whence they say that only for those who make the elements infinite do all things come out according to plan [συμβαίνειν κατὰ λόγον]" (In Physica 28,22-24 = DK Democritus A38). Lucretius spells out the Anaximandrian argument and explains why things would not come out right if the ἀρχαί were not infinite. What would go wrong is that things, and specifically worlds, would not come-to-be, and would not be sustained in existence if they did: "for the store of matter, driven abroad from its union, would be rushing dissolved through the great void, or rather would never have been compacted to form anything, since when

[περιέχει] [all the non-eternal self-movers and unmoved movers] … and is a cause of the fact that some of them are and others are not and of continuous change" (259a3-5, cited above), he is deliberately invoking the language of these pre-Socratics, who speak of an infinite περιέχον that governs our world from outside.[11] But, against these pre-Socratics, Aristotle separates the efficient and the material causes of the inexhaustibility of generation (explicit at GC I,3 317b33-318a10), and makes the περιέχον only an efficient cause. The sublunar world is materially closed, and the material cause of the inexhaustibility of generation is the infinitely reusable sublunar matter (so Physics III,8 208a8-11 and GC I,3 318a13-27, both responding to the Anaximandrian-Democritean argument for the infinite); the heavenly bodies influence the sublunar world not by sending down pieces of themselves, but only by their motions, which are the efficient causes of motions down here (Meteorology I,2 339a27-32). There is thus no need to posit anything materially infinite; but the inexhaustibility of generation does require as its efficient cause the heavenly motions, which are infinite in the sense that numerically the same motions continue uniformly forever. And so Aristotle, again deliberately alluding to the pre-Socratic theory of some ἄπειρον περιέχον as the ἀρχή of motion and generation, says that the movers of the infinite heavenly motions must have ἄπειρος δύναμις, and just for this reason cannot be bodily (so Physics VIII,10, echoed Λ7 1073a5-11; Aristotle having argued in Physics III, against the pre-Socratics, that there can be no infinite body). Indeed, even without the issue of the movement of the heavens, Aristotle would probably say that an ἄπειρος δύναμις is required to counteract for infinite time the natural tendency of the four sublunar elements to separate themselves out to their natural places.

I will say more below about exactly what the heavenly bodies do that has this effect. But for now, a closer look at how Aristotle solves the aporia of GC II,10 337a8-10--why the four sublunar elements have not become separated--will make it clearer what sublunar explanandum the heavenly motions are needed to explain. After raising the aporia, Aristotle answers briefly that "the cause is the transformation [of the elements] into each other" (337a10-11), and then further that "this change comes about on account of the twofold locomotion [sc. the motion of the sun, on which more below], and on account of the change none of [the elements] can remain in any determinate place" (337a12-15). The idea here is that if body A, while being in roughly the natural place for body A, is transformed into body B, it will no longer be in its natural place, and so must move toward the natural place for body B; and whatever agent is responsible for transforming A into B will also be responsible for its subsequent local motion (so Physics VIII,4 255b13-256a3). But how are the heavenly motions responsible for the transformations of the elements? The text we have just seen speaks of the "twofold locomotion," and GC II,10 spells this out a bit further by saying that "when the sun is approaching there is coming-to-be, and

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scattered abroad it could never have been brought together. For certainly neither did the ἀρχαί place themselves by design each in its own order with keen intelligence, nor assuredly did they make agreement what motions each should produce, but because, being many and shifted in many ways, they are harried and set in motion with blows throughout the universe from infinity, thus by trying every kind of motion and combination, at length they fall into such arrangements as this sum of things consists of" (Lucretius I,1017-28, tr. Smith±). For reconstruction of Leucippus' and Democritus' thought about the infinity of the ἀρχαί, see my "Anaxagoras, Empedocles, Leucippus."

[11] Aristotle in a number of places attributes to some (often only vaguely specified) earlier thinkers a notion of something ἄπειρον as περιέχον, and as an ἀρχή and even somehow divine: most importantly at Physics III,4 203b10-15 (which perhaps quote), also Physics III,6 207a16-21; but see also GC II,5 332a24-5, and by implication Physics III,5 205b1-5. He takes over for himself a positive description of some divine ἀρχή as περιέχον (not as ἄπειρον, but see discussion below), not only in the Physics VIII,6 passage cited, but also at Metaphysics Λ8 1074a38-b3 and De Caelo I,9 279a22-8 and II,1 283b26-9. In these texts it is clear that he is deliberately alluding to and reinterpreting earlier descriptions of some ἀρχή as περιέχον.

when it is receding there is passing-away" (336b17-18).[12] Since "we" (Aristotle's intended audience) live in the northern hemisphere, the sun is approaching us (although not approaching the center of the earth) when it moves from its southernmost point at the winter solstice to its northernmost point at the summer solstice, and it is receding from us when it moves southward from the summer solstice to the winter solstice. These locomotions produce an as-it-were-quantitative change in the length of daylight, which in turn produces a qualitative change toward heat or cold, which in turn produces substantial change among the elements. "Since the sun is moved in a circle, when it is approaching it takes up the moist by means of the heat, and when it comes to be further away the vapor which has been taken up is condensed again into water on account of the cold" (Meteorology II,4 359b34-360a2, cp. I,9 346b20-31). That is to say, the heat turns some of the water into moist exhalation (that is, the element commonly called air, though properly air is a mixture of the two exhalations); likewise, Aristotle goes on to say, in heating the earth it turns a small portion of it into dry exhalation (the element commonly but improperly called fire, Meteorology I,3 340b19-32). Since these exhalations are light where earth and water are heavy, they will rise to their new natural place; and when the contrary process of cooling turns some of the moist exhalation into water and makes it heavy, it will fall to its new natural place as rain (the dry exhalation, more mysteriously, drives the winds). This is how the sun stirs up the κυκεών of the sublunar elements, causing substantial transformations among the elements and thus also locomotions (the rising of the exhalations, rain, winds); presumably this stirring also brings the elements into contact in such a way that composites of the four elements will be generated. And while the transformation of water and earth into air and fire must involve substantial passing-away as well as substantial coming-to-be, Aristotle's view is that this transformation, caused by the approach of the sun, is more properly described as coming-to-be, because the differentiae of air and fire are positive while those of earth and water are privative (GC I,3 318a35-b33, esp, b27-33); the opposite transformation, caused by the recession of the sun, is more properly described as passing-away.

