Contrariety and Change: Problems Plato Set for Aristotle*

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I

Plato and Aristotle both believe that contrariety is fundamental to the analysis of change. At *Phaedo* 70e4-71a10, for example, Socrates says that all things that have an origin (ἔχει γένεσιν) and that have contraries (ἐναντίαι)[1] come to be (γίγνεται) from (ἐκ) contraries. Thus if something comes to be larger, it must previously have been smaller, and vice versa. Other illustrations include coming to be weaker, faster, more just, and better from the contrary conditions. "Everything," Socrates says, "comes to be in this way: contrary things from contraries" (*Phaedo* 71a9-10). Aristotle expresses a remarkably similar view at *Physics* I.5, 188b21-26:

> [A]ll things that come to be, come to be from contraries (ἐξ ἐναντίων), and all things that pass away, pass away into contraries or intermediates (εἰς ἐναντία καὶ τὰ τούτων μεταξύ). And the intermediates are from contraries. For example, colors come to be from pale and dark (ἐκ λευκοῦ καὶ μέλανος). And so all of the things that come to be by nature are either contraries or things that come to be from contraries.[2]

Although the *Phaedo* offers different examples and says nothing about intermediates,[3] there are enough similarities between what the *Phaedo* and the *Physics* say to commit both Plato and Aristotle to the idea that all things have their origins in contraries.

If we wish to understand Plato's and Aristotle's accounts of change, then, we must first understand their accounts of contrariety. Their accounts differ on a number of points. They disagree profoundly on the ontology of contrary features. Aristotle formulates a definition of contrariety; Plato never does.[4] They even disagree about what features count as contraries: largeness and smallness, for example, are star examples of contraries for Plato, but Aristotle denies that these features are contraries at all (see *Categories* 6, 5b14-29). We believe that the story of how Plato and Aristotle came to hold their views on contrariety is fascinating and well worth telling. In this paper we tell the first part of the story, Plato's, and give a brief sketch of some of Aristotle's reactions.

II

We begin with the *Phaedo* version of the theory of forms:

> I'm going to try to explain to you the kind of cause I have been concerned with. I go back to those oft-mentioned things and proceed from them, laying it down that there is something beautiful itself by itself (τι καλὸν αὐτὸ καθ᾿ αὐτό), and good, and tall, and all the rest. If you grant me them and agree that they exist, I hope from them to explain *cause* to you, and to show you how the soul is immortal. ... Consider, then, whether you agree with me on what comes next. For it seems to me that, if anything is beautiful other than the beautiful itself (αὐτὸ τὸ καλὸν), then it is beautiful for no other reason than that it shares in (μετέχει) that beautiful. And I say this about everything. (100b3-c6)

Thus Socrates begins by positing the existence of forms corresponding to the features beauty, goodness, tallness, and "all the rest." Then he appeals to these forms in explaining why certain objects have the features in question. Suppose, for example, that Helen is beautiful. Then according to the *Phaedo*, what makes her beautiful is her sharing in the beautiful itself: she is beautiful precisely *because* she "shares in the beautiful itself." Moreover, her sharing in the beautiful itself is the *only* thing that, according to the theory, can make her beautiful: she is beautiful *for no other reason than* that. According to the theory, then, Helen's sharing in the beautiful itself is both necessary and sufficient for her being beautiful.

Since Plato seems to say so clearly here,[5] it is commonly supposed that he believes that for any object and any feature, the object's sharing in the form corresponding to the feature is both necessary and sufficient for the object's having the feature. There are, however, good reasons for thinking that *Phaedo* 100bc overstates Plato's real view, at least in the *Phaedo*. First, a case can be made for the claim that the *Phaedo* restricts the scope of its theory to forms for *contrary* features. Only forms for contraries are mentioned in Socrates' initial list at 100b6, and no forms for features other than contraries are mentioned elsewhere in the dialogue.[6] In any event, since we are interested here simply in contraries, we shall consider the theory only in its application to contrary features and leave open the question of its applicability to other features.

More importantly, at least for our purposes in this paper, there is reason to think that in the case of the features it considers with regard to which things change, the *Phaedo* does not in fact accept the claim that sharing in a form is sufficient for having the corresponding feature.[7] Consider the discussion of comparatives at 102a-103a. Here what is taken to be in need of explanation is the fact that Simmias is both larger than Socrates and smaller than Phaedo (102b4-5). At 102c10-11, Socrates tells us that in such a case—"when he is between the two of them" (102c11)—"Simmias has the name of being both small and large" (ὁ Σιμμίας ἐπωνυμίαν ἔχει σμικρός τε καὶ μέγας εἶναι). We take it that "having the name of being both small and large" here is periphrastic for "is both small and large." If so, Socrates is telling us that if Simmias is both larger than Socrates and smaller than Phaedo, then Simmias is both large and small. In this case, then, Simmias is said to have the feature largeness in virtue of being larger than Socrates. And although, as we shall see, mention is made of Simmias's sharing in the large itself in the explanation of his being larger than Socrates, other things—Socrates, in particular—must be mentioned as well. So in this case, sharing in a form is not sufficient, by itself, for having the corresponding feature.[8]

In cases in which an object's sharing in a form is sufficient for its having the corresponding feature, we shall say that the object has the feature *unqualifiedly*, or that it has the feature *without qualification*, or that the feature is predicated *unqualifiedly*. So, for example, since sharing in sickness was sufficient to make Plato sick on the day of the *Phaedo* (59b10), he was unqualifiedly sick on that day. In other cases, where a more complicated situation—like Simmias's being larger than Socrates—is required in order for an object to have a feature, we shall say that the object has the feature *qualifiedly* or *with qualification*. Simmias's being large is an example of one, but not the only, variety of qualified predication in Plato. In the next section we shall look at just enough of the details of *Phaedo* 102cd to explain how this kind of qualified predication—being large relative to something else—differs on Plato's account from being unqualifiedly large. After that, we shall briefly describe some other varieties of qualified predication in Plato.