A crucial feature of this Aristotelian account of how the περιέχον causes changes in our world, as opposed to Democritus' account, is that the influence from the περιέχον is periodic. And the effect of this periodic influence is not merely that the sublunar world fails to reach an eventual steady state, but that it goes through an at least roughly periodic sequence of changes, which Aristotle describes as an "imitation" of the perfectly periodic circular motion of the sun. Since sublunar things are too "remote from the ἀρχή" (GC II,10 336b30-31) to exist eternally, they do the next-best thing, which is to come-to-be eternally;[13] "the cause of this, as has been

[12]since Aristotle has said that the motion must be twofold "in order that not just one [of the two changes, namely coming-to-be and passing-away] will result," the two motions must be the approach and recession of the sun, i.e. its motion northward from winter to summer solstice and southward from summer to winter solstice, not (as one might have guessed) the daily equatorial and the yearly ecliptic motions of the sun. (so, rightly, Joachim ad loc.) it is not as if e.g. the equatorial motion were responsible for generation and the ecliptic motion for corruption. rather, "it is not the first locomotion that is the cause of coming-to-be and passing-away, but the motion in the oblique circle: for to this belong both continuity and being moved with two motions. For if coming-to-be and passing-away are to be always continuous, something must always be in motion, in order that these changes may not fail, and [be moved by] two [motions], in order that not just one [of the two changes] will result. So the locomotion of the whole [=the daily motion] is the cause of continuity, and the inclination is the cause of approaching and receding" (GC II,10 336a31-b4). I will return to the issues raised by this paragraph, and in particular the relation between the ecliptic motion of the sun and its approach and recession, for a detailed discussion below

[13]Aristotle actually says that God [ὁ θεός] contrived this as second-best (336b31-2); this echoes the style of the demiurge's deliberations in the Timaeus, but it is hard to see how it could be more than a figure of speech for

said many times, is the circular locomotion: for this alone is continuous. And for this reason even the other things which change into each other according to their affections and powers, like the simple bodies [i.e. the sublunar elements], imitate circular locomotion. For when air comes-to-be out of water, and fire out of air, and then water again out of fire [presumably via air again], we say that the coming-to-be has 'come around in a circle,' by returning on itself [διὰ τὸ πάλιν ἀνακάμπτειν]: and in this way rectilinear locomotion too is continuous by imitating circular locomotion" (336b34-337a7). We can distinguish two claims here. First, the inter-transformations of the sublunar elements, and their locomotion up and down, "imitate circular locomotion" in that they can be eternally "continuous," in the restricted sense in which they are capable of this, only by repeatedly going through a "cycle" of changes which bring them back periodically to the same state (for this to be truly continuous, the "cycle" of changes would have to be a single change--and preferably a uniform change--rather than a series of successive changes, and Aristotle thinks this is possible only in circular locomotion). But also, second, the fact that the sublunar elements in their inter-transformations and locomotions "imitate circular locomotion" in this sense is due to the causal influence of the circular motion of the sun, in the manner described in the Meteorology. "If what is moved in a circle always moves something, the motion of these things too must be circular. Thus because the upper locomotion [is circular], the sun moves in this kind of circle, and since it is thus, on its account the seasons come-to-be in a circle and return on themselves [ἀνακάμπτουσιν]; and since these things [sc. the seasons] come-to-be in this way [sc. circularly], so again do the things that are brought about by them" (GC II,11 338b1-5). While Democritus takes merely the inexhaustibility of motion and generation as his explanandum, Aristotle demands an explanation more specifically of their (rough) periodicity, and he thinks that the only scientifically adequate way of explaining the rough periodicity of sublunar events is to explain how they are caused by something which is perfectly periodic, i.e. an eternal circular locomotion, which can itself be caused by something that remains eternally in the same state. The program of the Meteorology is to show in detail how the rough periodicity of non-biological sublunar events is caused by the motions of the heavens. Meteorology I,1 separates out meteorological phenomena as those which "occur by nature, but are more disorderly than the first element of bodies [i.e. than the naturally rotating aether]" (338b20-21), and Meteorology I,2 adds that "the cause as ἀρχὴ κινήσεως [of these phenomena] is to be attributed to the power of the things that are eternally moved" (339a30-32, referred to above), which means not simply that the heavenly bodies are among the causes of sublunar events, but that the program of the Meteorology is to explain sublunar events by tracing them back to their heavenly causes. This is a revisionist program, and its revisionism is already in the opening lines of the treatise: for although Aristotle says innocently that he is continuing "what all the earlier [philosophers] called meteorology" (338a26), in fact the pre-Socratics treated the sun and moon and stars too under "meteorology," and explained them in the same ways that Aristotle explains properly meteorological phenomena (thus Heraclitus' sun, like an Aristotelian comet, is exhalation from the earth or sea that has risen and become inflamed). So Aristotle is being revisionist, firstly in exempting the sun and moon and stars from meteorological explanation and explaining them instead through an element in eternal circular motion, and secondly in tracing

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Aristotle. he is, however, serious about the teleological explanation of the eternal coming-to-be of the members of a given species (biological or otherwise), here as in DA II,4

back the "more disorderly" meteorological phenomena to properly celestial motions as their efficient causes, which impose some order on the disorderly sublunar material.[14]

The argument continued: why the generation of animals requires heavenly regulation

While this material from the On Generation and Corruption and the Meteorology is certainly in the background in Physics VIII,6, that chapter does not mention the sublunar elements as such. Keeping to the abstract language used throughout Physics VIII, it speaks of the coming-to-be of self-movers (that is, animals) and of the per accidens coming-to-be of their constituent unmoved movers (that is, souls). But the crucial lesson to retain from the On Generation and Corruption and the Meteorology is that the explanandum which requires the heavenly motions is not just the inexhaustibility of coming-to-be (whether of the elements or of animals), but its rough periodicity. When Aristotle says that "a human being is generated by a human being and by the sun" (Physics II,2 194b13), or that the efficient causes of a human being are not only the father but also "the sun and the oblique circle" (Λ5 1071a14-16), it is not clear how exactly the sun exercises its influence; but whatever it does, its effect is not simply to generate human beings but to ensure that the human species continues to observe at least roughly the same period of gestation, the same period of development until sexual maturity, and the same lifespan. All such periods, for any species of animal or plant, are determined by the periods of the heavenly bodies.

> It is reasonable that the times of gestation and generation and of life of all [animals] are trying [βούλονται: cp. Phaedo 74d9-e4, where a sensible object βούλεται to be like a Form, but falls short of it] to be measured by natural periods. By "period" I mean a day and a night [= a day-and-night?] and a month and a year and the times that are measured by these [i.e. are multiples of these], and also the periods of the moon: the periods of the moon are the full moon and its disappearance, and between these the half-moons. For according to these the moon comes together with [συμβάλλει πρός] the sun: for the month is a common period of both sun and moon [i.e. the month that determines periods of sublunar things is not the sidereal month, the time it takes the moon to return to the same position in relation to the fixed stars, but the synodic month, the time it takes the moon to return to the same position in relation to the sun: e.g. the time from one full moon to the next is the time from one opposition of sun and moon to the next]. The moon is an ἀρχή [of sublunar things] on account of its partnership with the sun and its sharing in its light, so that it becomes as it were another lesser sun, and for this reason it contributes to all generations and perfectings. For heat and cold up to some due proportion produce generation, and beyond it corruption; and the motions of these stars [= sun and moon] control the limits both of the beginning and the ending of these. For just as we see that the sea and watery nature in general come to rest and are moved according to the motion and rest of the winds, and that air and winds [move or rest] according to the periods of the

[14]even regarding the seasons (with their alternations of hot and cold, wet and dry) as effects of the motion of the sun in the ecliptic is not to be found in pre-Socratic περὶ φύσεως treatises: in e.g. the Hippocratic On Breaths, the seasons are basically meteorological phenomena, and while they have something to do with the sun, the behavior of the sun is just one more aspect of the meteorological change, not something outside the meteorological system and causing the other phenomena (of hot and cold and wet and dry and so on)

> sun and moon, so also it is necessary that the things that grow from these things and are amidst them [= living things, dependent on air and water] should follow them, since it is reasonable that the periods of the less powerful things should follow those of the more powerful--for a wind too has a kind of life and generation and corruption. And perhaps the rotations of these stars have other ἀρχαί [= their eternal unmoved movers]. Thus nature is trying [βούλεται] to count out the generations and ends [of living things, or sublunar things generally] by the numbers of those things [= the heavenly bodies], but does not achieve precision because of the indeterminacy of matter and because there arise many ἀρχαί which, by impeding the generations and corruptions [that would be] according to nature, often cause things to fall out contrary to nature. (GA IV,10 777b16-778a9)[15]

Aristotle says little to help us with the details of how the heavenly bodies act so as to regulate the periods of life and gestation of animal species. The sun moves toward us, northward, from winter to summer solstice, and away from us, southward, from summer to winter solstice, and "when the sun is approaching there is coming-to-be, and when it is receding there is passing-away" (GC II,10 336b17-18, cited above), but is this sufficient to explain why the natural life-span of some species of animal should be some fixed multiple of a year? From such texts as we have, it seems that the heavenly bodies' activity in regulating sublunar changes is mediated entirely through their giving heat, or heat and light (the cycle of the seasons involves an alternation of wet and dry as well as of hot and cold, but the alternation of wet and dry results from the exhalations caused by the heat caused by the motion of the sun). In most of the texts, Aristotle speaks only of the influence of the sun on the cycle of the seasons, and says nothing about the influences of other heavenly bodies: the passage just cited speaks also of the influence of the synodic month, as does one other passage, GA IV,2 767a1-8, and in both texts the moon's influence works, like the sun's, through the small contribution its light makes to heating the sublunar world. Perhaps, if pressed to explain the natural life-spans of long-lived animals such as human beings, Aristotle would also invoke effects of longer heavenly cycles such as those of Jupiter and Saturn, but he in fact never says anything about such planetary influences.[16] Although the phrase "a human being

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[15]cp. GC II,10: "for this reason [sc. the alternating motions of the heavenly bodies, causing generation and corruption in turn] the times and lives of each [species] have a number by which they are determined. For there is order in all things, and every tme and life is measured by a period [of some heavenly body], but not all by the same period, but some by a lesser and some by a greater: for the period and the measure is for some of them a year, for some of them more, for some of them less …. but it often happens that things perish in less time … for matter being non-uniform [ἀνώμαλος] and not everywhere the same, necessarily generations too are non-uniform, some faster, some slower" (336b10-15, 20, 21-3)

[16]the On Length and Shortness of Life does not really live up to the promise of the title, saying some general things about why some kinds of animals and plants live longer than others, but saying nothing about how a natural lifespan of each species (measured in years or in multiples of some other heavenly period) is determined; there is no mention of anything astronomical. Meteorology I,3 341a19-23 seems to imply that the sun is the only heavenly body to have any significant influence (by heating) on the sublunar world, dismissing both the moon and the (fixed?) stars. it may be worth noting that GA IV,2 767a1-8, one of the two texts to attribute an influence to the moon (specifically on women's menstrual cycles, although context seems to imply that there are other effects too), says that the moon's τροπαί are irrelevant: i.e., although ceteris paribus the moon will produce more light and so more heat when it is in Cancer than when it is in Capricorn, the only difference large enough to actually matter is the moon's phase, so that the relevant period is the synodic and not the sidereal month (as the GA IV,10 passage also implies, but less emphatically); this suggests that the other stars, which do not have phases and give much less light than the moon,

is generated by a human being and by the sun" certainly suggests that the sun plays a direct role in biological generation, it is possible that the sun influences human beings only by determining the environing heat and moisture, that is, only by its meteorological influence and not by a direct biological influence. The text that comes closest to offering a foundation for a direct biological influence is GA II,3: "in the seed of all [animals that produce seed] there is present what makes the seed generative, the so-called heat: this is not fire or any power like that, but what is contained in the seed and the foamy πνεῦμα, the nature in the πνεῦμα, which is analogous to the element of the stars" (736b33-737a1). But, while it is possible that Aristotle thought that the vital heat of the father was an instrument of the solar heat, or a cause cooperating with the solar heat, in generating the offspring, this text says only that they are analogous. And when Aristotle explains the comparison, he says only that "for this reason fire does not generate any animal, nor does any [animal] seem to be constituted in things, either moist or dry, that are inflamed, whereas the heat of the sun and that of animals do have this ἀρχή of life, not only through the seed but through any other natural residue there may be" (737a1-5). In other words, the role that the male seed plays in sexual generation is analogous to the role that the sun plays in spontaneous generation (so explicitly GA II,6 743a26-36), but it is not clear that the sun also plays this kind of role in sexual generation, which is the only way that the higher animals, such as human beings, are generated. The role of the sun's heat in spontaneous generation would presumably be like its role in bringing plant seeds to sprout in the appropriate season, or in causing reptiles' eggs to develop and to hatch after the appropriate period (reptiles' eggs are "concocted" by the heat of the sun, while in birds' eggs the mother's vital heat does most of the work although the seasonal heat also contributes, GA III,2 752b28-753a21), and perhaps there is some remote mammalian analogue, or perhaps the male seed does all the work. But, however it happens, if a plant or animal species acts in different ways according to a seasonal cycle, it cannot be simply a coincidence that the sublunar species and the sun go through their cycles in synchrony: there must be a causal connection, and this means that the yearly motion of the sun must somehow be a cause of the cycle of the sublunar species.

However, Aristotle is also making a broader claim: if there is some natural time-span which a given species of plant or animal takes to go through a given sequence of activities (e.g. a gestation period or a life-span), whether these activities are correlated with the seasons or not, then there must be a causal explanation for this time-span. Thus if the gestation period of the elephant stands in a fixed ratio to the period of the revolution of the sun in the ecliptic, there must be some explanation of why the periods stand in this ratio, and this can only be because of some causal connection between the sublunar species and the heavenly motions. We might find this claim less plausible than the narrower claim that cycles that are synchronized with the cycle of the sun (e.g. if oak trees put forth leaves in the spring and shed them in the fall) must be causally connected to the sun's motions. After all, the nature of an elephant determines that the elephant should go through a certain series of developmental stages: why shouldn't the nature of the elephant also determine that it should take time T_1 to go through these stages, and why shouldn't the nature of the sun independently determine that it should take time T_2 to complete the circuit of the ecliptic, so that the period of the elephant and the period of the sun would be in the ratio T_1:T_2 even if the elephant and the sun lived in two separate and causally unconnected cosmoi? However, this way of thinking depends on a notion of absolute time which Aristotle has rejected. It is not wrong to say that the nature of the elephant determines that an elephant embryo

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will not have any significant sublunar effects. curiously, although the GA IV,10 passage speaks of an influence of the moon on the sea (mediated by the winds!), the Meteorology says nothing about this at all.