III

Plato explains what makes Simmias larger than Socrates in two different ways whose connection with each another, and with the earlier discussion of sharing in forms, is unfortunately not obvious. According to the first explanation,

> [Simmias] surpasses Socrates ... because Socrates has smallness relative to (πρός) his (viz., Simmias's) largeness.[9]

According to the second explanation, when Simmias is compared to Phaedo, who is larger than he is, and Socrates, who is smaller,

> Simmias has the name of being both small and large when he is between the two of them, submitting his smallness for the largeness of the one (viz., Phaedo) to surpass, and

> presenting his largeness to the other (viz., Socrates) as something surpassing his smallness.[10]

These two explanations raise a number of questions that Plato does not answer. Even though we may assume that Simmias's sharing in the large itself is part of the explanation for his largeness, Plato does not tell us how his largeness is related to the large itself. Both explanations use the language of "surpassing," the first in stating the fact to be explained, the second in explaining that fact; we assume that in the first explanation "[Simmias] surpasses Socrates" is a stylistic variant of "[Simmias] is larger than Socrates."[11] The second explanation has it that the fact in need of explanation is Simmias's having the name of being large. And, as before, we assume that "having the name of being large" is periphrastic for "being large"; we also assume that "being large" here is elliptical for "being large relative to Socrates."

Even on these assumptions, the two explanations differ both in how they describe the fact to be explained and in how they explain that fact. The first has Simmias's being larger than Socrates as the fact to be explained, the second has Simmias's being large relative to Socrates as the fact to be explained.[12] More importantly, the first description depicts Socrates' smallness as something he has relative to someone else's largeness, while the second apparently depicts it as something that he has independently of any comparison with what anyone else has but that may be compared to what others have. These two explanations of why Simmias is larger than Socrates[13] are hard sayings whose interpretation is beset with difficulties we shall not deal with in this paper.[14] For our purposes, it is enough to note that on either explanation, Simmias's sharing in the large itself is not, by itself, sufficient for his being large. In addition, Socrates must share in the small itself, and Socrates' smallness must be appropriately related to Simmias's largeness.

According to the *Phaedo*, then, an object may be large in either of two ways. If a thing is large simply because it shares in the large itself, we say (following the conventions introduced in the previous section) that it is *unqualifiedly* large. If it is large because it is larger than something else, or large relative to something else, we say that it is *qualifiedly* large—qualified by a relation to or a comparison with something else. Although many features (e.g., beauty, hotness, and heaviness) admit of comparison, it not clear whether or to what extent Plato intends us to generalize from the cases of largeness and smallness that we have just considered. Suppose, though, that we have a feature to which the *Phaedo* account applies. The conditions for having the feature unqualifiedly and for having it relative to something else are different enough to allow one and the same individual to have the feature relative to something else but to lack the feature unqualifiedly. Purple is lighter than indigo, for example, but purple is not a light color. Although Claremont is cooler in the summer than Death Valley, it still gets unbearably hot. For this reason, we take it that features predicated without qualification are different from features whose predication is qualified—not just for features predicated in comparison, but for all varieties of qualified predication.

IV

In addition to the predications discussed in the previous section, which involve **Individual Comparison**, there are several other kinds of qualified predication in Plato's writings. Qualified predication may also involve:

Sortal Comparison. According to the *Hippias Major*, the most beautiful ape is ugly relative to human beings, the most beautiful pot is ugly relative to maidens, and the most beautiful maiden is ugly relative to the gods (289b). Apes, pots, human beings, and maidens are accordingly "no more beautiful than ugly" (289c).[15] We are familiar with many examples involving this sort of qualification. Someone can be large for a jockey, small for a football player; fast for a football player, slow for a sprinter; and so on.

Here we have a variety of qualified predication in which something is said to have a feature (e.g., beauty) relative to one kind of thing (e.g., maidens), and the contrary feature (ugliness) relative to things of another kind (gods). The difference between these qualified predications and predications involving comparatives is clear from the fact that if Socrates is five feet tall and Thelonius is an inch taller, Thelonius is tall relative to Socrates but short for a human being. Similarly, even if Claremont is large relative to La Verne, it is not large for a city in Southern California.[16]

Earlier in the *Hippias Major* it is affirmed that just people are just by justice (287c1-2), that wise people are wise by wisdom (c5), that good things are good by the good (c4-5), and that beautiful things are beautiful by the beautiful (c8-d1), in language close to that of the *Phaedo*.[17] So the *Hippias Major*, like the *Phaedo*, allows for the possibility that things can have features unqualifiedly, as well as by sortal comparison or in relation to other things.