(if all goes according to nature) will take N_1 days from conception to birth, but this cannot be simply an intrinsic property of the elephant, relating it to an absolute unit of time: a unit of time, such as the day, can only be the period of some physical motion, and to say that the elephant embryo takes N_1 days from conception to birth is to make a relational statement about the elephant and some other physical thing, e.g. "the elephant is born after the sun has risen N_1 times after the elephant was conceived," or "the elephant is born after the fixed stars have completed N_1 revolutions around the celestial pole after the elephant was conceived." It may well be part of an elephant's nature to be born after the sun has risen N_1 times after the elephant was conceived, but this would mean that it is part of an elephant's nature to be affected in certain ways by the sun. Or perhaps it is part of an elephant's nature to be affected in certain ways by the fixed stars, and it is also part of the sun's nature to be affected in certain ways by the fixed stars. But, since there is no absolute unit of time, the natures of the elephant and the sun cannot determine their periods to be in any fixed ratio unless the elephant and the sun are in some kind of causal connection. Or rather, there is indeed an absolute unit of time, namely the period of the revolution of the fixed stars around the celestial pole (the sidereal day), but this is the absolute unit of time for all other natural motions only because all other natural motions are causally dependent on the motion of the fixed stars.

But Aristotle is also making another and yet stronger claim. Physics VIII,6 says that "even if thousands of unmoved movers and many self-movers pass away and others come-to-be to replace them … nonetheless there is something which surrounds [them all], and this is over and above each of them, and is a cause of the fact that some of them are and others are not and of continuous change," since "neither each of [the non-eternal unmoved movers], nor all of them together, is the cause of [self-moved movers, and thus per accidens their unmoved movers, being generated] always and continuously: for this fact is eternal and necessary; and all [the non-eternal unmoved things together] are infinite, and do not all exist together." While the generation of each individual animal is explained by the soul of its father, Aristotle also thinks that over and above the individual generations there is also a further effect, the continuity of generation, and that infinitely many causes not existing simultaneously could not come together to produce such a single determinate effect. Our problem was to explain why this was a single determinate effect that would need to be coordinated. Part of the answer was that the rough periodicity of the animals' life-cycles, or more generally the fact that the animals have roughly determinate time-spans for gestation, maturation and life, requires a cause over and above the individual animals; if the time-spans remain (even roughly) "the same" in that they remain in the same ratio to the periods of the heavenly motions, then the generation of the animals must be somehow causally connected to the heavenly motions. But Aristotle is not simply saying that if the animals' activities have determinate time-spans, then they must have causes in the heavens: he is saying that the continuity of generation of the animals requires that their activities have roughly determinate time-spans, and therefore that they have causes in the heavens. I think his reasons must be something like the following. Suppose that the time-spans of the activities of an individual animal are not regulated by any single movement (such as the rotation of a heavenly body) which coexists with every member of the species and imposes uniform time-spans on all of them. So, when Jumbo is born, he is given a determinate nature by his father, and will naturally progress through a determinate series of stages, but there will be nothing to determine at what speed he should progress through them. There is no objective way to compare his life-span directly with his father's if neither is entirely contained in the other, nor would there be an objective way to compare them both to a uniform standard (to two equal segments of the uniform

motion of a heavenly body). So there is no sufficient reason why the time-span between Jumbo's birth and the birth of his first offspring should be even roughly, or even to within an order of magnitude, the same as the time-span between the birth of Jumbo's father and Jumbo's own birth. If we suppose that the sun continues to move around the ecliptic but that there are no causal connections between its motion and the generation of elephants, then it might happen that there are N revolutions of the sun between Jumbo's father's birth and Jumbo's birth, but only ½ N revolutions between Jumbo's birth and Jumbo's offspring's birth, only ¼ N revolutions between Jumbo's offspring's birth and the following generation, and so on, so that after 2N revolutions of the sun an infinite number of elephants would have been born--and they would presumably all have died, so that there would be no more elephants to continue the species. It might equally happen that there are N generations of some animal species within one revolution of the sun, but only ½ N generations of that species in the next revolution of the sun, ¼ N generations of the species in the next revolution of the sun, and so on, so that after infinitely many revolutions of the sun there would have been only 2N generations of the species. In either of these cases, the generation of the species would not be continuous and inexhaustible; if it is in fact continuous and inexhaustible, that requires a cause.

These wild accelerations and decelerations of natural processes never in fact happen, because there is in fact a causal connection between sublunar species and the heavenly motions, and the heavenly motions themselves (or the first of the heavenly motions, the rotation of the fixed stars) give an absolute standard of time. But thought-experiments in which normally uniform processes would radically speed up or slow down are not beyond the imagination of the Greek authors. Of course, in myths of the golden age, it is typically said that human life-spans were much longer. But the philosophers also give "scientific" versions of these myths. For the atomists, our cosmos itself is aging, and all the species within it are declining in fertility and vigor. For Empedocles, the daimons are "long-lived" until they commit some sin and are reincarnated as mortals, and their long life seems to be connected with living under the reign of Love, since it is Strife that causes death.[17] But for Plato and his school the periods of things down here are regulated by the periods of the heavens, and so if life-spans change down here it is because the motions of the heavens have changed. Republic VI says that the sun provides "coming-to-be and growth and nourishment, not being itself [within the realm of] coming-to-be" (509b2-4; this is the basis for a comparison with the Good, which provides being but is itself superior to the realm of being); this function of the sun seems to be especially connected with its motion, for Socrates in a Heraclitean mood offers to prove that the golden cord of Iliad VIII,19-26 (through which Zeus can pull everything else together up to him, remaining himself unmoved) is the sun, so that "for as long as the revolving [heavens] and the sun are moved, all things among gods and humans are and are preserved, but if this stopped and as it were bound, all things would be destroyed, and it would be as they say 'the world turned upside down [ἄνω κάτω πάντα]'" (Theaetetus 153d1-5). (It does not matter how seriously Plato is committed to all this; what matters is that the ideas were in circulation and familiar to Aristotle.) If the cessation of the sun's motion would cause a cessation of all natural processes down here, then presumably a slowing down of the sun's motion would cause things here too to slow down.

Most strikingly, in another text, Plato considers an extreme extrapolation of this kind of speculation: that if the (daily) motion of the sun and the other stars were reversed, the life-

[17]for the atomists, see Lucretius 2.1105-74; for Empedocles see B115, and the Strasbourg Empedocles d1-6 may also be relevant; B128 and B130 are drawing on golden-age traditions, where the golden age seems to be under the reign of Love ("Kupris"in B128, φιλοφροσύνη in B130)

activities of animals down here would happen in reverse order (Statesman 269a1-274e4). Plato is presumably not being entirely serious here, but again all that matters is that he is playing with current ideas about the mutability of mortal life and especially of its periods. He makes it explicit that he is giving a philosophical interpretation of myths about the golden age of Kronos (269a7-8). He is also taking up ideas from Empedocles: the periods in which the divine demiurge himself steers the world correspond to the reign of Love, and the periods in which the god abandons the world to itself correspond to the reign of Strife. But Plato is updating Empedocles and producing a more "scientific" account, by explaining the changes in the world by a reversal of the motions of the heavens: when God steers the world, it rotates in one direction, and when he abandons it it unwinds in the opposite direction (Statesman 269c4-270a9),[18] and the other changes are a consequence of this (270c4-5). "One must deem this change"--the reversal of rotation--"to be the greatest and most complete τροπή of all the τροπαί which take place in the heaven" (270b10-c2). The word "τροπή", most literally "turning" or "reversal," is a common astronomical term, usually meaning the solstices, that is, the places or times at which the sun reaches the extreme northern or southern point of its yearly course and "turns back" in the opposite direction (the word is as old as Hesiod in this sense);[19] Plato and Aristotle also speak of the other planets as having τροπαί, presumably at their northern and southern limits in the tropics of Cancer and Capricorn (Plato of all the planets, Timaeus 39d8, Aristotle of the moon, GA IV,2 767a7 and Meteorology II,1 353b8-9). The greatest of all heavenly reversals, however, would be the reversal of rotation of the heaven as a whole: all of the stars together would reverse their main motion, east-west-east, whereas in ordinary τροπαί only the sun and the other planets reverse their much slower motion south-north-south. These great reversals, too, are imagined as happening according to a cycle, probably inspired by the Empedoclean cycle of the reigns of Love and Strife, but analogous to the cycle of the sun's τροπαί: God lets go of the world, each time, "when the periods [= number of revolutions of the heaven] have reached the measure of the appropriate time" (Statesman 269c6-7), and there also seems to be a set period ("the time being completed," 273d1) from when God lets go of the world to when it becomes so disordered that he must take it in hand again. The effects of this cycle are a grander version of the effects of the cycle of summer and winter, where (according to Aristotle) the motion of sun from the winter to summer τροπή yields coming-to-be, and its motion from summer to winter τροπή yields passing-away. So too, in these grand cycles, "coming-to-be too reverses the direction of its cycle [συνανακυκλουμένης εις τἀναντία τῆς γενέσεως] and follows the τροπή" (271b7-8),[20] and this reversal is taken to fantastic extremes in the reversal of biological aging and the revivification and reemergence of dead animals and plants from the earth.[21] I am not suggesting, of course, that Aristotle believed that a reversal of cosmic rotation would cause a reversal of biological processes (what matters is whether the sun is approaching or receding from us, not whether it is going west or east); I am not suggesting that Plato believed it either. But Aristotle is quite aware of the Statesman passage, sometimes responding more closely to it than to the Timaeus, and he takes over its basic assumptions that the periods of life of sublunar creatures are mutable, that

[18]deal with Rowe's denial of this

[19]there are also τροπαὶ ἠελίοιο at Odyssey XV,404, but the sense is (to me) unclear

[20]is γένεσις actually the subject of ἔπεσθαι? perhaps rather it's the corpses being revivified? d check Rowe

[21]Plato uses this to explain myths of the "earthborn" and also the earth's spontaneous production of crops, a traditional feature of the golden age (taken up also by Lucretius); very likely he is also playing with ideas from Empedocles about the pre-sexual generation of animals

they need the heavens to regulate them, and that they would become radically disordered if the heavens ceased to regulate them or if the heavenly motions themselves became disordered.[22]

The argument continued: why astronomical or cosmic reversals require a single eternal motion

The background in Empedocles and the Statesman myth helps to make a further point about Aristotle. His insistence that a regular (or roughly regular) eternally repeating series of motions must be regulated by a single eternally continuous uniform motion has applications beyond the meteorological and biological cases. Aristotle makes the same point in arguing against Empedocles, and his criticisms of Empedocles would also apply against the Statesman. The issue is whether Empedocles has given a sufficient reason for the alternation of the reigns of Love and Strife, and thus for the alternation between rest (when either Love or Strife is totally dominant) and motion (in between). Aristotle has argued that Anaxagoras can give no sufficient reason why νοῦς should begin to cause motion at some one moment after being inactive for an infinite time. But is an alternation of motion and rest better explained by "saying that it is thus by nature, and taking as an ἀρχή what Empedocles seems to have said, that it belongs to things of necessity that Love and Strife should rule and move them in turns, and that they should be at rest for the time in between" (Physics VIII,1 252a6-10)? Aristotle grants that it is

> better [than Anaxagoras' account, to say] as Empedocles does, and anyone else who may have said so, that the universe is at rest and in motion again in turns: for this would possess some order [sc. whereas there is no order or proportion in remaining at rest for infinite time and then beginning to move]. But someone who says this should not just say it, but also give its cause, not positing or asserting an unargued assertion, but supporting it with either an induction or a demonstration. For these things which have been posited [i.e. Love and Strife] are not the cause [of the universe's being at rest and in motion again in turns]: this was not the essence of Love or Strife, rather what belonged to the former was to combine, and to the latter to separate …. And [to say that Love and Strife rule, or possibly that motion and rest occur] for equal times also requires some account. And in general, it is not right to suppose that this is a sufficient ἀρχή [i.e. a stopping-point of explanation], that something always is or always happens [γίγνεται] in this way; this is what Democritus traces back the causes of natural [phenomena] to, that it happened in this way before also; but he would not see fit to seek a [further] ἀρχή of what always is. This is right in some cases, but not in all. For the triangle always has angles equal to two right angles, but nonetheless there is a further cause of this eternal [truth]; but of [genuine] ἀρχαί, which are eternal, there is no further cause. (252a19-27, a31-b5, partly cited above)

Thus while it may be true that, from all eternity, Love and Strife have ruled in turn for equal times, this fact would itself require an explanation, and neither Love itself nor Strife itself is enough to explain it (it belongs to the essence of Love to combine things; it does not belong to the essence of Love to, e.g., wear itself out after 3000 years, and there could be no absolute standard of a "year" that could persist while the universe alternates between motion and rest).

[22]perhaps note also the idea that some very long heavenly period brings destruction to much of the earth; in Plato (Statesman, Timaeus {note παράλλαξις}, Laws, in Aristotle (Meteorology, Λ8, where else?)

Nor are Love and Strife together enough to explain the alternation: Love and Strife together explain why there is both combining and separating, but the combining and separating powers could each be acting constantly throughout time, without alternation between a rule of Love and a rule of Strife. To explain the alternation, there must be some further ἀρχή which regulates the activity of Love and Strife, bringing it about that Love's activity rises and declines in accordance with a fixed cycle, and that Strife's activity rises and declines in a complementary cycle, being at its maximum when Love's activity is at its minimum and conversely. So, as Aristotle says in Λ6, "if ἐνέργεια is prior to δύναμις, there was not chaos or night for an infinite time, but always the same things, either in a cycle or otherwise: but if there is always the same thing cyclically, there must remain [i.e. exist eternally] something which always acts in the same way" (1072a9-10); and this is apparently the reason why "for those who posit two ἀρχαί there must be another more principal [κυριωτέρα] ἀρχή" (Λ10 1075b17-18; Aristotle has just complained that no one explains why there is always coming-to-be, i.e. why the world does not reach a steady state, and the further ἀρχή would explain this by explaining the cycle).[23] And Aristotle would surely bring a similar criticism against the Statesman, where there is a cyclical alternation between periods of God's activity and inactivity in turning the world. Why, once God has taken personal control of the world, does he let it go again? Plato says simply that he lets it go "when the periods [= number of revolutions of the heaven] have reached the measure of the appropriate time" (Statesman 269c6-7, cited above), but what could there be in the essence of God that makes it appropriate for him to turn the world (say) 3000 times in sequence and no more? Plato says that "for [God] to move [the world] at one time in one way, at another time in the contrary way, is not permitted" (269e6-7, cp. 269e9-270a1), very close to what Aristotle will conclude in Λ6, but Plato nonetheless allows that God can move the world at one time, and fail to move the world at another time. Aristotle will reply that if an agent acts on a patient at one time and fails to act on it at another time, there must be some cause for this difference--the agent has changed or the patient has changed or the agent is closer to the patient at one time and farther from it at another. And if God sometimes moves the world, and sometimes fails to move the world, in an eternal alternating pattern, there must be some eternal cyclical change that causes this alternation.