Pure Relation. *Republic* 479b3-4 asks, "And again, do the many doubles appear any the less halves than doubles?" Apparently the idea is that a group (e.g., six dice) may be called *double* in relation to one group (e.g., three dice) and *half* in relation to another group (e.g., twelve dice).[18] Although there are obvious similarities between this case and the qualified predication of largeness and smallness,[19] the predication of double and half involve no comparatives: although the group of six is half in relation to the group of twelve, it is not *more* half, and although it is double in relation to the group of three, it is not *more* double.

Respect. An object can enjoy a feature in one respect and the contrary feature in another respect. At *Republic* 436ce, for example, Socrates says that we should describe a spinning top as at rest with respect to its axis but in motion with respect to its circumference. And in the *Symposium* a man can be beautiful with respect to either or both of two parts of himself: his body and his soul (210bc).

Perceiving Subject. According to the theory of vision of the *Timaeus* and the "Heraclitean" theory of vision of the *Theaetetus*, what is white for one perceiver can be black for another. And what is beautiful for one perceiver or from one point of view or under one set of circumstances can be ugly for (from, under) another.[20]

V

In dealing with the *Phaedo*, it is important to bear in mind its limited agenda. Plato's principal focus is on the issue of the immortality of the soul, and although Socrates claims that to allay the worries of Simmias and Cebes on this point requires a "complete investigation" of the causes of coming to be and ceasing to be (95e8-96a1), many issues arise that go unaddressed because they do not directly affect the main point at issue. So, for example, as we have seen, the *Phaedo* is not clear on the range of features for which there are corresponding forms. In addition, the *Phaedo* distinguishes between plain ("safe but stupid," 105c1) and fancy ("more elegant," 105c2) explanations of certain phenomena. Thus we can explain why the stove is hot in the plain mode by appeal to the hot itself, and in the fancy mode by appeal to fire (105c1-2). But the *Phaedo* is silent on the question of the relation between these two modes of explanation, and on the question why certain features (e.g., largeness and smallness) apparently lack fancy explanations. Still other unanswered questions have to do with the *Phaedo*'s sketchy treatment of qualified and unqualified predication; we take up some of these in the next few sections.

VI

Plato's acceptance of the varieties of qualified predication described in section IV above introduces complications in understanding his claim that contraries come to be out of contraries.

Some Platonic contraries—e.g., life and death, odd and even—are mutually exclusive: no object can exhibit both at the same time. Since no object can exhibit both members of a pair of exclusive contraries at the same time, it follows that no object can have one such contrary at one time and the other at a later time without changing during the interval. For example, the number of members in a group cannot be even at one time and odd at the next unless the membership increases or decreases in size. But many Platonic contraries are not exclusive in this way. Simmias is large relative to Socrates and at the same time small relative to Phaedo; a maiden is beautiful relative to pots and at the same time ugly relative to gods; a spinning top is in motion with respect to its circumference and at the same time at rest with respect to its axis.[21] This illustrates Plato's willingness to admit the possibility of compresence for contraries as well as for non-contrary features (like health and beauty, or largeness and justice) that anyone would expect objects to be able to have at the same time. Whenever contraries can be predicated of the same object at the same time, it is possible for something to have one of the contraries at one time and the other at a later time without changing in the interval. Simmias will be large if we compare him to Socrates in the morning and small if we compare him to Phaedo in the afternoon, but his size does not change during the day. This raises questions about how to understand Plato's claim that contraries—as he conceives of them—come to be out of contraries, and about how much this claim can help us in understanding change and coming to be.

Republic IV includes a claim about incompatibility for contraries that seems to offer some help:

1. **Exclusion**: Nothing can be in contrary states or do or suffer contraries at the same time, in the same respect, and in relation to the same thing. (*Republic* 436b8-c1; see also 436e8-437a2 and 439b5).

This principle tells us that whenever contraries are predicated, they must be predicated either of different objects or of the same object at different times, in different respects, or in relation to different things. For example, a man who is standing still and moving his arm requires a division in the object of the predications of rest and motion: part of him is at rest, part in motion (436c). Similarly the collection of Musketeers is both odd and even: odd prior to D'Artagnan's joining them, even afterwards. A top can be at rest and in motion at the same time: at rest with respect to its circumference, in motion with respect to its axis (436d). And Simmias is both small and large: large in relation to Socrates, small in relation to Phaedo.

As far as we know, Plato nowhere explicitly sets out conditions that distinguish contraries from non-contrary features, but Exclusion might be used for this purpose. We see no reason why Plato should not accept the following as a partial characterization of contrariety:

2. **Contrariety**: Two features are contraries just in case no single object can be or do or suffer both features at the same time, in the same respect, and in relation to the same thing.[22]

This condition does partially characterize contrariety: it counts genuine contraries as contraries. But it seems inadequate in at least two respects. First, since no single object can be both hot and warm at the same time, in the same respect, and in relation to the same thing, (2) classifies hotness and warmth as contraries. This seems odd both in counting hotness and warmth as contraries and in allowing that hotness has more than one contrary.[23] Second, since no act can be both unjust and virtuous, virtue and injustice count as contraries according to (2). This seems odd, too: injustice is a species of vice, the contrary of virtue, and virtue is the genus of justice, the contrary of injustice.[24]

Since (1) and (2) are not sufficient to define a notion of contrariety that is adequate for use in the analysis of changes involving qualified predications, it is natural to ask whether these conditions are more helpful in the case of changes that involve unqualified predications. We think the answer is no. On the plainest reading of *Phaedo* 102c10-d2, Simmias has the largeness that makes him larger than Socrates and the smallness that makes him smaller than Phaedo at the same time and independently of any comparisons to Socrates and Phaedo. If so, he is unqualifiedly large at the same time as he is unqualifiedly small, and these unqualified predications are not contraries at all, let alone contraries with respect to which Simmias could change. The text of the Phaedo does not make it clear whether this is correct, or—if it is correct—whether it warrants generalization to the conclusion that only qualified predications are contraries. But this conclusion does seem to be warranted by Exclusion (1). The wording of this principle and the examples Plato uses to illustrate it (the spinning top, and the man who stands still while moving his arms at *Republic* 433c-e) suggest that if Exclusion gives a necessary condition for contrariety, then contraries are qualified rather than unqualified predications.