The alternation between the reigns of Love and Strife, or between the periods when God moves or lets go of the world, would be analogous to the alternation between the sun's heating (the northern hemisphere of) the sublunar world in summer and failing to heat it, or heating it less, in winter: this alternation is explained by the sun's being alternately closer (further north) and further away (further south). Indeed, Empedocles describes Strife as alternately "reaching the lowest depth of the vortex" when its activity is greatest and "standing apart at the furthest limits of the circle" when it has been banished from the world integrated by Love (both B35; for the latter cp. B17 l.19 and B36). So it has regular motions toward us and away from us, like the sun, and its motions would require a cause, just as the sun's do. But if we posit one ἀρχή to explain Strife's motion toward us, operating by turns with another ἀρχή that explains Strife's motion away from us, this will simply force a regress to some further ἀρχή that regulates the activities of these ἀρχαί and explains their alternation. To avoid a regress, we need a single ἀρχή causing a single eternal periodic motion, and causing both the approach and the recession of the

[23]in context the reference seems to be to Empedocles rather than to Plato or Xenocrates (Empedocles has been mentioned more recently, though all these people are in the background; and Aristotle goes on in the next sentence to say that "those who posit the forms" are likewise in need of a higher ἀρχή to explain participation, which seems to imply that the dualists of 1075b17-18 do not posit forms)

agent--in the hypothetical cases, the approach and recession of Empedocles' Strife or of the God of the Statesman, and, in the world as it really is, the approach and recession of the sun.

Aristotle's explanation of the approach and recession of the sun deserves some reflection, because--although it is perfectly correct, within its limits--it was not the explanation that Greek physicists initially found obvious, and because it is paradigmatic for the way that any imaginable cosmic cycles would have to be explained. As we have seen, Aristotle speaks of a "twofold locomotion" of the sun (GC II,10 337a12-13), where the context (336a31-b19) makes clear that the two motions are the motions of approach and recession, i.e. of northward motion from winter to summer solstice and of southward motion from summer to winter solstice. So construed, these are not circular motions, but back-and-forth rectilinear motions; and Aristotle has argued vociferously in Physics VIII,7-8 that such back-and-forth rectilinear motions do not constitute a single eternally continuous motion but two contrary motions separated by rests (esp. VIII,8 261b31-262a35, 262a12-17). But, Aristotle says, these two rectilinear motions are caused by a single circular motion, the motion in the "oblique circle" of the ecliptic: "it is not the first locomotion that is the cause of coming-to-be and passing-away, but the motion in the oblique circle: for to this belong both continuity and being moved with two motions. For if coming-to-be and passing-away are to be always continuous, something must always be in motion, in order that these changes may not fail, and [be moved by] two [motions], in order that not just one [of the two changes] will result. So the locomotion of the whole [=the daily motion] is the cause of continuity, and the inclination is the cause of approaching and receding" (GC II,10 336a31-b4).[24]

Aristotle's analysis here follows Plato and mathematical astronomy, but involves major conceptual changes as against earlier natural philosophy and naïve astronomy.[25] The naïve Greek way of describing the motions of the sun is to say that there is a daily westward motion (a continuous circular motion, if we admit that the sun moves "under" the earth at night just as it moves "over" the earth in the day), and then yearly rectilinear motions northward from winter to summer solstice and southward from summer to winter solstice.[26] The northward and southward motions and their reversals were an obvious problem for natural philosophy to explain: when Aristotle says that philosophy starts from θαῦμα, one of his three examples is θαῦμα at the τροπαί of the sun (Metaphysics A2 983a12-15). There seem to have been two common explanations for the τροπαί: either the sun is blown back, at the northern and southern limits of its course, by a wind or a mass of condensed air which resists the sun's passage; or, because the sun depends for its nourishment on exhalations rising from the sea, it is continually moving in search of fresh nourishment, and turns back when it reaches the northern or southern limits

[24]cited in a previous note; d rationalize?

[25]before Aristotle, the only philosophers who show signs of being influenced by mathematical astronomy are Plato and Philolaus (who makes the earth orbit the central fire once a day [with the same face always turned toward the central fire], and the sun orbit the central fire once a year--if we assume that the plane of the sun's orbit is inclined to the plane of the earth's orbit, this will produce the right results). the idea that the sun, rather than just lagging behind the westward motion of the fixed stars, and having its own northward and southward motions, has its own motion in the zodiac against the background of the fixed stars, presumably somehow comes to the Greeks from the Babylonians (who have detailed calculations of the sun's zodiacal motion--dates for this?), as does the zodiac itself. Oinopides, who is supposed to have determined the inclination of the zodiac, is probably the first Greek to show this influence

[26]strictly speaking, these are not rectilinear, but back-and-forth motions on a segment of a circle. it is striking that Physics VIII,8 262a12-17, in the course of an argument that back-and-forth rectlinear motions are not continuous, goes out of its way to point out that the conclusion also holds for back-and-forth motions on a circle. I would be very surprised if he were not thinking of the motion of the sun between the solstices

beyond which no nourishment is available.[27] On either of these accounts, the sun proceeds northward until some discrete event stops it and reverses it, and then it proceeds southward until some other event stops it and reverses it again; there is no single cause that produces both the northward and the southward motions and their stoppings and reversals. For Aristotle, by contrast, the sun will have, not a daily westward motion and yearly northward and southward motions, but a daily westward circular motion and a single continuous yearly motion, moving it roughly eastward in an "oblique circle" against the background of the fixed stars.

It is crucial for Aristotle's analysis that the sun's motion must be measured, not simply relative to the observer, but relative to the fixed stars. By far the largest component of the sun's motion as we observe it is the daily westward rotation. But this motion is common to all the heavenly bodies, and to isolate the much slower distinctive motion of the sun, we have to observe the sun in a way that cancels out the effects of the shared daily motion. The obvious way to do this is to observe the sun's position at the same time on successive days, when the daily motion will have brought it back to the same position, and any change must be due to the sun's distinctive motion. On this much Aristotle and his predecessors can agree. But how exactly do we determine "the same time on successive days"? Perhaps the most obvious possibility is to observe the position of the sun on the horizon at sunrise on successive days: this will give alternating northward and southward motions, since the sun will rise due east at spring and fall equinoxes, further north in spring and summer (reaching furthest north and turning back at summer solstice) and further south in fall and winter (reaching furthest south and turning back at winter solstice). Likewise, we might observe the position of the sun on the horizon at sunset, getting similar results (it will set due west at the equinoxes, further north in spring and summer, and further south in fall and winter). But Aristotle will rightly deny that sunrise happens at "the same time on successive days." Certainly we cannot say that both sunrise and sunset happen at the same time every day, since the time between sunrise and sunset is obviously greater in the summer than in the winter. And it seems plausible (and is in fact true) that as sunset happens later each day as we go from winter to summer solstice, so too sunrise happens earlier each day in that period, so that the time elapsed between one sunrise and the next is a bit less than an average "day" as we go from winter to summer solstice, and a bit more than an average "day" as we go from summer to winter solstice. So if we say that the daily motion is what brings the sun around from eastern horizon to eastern horizon, and that the yearly motion is responsible only for its being sometimes north of true east and sometimes south of true east, then the daily motion will not be a uniform motion, since it will sometimes take more time and sometimes less to bring the sun from the eastern horizon back to the eastern horizon. This would be disastrous for the whole program of analyzing