VII

Worse still, Plato's acceptance of qualified predications of contraries threatens to make change incoherent, as he himself seems to have realized. At *Theaetetus* 155ad, Socrates introduces three general principles governing change:

3. If a thing has a feature (e.g., a certain size or number) at t_2 that it lacked at an earlier time t_1, then between t_1 and t_2 it came to have that feature (155b).

4. If a thing remains the same with respect to a feature (e.g., if it remains the same in size or number) between t_1 and t_2, then it does not come to have another, incompatible feature at t_2 (e.g., it does not come to be larger or smaller in size or number at t_2 than it was at t_1) (155a).

5. If nothing is done or happens to a thing (e.g., if nothing is added to or subtracted from it) between t_1 and t_2, then it remains the same (e.g., in size or number) between t_1 and t_2 (155b).

These claims seem to be obvious truths about change generally or quantitative change in particular. According to 155bc, however, when applied to everyday occurrences, the claims seem to imply a contradiction. Suppose that in January Socrates is large relative to the boy Theaetetus, that Socrates neither gains nor loses any of his substance during the course of the year, and that Theaetetus grows so much that by December Socrates is small relative to Theaetetus. Then Socrates has a feature in December that he lacked in January: smallness relative to Theaetetus. By (3), he must have come to have that feature between January and December. But by (4) and (5) he didn't: Since he neither gained nor lost any of his substance during the year, it follows from (5) that he remained the same. And if he remained the same during the year, (4) tells us that he could not have come to be smaller than Theaetetus.[25]

Puzzles of this sort show that for some contraries that belong to things relative to something else, an object that has one of the contraries at one time can have the other at another time, without having changed. Plato can appeal to Contrariety to avoid this result in some cases. For example, in the dice puzzle, the group of six dice is larger by half relative to one group and smaller by half relative to another, and according to Contrariety these two features are not contraries. But we can easily modify Plato's example to provide a case in which the group of six dice passes from contrary to contrary without changing. Suppose we compare the group of six to a group that increases in size from four members to twelve. Then the group of six is first larger by half and then smaller by half relative to one and the same group. According to Contrariety, being larger by half and being smaller by half relative to one and the same group *are* contraries. But even though these features count as contraries, the group of six, which was earlier larger by half than the second group, can be smaller by half later, without undergoing any change. And Contrariety does not help with the original growing-boy puzzle at all: even though it was Theaetetus and not Socrates who changed, being large relative to Theaetetus and being small relative to Theaetetus qualify as contraries according to Contrariety, since Socrates cannot be both small and large relative to Theaetetus at one and the same time. Analogous cases can be constructed for relative and for comparative predications involving temperature, color, and other features.

VIII

Plato's problems in the *Phaedo* and the *Theaetetus* are not problems for us. To explain why Simmias is larger than Socrates and smaller than Phaedo, we introduce numerical measures of quantities: if

Simmias's height is six feet, Socrates' is five feet, and Phaedo's is seven feet, then Simmias is larger than Socrates and smaller than Phaedo because six is more than five and less than seven. So an obvious question to ask is why Plato didn't do what we would do in dealing with the issues raised in such passages as the *Phaedo*'s tortured discussions of qualified largeness and the *Theaetetus*'s puzzles of the dice and the growing boy? Why didn't he use numerical measures to analyze the fact that Simmias is smaller than Phaedo and taller than Socrates? Instead of worrying about how, without changing in size, Socrates was at one time larger than Theaetetus and at another time smaller, why didn't he give numerical measures of Socrates' and Theaetetus's heights at the relevant times? Why did he attach so much importance to the fact that one group of dice is smaller by half than a second group and larger by half than a third when he could have counted the dice in each group and compared the numbers?

It is easy to answer such questions unsympathetically. One unsympathetic answer is that Plato's apparent lack of interest in numerical measures in dealing with quantitative features like largeness and smallness betrays a remarkably inadequate and primitive notion of measurement. Another unsympathetic answer is that Plato was merely kicking up sand by presenting spurious puzzles he could easily have avoided. We certainly agree that ancient Greek measurement theory and practice were less sophisticated than our own. We also agree that Plato knew that some of these puzzles can be used to support sophistical positions.[26] But we also think that Plato was concerned with issues involving such qualified predications as relative magnitudes that could not be resolved simply by assigning numerical measures to lengths, temperatures, weights, volumes, and other quantities. And we think there was reason to suppose that these issues must be resolved if numerical measures of such quantities are to be as theoretically and practically useful as we can now assume them to be.