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[27] the first explanation is apparently that given by the thinkers Aristotle refers to at Meteorology II,1 353b5-9 and II,2 355a21-5, and certainly by Anaximenes A15 and Anaxagoras A72 (both from Aetius p.352 Diels), Anaxagoras A42, and Herodotus II,26, and is the correct interpretation of the much-disputed Heraclitus B120; it is also mentioned as a possibility by Lucretius 5.637-49 (and cp. 5.509-23). the second explanation is given by the thinkers Aristotle refers to at Meteorology II,2 354b33-355a5 and by Cleanthes (SVF I,501 and cp. 504-5; he reinterprets the Homeric circular world-surrounding river Oceanus to make it fill the band, on a spherical earth, between the tropics of Cancer and Capricorn; since the sun is dependent on exhalations from Oceanus, it never goes north of Cancer or south of Capricorn), and is also mentioned as a possibility by Lucretius 5.523-5 (not explicitly mentioning the yearly course of the sun). Alexander in his commentary on the first Meteorology passage (In Meteorologica 67.3-12) seems to confuse the two opinions, and it is not clear how much he is ascribing (on Theophrastus' authority, he says) to Anaximander and Diogenes of Apollonia. there is some discussion of these texts and issues--not without some confusions--in Otto Gilbert, Die meteorologischen Theorien des griechischen Altertums (Teubner, 1907) p.686 and Charles Kahn, Anaximander and the Origins of Greek Cosmology (third edition, Hackett, 1994), pp.65-7 and pp.102-3

the sun's motion into a number of uniform motions. The best hope for giving an objective standard of "the same time on successive days" purely in terms of the sun's visible motion is to give up on sunrise and sunset and instead to say that noon (the moment when the sun is highest in the sky, or equivalently when it is due north or south of the zenith) happens at the same time each day: we would then measure the period of a day as the period from noon to successive noon, what astronomers call the "true solar day." We can then try to measure the sun's distinctive motion by observing its position at successive noons. This will, like the sunrise and sunset measurements, yield alternating northward and southward motions, with the sun at noon being further north in (northern hemisphere) spring summer, turning back at summer solstice, and further sorth in (northern hemisphere) fall and winter, turning back at winter solstice.

Aristotle rejects this analysis as well. In fact, the period from noon to successive noon, the "true solar day," is not constant, although its variation is much subtler than the variation of the period from sunrise to successive sunrise, and I am not sure that Aristotle knew of it.[28] But Aristotle does not think that either the "true solar day" or the constant "mean solar day" (if he was aware of the distinction) is the correct measure of the sun's daily westward rotation. It is crucial to Aristotle's analysis that the sun's daily motion, against which its distinctive yearly motion must be measured, is a motion common to all the heavenly bodies; and we must measure this common daily motion by observing the motion of the fixed stars, since they have only this motion, uncomplicated by the distinctive motions of the sun and the other planets. Thus the sun's distinctive motion will be measured by observing the discrepancy between the motions of the sun and of the fixed stars, i.e., by measuring the sun's motion against the background of the fixed stars. We can proceed, as before, by observing the sun at the same time on successive days, so as to cancel out the effects of the daily motion; but now "at the same time on successive days" must mean "when the fixed stars have come back to the same position." Of course, since the fixed stars are not visible in the daytime, we cannot directly observe where the sun is when a given fixed star returns to the same position. But we can determine the period of the fixed stars by observing the successive risings of any given fixed star, during the portion of the year when its risings are visible. And it does not take great sophistication to see that this period is neither a true nor a mean solar day. To put it in naïve terms (taking a "day" to be a true or mean solar day), the fixed stars rise a bit earlier each day, so that, when a year has elapsed, the rising-time of (say) Sirius has advanced by a whole day, so that it again rises at the same time of day (this fact is crucial for Hesiod's fixing of the agricultural calendar by the risings of the stars). In terms of a modern clock, which measures out 24 hours per mean solar day, the period of the fixed stars is roughly 23 hours 56 minutes. On Aristotle's view, however, it is not the (true or mean) solar day but the period of the fixed stars (the sidereal day) that is the natural measure of time. Thus in talking about the "unit" in each genus that is the natural standard by which all things in that genus are measured, Aristotle says that "in astronomy this kind of unit [sc. the unit in the genus of motion, namely the simplest and swiftest motion] is an ἀρχή and a measure: for they posit that the motion of the heaven, against which they judge the others, is uniform and most swift" (Metaphysics Iota 1 1053a10-12).[29] Aristotle does not explicitly say here that "the motion of the

[28]Ptolemy gives a treatment of this; the variation in the true solar day is what is called the "equation of time" (see e.g. Neugebauer's History of Ancient Mathematical Astronomy for some discussion)

[29]likewise Physics IV,14 223b18-13: "if the first is the measure of all the things in the same genus, uniform rotation is most of all a measure [of motion and of time] .... This is why time appears [to some people] to be the motion of the sphere, since the other motions are measured by this, and time is measured by this motion." So too De Caelo II,4 287a23-6: "if the measure of motions is the locomotion of the heaven on the ground that this alone is continuous and

heaven" is the motion of the fixed stars, but there is nothing else it could be: the only other heavenly motion that is almost as swift would be the apparent motion of the sun, which is not simple or uniform, and the De Caelo makes it explicit that it is specifically "the ultimate [= outermost] revolution of the heaven" which is "simple and most swift, and the others are slower and multiple (for each [planet] is borne contrary to the heaven [i.e. eastward] in its own circle)" (DC II,10 291a34-b3). So, rather than say that the fixed stars rise a bit earlier each day, or that they complete their circuit in a bit less than a day, the right thing to say is that the period from noon to noon, the period of the sun's return to the meridian line, is a bit more than a "sidereal day," so that the sun "lags behind" the motion of the fixed stars: or, rather, that the sun is moved with the fixed stars, and also has its own slow motion which goes contrary to the motion of the fixed stars.[30] Thus in order to cancel out the daily motion that the sun shares with the fixed stars, so as to isolate the sun's own proper motion, we will have to compare the sun's position now with its position at successive times when the fixed stars have come back to the same positions: in terms of a modern clock, this means comparing the sun at noon today not with the sun at noon tomorrow, but with the sun at 11:56 am tomorrow, at 11:52 am the next day, and so on. Between one such observation and the next, the sun may have moved north or south, but in any case east, and it will cross the whole heaven roughly eastward in a great circle in the course of a year. Thus on this account the sun's proper, yearly, motion will not be an alternating north-south motion but a uniform circular motion:[31] we would see this motion as the path the sun traces out against the background of the fixed stars if we could see the sun, as we see the moon, against the starry heavens (indeed, we can most easily track the sun's yearly path against the constellations by observing the moon when it is full and thus opposite the sun, which allows us to locate the sun against the constellations once a month).

This tracing back of a phenomenal alternating rectilinear motion to two underlying uniform circular motions is paradigmatic for Aristotle's program of explaining all periodic changes through eternally uniform circular motions. Still, Aristotle's program is not supposed to depend on this particular example. His claim is that the inexhaustibility of generation depends on an eternal roughly periodic cycle of changes, which in turn depends on a single eternal, absolutely

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uniform and eernal, and in each [genus] the least thing is the measure, and the swiftest motion is the least, the motion of the heaven would be the swiftest of all motions"

[30]compare Timaeus 39a4-b2: it appears that the motion of (say) Saturn overtakes the motion of (say) Mars or the moon, because Saturn departs less from the daily motion than the inner planets do; but in reality this is because the proper motion of Saturn, by which it counteracts the daily motion, is slower than the proper motion of the inner planets (same point in compressed form Laws VII 822a4-b1). Plato here probably intends a criticism of Democritus, who says that the sun and moon are left behind by the motion of the fixed stars because they are lower down and drag behind the motion of the vortex (Democritus A88, cp. A40, which also mentions the other planets). Incidentally, Democritus' theory here marks a major advance over Leucippus (A1), for whom the circle of the sun is the outermost, the moon the innermost, and the other stars in between. Democritus is aware of the sun's "lagging behind," where Leucippus is not. Democritus wrote a work on astronomy (B11r-14), apparently devoted mainly to calendric questions and to updating Hesiod on the star-risings and meteorological phenomena of each time of the year, and is even said to have written a book on the planets (B5b), but Seneca (Democritus A92) says that Democritus did not yet know how many planets there were or have proper names for them. Democritus, in saying that the sun lags behind the fixed stars, is in the avant garde of Greek knowledge of astronomy, and Plato in saying instead that the sun moves with the fixed stars and has its own motion in the (roughly) opposite direction is taking a further step beyond Democritus

[31]thus rather than saying that the sun's daily motion is westward a bit slower than the fixed stars, and that its yearly motions are northward and southward, we will say that the sun's daily motion is westward at exactly the same speed as the fixed stars; the sun's westward tendency, as compared with the fixed stars, will now be not part of its daily motion but part of its yearly motion, considered together with its motion northward or southward

uniform change, which must be a circular motion. This is supposed to remain true even if the westward motion of the fixed stars is not uniform, or even if (as the Statesman proposes) this motion lasts only a finite time before stopping and being replaced by an eastward motion. We have every reason to believe that the motions of the heavens are regular: as Aristotle says against Democritus, "there are some who make spontaneity [causally] responsible for this heaven and for all cosmoi: for they say that the vortex, and the motion which separated out the universe and arranged it in this ordering, came-to-be spontaneously. Now this itself is remarkable, for they say that animals and plants do not exist or come-to-be by chance, but that either nature or νοῦς or something else like this is the cause (for it is not any chance thing that comes-to-be out of the seed of each thing, but out of this kind of seed an olive-tree comes-to-be, out of that kind a human being), but that the heaven, and the most divine of the things that appear to us, have come-to-be spontaneously, and have no such cause as animals and plants do. But if this were so, it would be worth examining, and it would be well to say something about it. For besides other ways in which this assertion is absurd, it is even more absurd to say these things when we see nothing coming-to-be spontaneously in the heaven, but in the [sublunar living things, which supposedly arise] not by chance we see many things hapening by chance, although it would be more plausible for the reverse to happen" (Physics II,4 196a24-b5). This is not a demonstration that the heavens are perfectly regular. Nonetheless, Aristotle claims to have shown that "spontaneity and chance are posterior to both νοῦς and nature: so that however much spontaneity may be a cause of the heaven [= the cosmos], νοῦς and nature must necessarily be a prior cause, of many other things and of this universe [= cosmos] in particular" (Physics II,6 198a9-13). In other words, even if this cosmos came-to-be in time, and not as the intended result of an Anaxagorean or Platonic νοῦς but as a byproduct of some other process, so that its uniformly rotating heavens have not always existed and presumably will not always exist, there must nonetheless be some longer-term regular process which leads to the generation of this cosmos and of other cosmoi before and after it: so even if the rotations of the heavens are not eternally uniform, there will be another eternally uniform process, namely the great cycles according to which cosmoi are generated and perish, like the cycles of Love and Strife in Empedocles, or of God's steering and withdrawing from the cosmos in the Statesman. Although Aristotle himself believes that our ordered cosmos is eternal, he does not think that the abstract arguments of the Physics can rule out the hypotheses of Empedocles or the Statesman (at least as long as they accept a single uniform process to govern the periodic alternation of cosmic rule). By contrast, he does think he has refuted Democritus, who thinks that there is nothing prior to the spontaneous atomic motions which combine to produce cosmoi. For, by the Physics II analysis of spontaneity, a spontaneous motion is always a byproduct of some prior natural motion, and it is explained only by being traced back to this prior motion, whereas for Democritus the spontaneous motions of atoms resulting from collisions are the byproducts of earlier spontaneous motions of atoms resulting from earlier collisions, and so back ad infinitum, never reaching back to a natural motion or to a starting-point of explanation. And as long as there is no original natural motion to begin the explanations from, there can be no explanation why cosmoi should be generated even roughly at any particular rate, and so explanation of why they should continue to be generated at all (rather than e.g. speeding up or slowing down ad infinitum, as in the animal case mentioned above).

Aristotle's point, that if a cycle is not perfectly or eternally regular, it needs some prior cycle to regulate it, can be seen as expressing a principle of scientific methodology, especially as practiced by ancient astronomers. A modern scientist, if he discovers observationally that a

quantity previously assumed to be constant is in fact changing over time, will not rest content with that discovery, but will try to find a law governing the variation of the quantity; this law will in turn refer to new and more fundamental natural constants. For an ancient mathematical-observational scientist--in practice, that means an astronomer--the problem will appear somewhat different. If he discovers an "anomaly"--say, that the moon travels a greater distance along the ecliptic in some days than in others--then he will try, not just to find a law, but in the first place to find a periodicity in the variation. Having found the period, a Babylonian astronomer might try to give a law for the variation by saying that the lunar velocity increases by a certain fixed amount each day until it reaches a set maximum, then declines by the same fixed amount each day until it reaches a set minimum, and so on. This will be a "cycle" in the sense that it is a fixed pattern of change, occupying a fixed period of time, that is repeated ad infinitum. But, in Aristotle's terms, this would not be a single uniform circular motion, but rather two different "rectilinear" motions, each proceeding uniformly for a while and then stopping and being succeeed by the contrary motion (of course, a change of a velocity is not literally a rectilinear motion; and of course they would be "two" motions only in species, and numerically infinitely many). From the point of view of Greek astronomers like Eudoxus, a Babylonian-style law is not explanatory, since it does not explain why these motions should periodically stop and reverse. The only kind of periodic change which is an acceptable starting-point of explanation is a single constant rotation: this is explanatory, not just because it is periodic, but because it is uniform, with no variation over time that would need to be explained. In insisting that the first and governing motions are uniform circular motions, Aristotle is endorsing the conclusions, and, more importantly, the methodological principles, of Eudoxian mathematical astronomy, as against pre-Socratic-style narrative physics. This leads Aristotle to a radical re-working of physics. But Λ6 is more concerned about the implications for the theory of non-physical, non-changeable ἀρχαί: since the first of physical things are some (one or more) bodies in eternally uniform motion, the first ἀρχαί of physical things will be the movers of those eternally uniform motions. Because these movers produce eternally the same effect, the movers are eternal, and they are also unchanging, or at least their unchanging activities give no reason to suspect that they themselves are changing. The rest of Λ6 is devoted to inferring a further description of these ἀρχαί, and to contrasting them with the inadequate ἀρχαί of Plato and the pre-Socratics.