In the *Statesman,* Plato says that the importance of the art of measurement derives from its application to practical crafts like weaving and clothes making (*Statesman* 284ab). Plato typically describes the successful practice of any practical craft as depending upon the avoidance or correction of excesses and deficiencies of various items. And in many cases the craftsman's task is to secure or maintain desirable relations between quantities. Thus the musician must avoid adjusting the strings of his lyre too tightly or too loosely. The physician must keep his patient from being hotter or colder than he should be. Like an athletic trainer, he must know whether the improvement of one man's condition requires him to eat more, less, or the same amount of food than another.[27] Disaster ensues, Plato says, if the craftsman disregards

> due measure (τὸ μέτρειον) by [applying] greater power to things that are too small [for it]—[too much] sail to a boat, [too much] food to a body, and [too many] principles (ἀρχαί) to a soul.[28] (*Laws* III, 691c1-3).

If sufficiency, excess, and deficiency are crucial in the practice of the crafts, the usefulness of a measurement system will depend upon the help it provides in determining whether a given quantity is too much, too little, or exactly just enough of what is required for the purpose at hand. And no measuring system can help with this unless we can find out what is enough and what is too much or too little for each given purpose. Thus Plato says the crafts, including statesmanship, depend upon the possibility of establishing standards (μέτρια) relative to which quantities can be called excessive or deficient (*Statesman* 284ac). In order to determine whether, e.g., a given amount of food is sufficient for the physician's purposes, it will not do to find out whether it is larger (smaller) than just *any* smaller (larger) amount.

> [T]he more and the less are to be measured relative (πρός) not only to each another, but also to the attainment of a due measure (πρὸς τὴν τοῦ μετρίου γένεσιν). (*Statesman* 284b1-c1).

The same holds, we suppose, for large and small amounts. A large amount of food would be large not just relative to *any* small amount; for the purposes of the physician, it would be large relative to the amount required to establish or restore the required bodily state. This makes it natural for Plato to think that an adequate theory of the crafts[29] must explain what it is to be larger and smaller, more and less, half, double, equal, etc., and what it is to be qualifiedly large, small, etc. But it must also account for the standard measures relative to which these comparatives and qualified predications of quantity can be used to characterize the excesses and defects that the various crafts must avoid, and the sufficient amounts they aim for.

It seems clear that the introduction of a system of numerical measures without an account of the due measures and of what it is to be large and small, etc., relative to them would have little to offer in answer to Plato's concerns about quantities in the crafts. For example, it would not help a doctor to know how to measure temperature in degrees without knowing how to use the resulting numbers to establish whether the patient's heat is medically deficient or excessive. Because of these concerns, we suggest that Plato would not think it illuminating to solve the puzzle of the growing by applying numerical measures of size. In order to satisfy Plato, a solution would have to specify and justify the choice of a due measure to which the heights of Socrates and Theaetetus could be compared, and then observe that although Socrates was no longer larger than Theaetetus, he had the same height relative to the due measure.

IX

A related point holds for the theoretical crafts of mathematicians and scientists who investigate problems without concern for practical application.

In our scientific theorizing, we are accustomed to the unqualified assignment of numerical magnitudes to distances, speeds, temperatures, and other quantities including physical constants (like the speed of light) whose values are thought to be fixed by nature independently of the conventions we employ in measuring them.[30] But many of the numerical measures used for such purposes represent magnitudes as multiples or fractions of specified units. Other numerical measures represent magnitudes by locating them in relation to specified members or bounds of a series. Where *x* and *y* are reference points, a magnitude may be represented by a number whose significance is explained by appeal to such qualified predications as *larger than x* and *smaller than y, in between x and y*, etc. For example, one way to construct a scale is to fix and assign numbers to its end-points, mark and assign a number (half way in between the first two numbers) to the midpoint, mark and assign numbers to points that lie half way between the mid-point and each of the end-points, and so on. That is to say, the meanings of typical numerical measures are established and can be explained in terms of qualified predications of magnitude.

The metric system illustrates how closely numerical and qualified measures may be connected. The meter was first defined in 1791 (on the recommendation of a committee of the French Academy of Sciences) as a certain fraction of the arc of the meridian, eight years before surveyors could complete a numerical measurement of that arc segment.[31] Before the surveyors even started their work, the meter unit was used to define such units as the gram—the weight of a fraction of a cubic meter of pure water at a specified temperature.[32] There are two ways to think about this. Because the meter was defined as a fraction of an arc to which no numerical measure had yet been assigned, we can think of such expressions as "ten meters" as shorthand forms of qualified (relational) predications of length. And we can think of relative measures of distances as essential to the meanings of numerical measures of weight in the metric system. Alternatively, we might think of uses of qualified measures as parts of a process the French Academy of Science went through to develop numerical measures whose subsequent use would make their humble origins in qualified predications of length less and less crucial to our employment and understanding of them.

Although this last view may be more congenial than the first to the practices of recent science, ancient theoreticians appear to have been more interested in qualified predications of magnitudes than in the numerical measures they could be used to establish. For example, even though Aristarchus, Hipparchus, Archimedes, and other ancient astronomers could and sometimes did estimate astronomical distances in numbers of stades,[33] they appear to have been far more concerned to determine proportions— e.g., of the diameter of the heavens to the diameter of the earth, and of the apparent size of the sun to the circumference of the zodiacal circle—than to find unqualified, numerical measurements of these quantities.[34]

We don't know why the determination of proportions and ratios took precedence over numerical determinations of quality. But Aristotelian biology illustrates a principled reason why the determination of a suitable measure for use with qualified predications of magnitude could be just as important to a theoretician as to a practical craftsman, and why it should be of considerably more interest to the theoretician than numerical measurements.

Aristotle says there are biological kinds[35] that differ from one another by more and less, excess and defect (e.g., at *Parts of Animals* I.4, 644a16-21 and 644b8-15). For example:

> Among the birds, the differentiation relative to each other is in the excess and the deficiency, or according to the more and the less (ὑπεροχῇ καὶ ἐλλειψει καὶ κατὰ τὸ μᾶλλον). For some are long-legged, some short-legged, some have a broad tongue, and some a narrow one; and similarly for the other parts. (*Parts of Animals* I.12, 692b3-7)

In his discussion of this passage, J. Lennox points out that the importance of such qualified predications derives from Aristotle's interest in classifying animals by features that can explain important facts about how they live:

> [A]t least in regard to living things, the “essence/accident” distinction is a distinction between those features which are required by the kind of life an animals lives and those which aren’t. If a crane is to survive and flourish, it must have, not simply “long” legs, but legs of a certain length, defined relative to its body, neck length, environment, feeding habits, and so on. (Lennox 1987, 356)

Thus Aristotle says the reason certain birds are long-legged is that they live in marshes. If their legs were too short or too long in relation to their neck and body sizes, they would not be able to walk with their heads high enough to see, bend down to find food well enough to flourish, etc. This, says Aristotle, is an example of nature making organs correspond to their functions, rather than making a function correspond to its organ (*Parts of Animals* IV.12, 694b12ff). Birds who live different sorts of lives in different environments will have legs that are short in comparison to marsh birds with crane-like life styles. Given Aristotle’s explanatory aims, then, qualified predications of size are crucial. Unqualified numerical predications of size are useless without reference to qualified magnitudes.

Lennox also suggests[36] that the *Philebus*’s discussion of quantity (*Philebus* 16d-18d and 22c-25b) is plausibly read along similar lines. Here Plato is concerned with what sorts of units are to be chosen for investigating items of various degrees and kinds of complexity. The usefulness of numerical measures depends upon what they tell us about qualified, rather than unqualified, predications of quantity—e.g., about how large or small a given quantity is relative to a unit or to positions in a series bounded by measures that are appropriate to the investigation at hand.

The moral of all of this is that with regard to theoretical as well as practical crafts, it would be reasonable for Plato think that a proper treatment of the puzzle of the growing boy would require not an appeal to unqualified numerical measures but an account of due measures and qualified predications of size made relative to them.

X

We think that much of what Aristotle says about contrariety—in *Metaphysics* X, for example—can plausibly be read as part of an attempt to develop a foundational account of measurement that would, among other things, make use of the insights in Plato's treatment of contrariety and, and the same time, respond to some of the difficulties with that treatment. We lack the space in this paper to argue for this story or to develop its details at any length, but we conclude with two brief suggestions about how Aristotle might have responded to some of the problems Plato set for him.

Consider the means at Aristotle's disposal for dealing with the growing-boy and dice puzzles from the *Theaetetus* (see section VII above). According to *Categories* 7, 8a31 ff.,

> **6**. A feature, F, is a relative (πρὸς τι) feature if what it is to be F—the being (τὸ εἶναι) of the feature—consists in its being related in some way to a feature, G, whose being consists in its being related to F.

For example, what it is to be double depends upon what it is to be half, while what it is to be half depends upon what it is to be double. Following Porphyry (*In Aristotelis categorias*, 125.25-29), we take Aristotle's point to be to distinguish the relative features of an object from features it possesses just in virtue of what belongs to it essentially or accidentally. To illustrate the distinction, recall Plato's groups of dice. One of them contained six dice. This quantity belongs to it non-relatively, just in virtue of its composition. By contrast, *larger* (*larger by half*) and *smaller* (*smaller by half*) are relative features. By itself, a group of six is neither larger nor smaller, larger by half, nor smaller by half. But it is larger by half than a group of four, and smaller by half than a group of twelve.[37] Recall Plato's observation that measurements in terms of relative largeness and smallness (πρὸς ἄλληλα μεγέθους καὶ σμικρότητος) are worthless to the practical craftsman because what makes something larger is just its relation to what is smaller, while what makes something smaller is just its relation to what is larger (*Statesman* 283d). So characterized, relative largeness and smallness fit (6) above so well that Aristotle's characterization of relative features could easily serve as a generalization of Plato's observation.

Since one thing's possession of a relative feature (*larger* or *smaller by half*, in this case) depends upon the possession by something else of a correlative feature (*smaller* or *larger by half*), what has a relative feature can lose it, and what lacks a relative feature can come to have it by virtue of facts about other things. To bring it about that our group of dice is no longer larger by half, we need only add some dice to the group we were comparing it to, or compare it to another, larger group. If we'd like our group to become larger all we have to do is subtract dice from the group of twelve, or compare it to another, smaller group. Thus, as Porphyry observed, relative features "come into and out of being without their subjects being affected" (Porphyry, 125.29). This is what we take Aristotle to mean when he says there is no change with regard to relatives (*Physics* V.2, 225b11).

This suggests a treatment of the puzzles of the growing boy and the dice. Aristotle can grant (3) above, according to which an object must come to have a given feature if it lacks that feature at one time and has it at a later time. He can also grant (4), according to which an object that has a feature across a span of time cannot have or come to have the contrary feature during that time span. But he can reject (5), according to which an object that has a feature *of any kind whatsoever* cannot cease to have that feature unless something is done to it or happens to it. Although (5) holds, e.g., for non-relative features, and for relatives possessed only by virtue of comparison to a fixed standards, an object can lose a feature without undergoing any genuine change as long as that feature falls under (6) above (see *Physics* V.2, 225b11-13). Therefore, contrary to (5), nothing needs to be done, and nothing needs to happen to a thing to make it lose or gain a relative feature of this sort. And so it is with the features acquired by the dice and by Socrates in the growing-boy example. They are features that fall within the scope of (6), not (5).[38]

XI

Our second and final suggestion has to do with features to which (5) applies. Aristotle's general strategy for regimenting accounts of change requires the scientist to identify the contraries with respect to which the object under investigation changes. For any given change, Aristotle supposes there should be a unique pair of contraries. Its members will be mutually exclusive features such that the change under investigation will consist of (a) the replacement of one contrary by the other, or (b) the replacement of one of the contraries by an intermediate falling somewhere in between it and its contrary, or (c) the replacement of one intermediate by another intermediate, or (d) the replacement of an intermediate by a contrary. For example, Aristotle thinks dark and light are the contraries involved in changes of color; red, blue, and all of the other colors are intermediates ordered by their relations to them. Accordingly, any color change will consist of (a) a completely light object turning completely dark (or vice versa), or (b) a completely light (or dark) object turning one of the intermediate colors, or (c) the replacement of one intermediate color by another, or (d) the replacement of an intermediate by light or dark.[39]

This scheme imposes a *uniqueness requirement* on contraries:

7. If a feature has a contrary at all, it has no more than one. (*Metaphysics* X.5, 1055b30, 1056a11, 19-20)

If all things come to be from and pass away into contraries, there must be contraries in all of the categories with regard to whose properties things can change. Ignoring substantial change, these categories include quantity, quality, and place (e.g., *Physics* V.2, 226a24ff. and *Metaphysics* XIV.1, 1088a31). In what follows, we restrict ourselves to have to do with changes in quantity.[40]

One of Aristotle's problems with quantitative change is that things can change with respect to quantities that don't seem to satisfy the uniqueness requirement. For example, condition (7) is not satisfied by such features as being one or more feet long, weighing one or more pounds, etc. (*Categories* 6, 5b11ff.). That is because each of these magnitudes is opposed not to just one but to an unlimited number of different magnitudes, no one of which has any better qualifications for being called its contrary than any other. Nevertheless, growing a foot and gaining a pound are certainly changes. To accommodate them in his general scheme, Aristotle must find a way to systematically identify such quantities as contraries or intermediates.

A second problem arises with quantities things have by virtue of comparison, e.g., *large relative to a millet seed* or *large relative to a mountain* (*Categories* 6, 5b17). Suppose the size of a particular seed or mountain is fixed. Then things can change with respect to this size: if something is large relative to a mountain at one time and small relative to the same mountain at a later time, it must have undergone a change in the interim. Like contraries, such quantities are mutually exclusive. Furthermore, they admit of intermediates.[41] And— as required for all contraries in *Metaphysics* X.4 and *De Interpretatione* 7-10— an object can lack both magnitudes, either because the object is something like a soul that is incapable of having any sort of spatial magnitude, or because it has an intermediate magnitude rather than one of the contrary ones. But comparatives like these are not definite quantities. Things that are large relative to a millet seed (avocado seeds, watermelons, huts, and mountains, for example) come in an enormous number of different sizes. This means that something whose size changes drastically need not change with respect to such comparative quantities: a sapling and the mighty oak it grows into are both large compared to a millet seed and small compared to a mountain. Such indefiniteness also distinguishes quantities predicated by comparisons between some actual object and the due measures Plato said were required for the successful pursuit of the crafts. For example, a nutritionally adequate amount of iron, an amount that is either small or large enough to cause blood abnormalities, and an amount that must be added to or subtracted from the diet to restore health will all be small relative to some objects of comparison (e.g., the amount of calcium in an oyster shell) and large relative to others (e.g., the amount of titanium contained in a thin slice of stewed morel). If quantitative contraries are to provide a basis for determining due measures, and if the magnitude of an object that has one of a pair of contrary quantities cannot change unless that magnitude is replaced by an incompatible quantity, contraries must satisfy a *definiteness requirement*:

8. For any pair of contrary quantities, nothing that has either quantity can be larger or smaller than anything else with the same quantity.[42]

Aristotle's second problem is to secure definiteness.

As we understand it, the leading idea of Aristotle's strategy for explaining how contrary quantities can satisfy both (7) and (8) is this: an ideal classification scheme would sort things into kinds such that—where K is one of these kinds—*as large* and *as small as is possible for a K* (or *for a normal*, or *for a fully developed K*, etc.) would be unique, definite magnitudes in relation to which intermediate sizes could be defined. Aristotle knows he must apply this idea in different ways to different sorts of quantities for different sorts of things. But here is one illustration of the general strategy.

Increase is a change in quantity that Aristotle characterizes as change "toward complete magnitude" (εἰς τέλειον μέγεθος). By contrast, decrease is a change away from this complete magnitude (226a23-32). It is not clear just what (if anything) this can mean in every case. But for an animal or plant that grows and shrinks (in size, weight, etc.) during the course of its life, Aristotle's talk of moving toward and away from complete magnitudes makes perfectly good sense if there is a definite maximum size (or perhaps a unique, developmentally ideal size) that normal, healthy, mature organisms of a given kind can attain and a minimum size beyond which no smaller organism of the kind can survive or retain its normal functioning. These sizes will differ from kind to kind; oak trees can grow larger than peonies, and dwarf wombats are smaller than dwarf horses. The magnitudes of maximal and minimal sizes are determined, according to Aristotelian biology, by the natural capacities of nutrition and growth possessed by normal organisms of various kinds. Change in size for an organism will then be increase toward the maximum or decrease toward the minimum for the kind to which the organism belongs.[43]

We believe that when Aristotle characterized contrariety as

9 **(a)** extreme or complete difference (μεγίστη διαφορά) at *Metaphysics* X.4, 1055a4; διαφορὰ τέλειος at 1055a16) between **(b)** predicates of the same genus (1055a26ff.)[44] **(c)** that can belong to the same recipient (δεκτικόν) or matter (ὕλη). (1055a29 ff.)[45]

he was generalizing from the sort of account we just sketched.[46] For growth or decrease in the size of an organism, the genus (9b) is size, and the extremely or completely different predicates (9a) falling under the genus of size are, e.g., *maximally large* and *maximally small for a stoat*. The recipients (9c) of which these contraries are predicated are organisms of a specific kind. Change in size for a stoat is a process by which the animal's body comes to be closer to one of the extremes and farther from the other than it was at the beginning of the process. Once the contraries are fixed, numbers of convenient units can be assigned to them, and these can be used to characterize intermediates. Suppose that for two numbers, n and m, n ounces is the minimum weight for a stoat and that m ounces is the maximum weight. Then we may think of n and m as measures of contrary sizes. And for any $n' \geq n$ and any $m' \leq m$, such that $m' > n'$, what is n' at one time and m' at another will have changed in size, increasing toward or decreasing away from the complete weight for a stoat. Growing from one of the n' to one of the m' will be a change because the object moves from one position relative to a complete magnitude to another—and similarly for shrinking from one of the m' to one of the n'. Growing larger will be a change because to grow larger will be to grow from one of the n' to one of the m'.

To see how this applies to due measures, imagine that you are an ancient Greek physical trainer who prescribes foods and exercises to maintain the fitness of a runner. You should know the maximal and minimal weights for normal human beings. You should know what intermediate weight range is healthy for humans, and appropriate for athletes like the one you are training. This knowledge will allow you to decide whether she weighs too much or too little. If you also know how much pasta is required to maintain weight in the proper range, you will be able to find out whether her diet includes too much or too little, and if necessary, how her pasta intake should be changed to remedy an excess or defect in weight.

At *Categories* 6, 5b24ff, Aristotle observes that what counts as many people in a village would not qualify as many people in Athens, and that what counts as many people in a house is less than what counts as many people in a theater. Thus a group of people is not many or few relative to the number of people who were actually in the house, the theater, the village, or the city at any particular time. Instead, *many* and *few* are understood—depending on what is appropriate for the relevant context—*as many for a house* (or *theater*, or *village*, etc.) These magnitudes are determined, not by the populations, but by the capacities of the relevant places. Aristotle's use of Sortal Comparisons to explain quantitative contraries is analogous to this: magnitudes are fixed by appeal to the abilities (e.g., for growth) that are characteristic of kinds of individuals, rather than the magnitudes that have actually been attained by the members of the kinds.

The idea that natural kinds are distinguished from one another to an important extent by the capacities (δυνάμεις) of their normal members is, of course, central to Aristotelian biology. Indeed, if what we have been suggesting in this section is correct, an important part of the work of an Aristotelian biologist (who studies natural differences between members of different kinds of organisms, or seeks to develop an adequate taxonomy of natural kinds) would be relevant to the identification of quantitative contraries.[47] We believe an examination of Aristotle's treatments of other contraries (e.g., contrary colors, tastes, directions, and motions in space) would reveal equally strong connections between the identification of contraries and other departments of Aristotelian natural science. It would be nice to find a text in which Aristotle says that his approach to the natural sciences had been shaped by the approach to the problems of change, contrariety, and due measure that Plato left him. It would be nice to find a text in which Aristotle says that his approach to natural science has the advantage of providing resources for dealing with precisely these problems. We don't suppose there ever were any such texts. But we don't need them to appreciate how important the Platonic problems of contrariety and change were to Aristotle's work in natural science and its philosophy.

NOTE

[*]We presented versions of this paper at California State University at San Bernardino, the University

[1]Although "contraries" is a standard translation of ἐναντία in Aristotle, "opposites" is often used as a translation in Plato. There is something to be said for this diversity of practice: Plato and Aristotle have different ideas about ἐναντίωσις. However, in the belief that it is a single thing they have different ideas about, we use "contraries" for both. Where required, we shall use the terms "Platonic contraries" and "Aristotelian contraries" to distinguish between them.

[2]See also *Metaphysics* X.4, 1055b16-17; *De Caelo* I.3, 270a14-17; *Generation and Corruption* I.7, 323b28-324a9.

[3]But *Phaedrus* 262a seems to anticipate Aristotle's notion of intermediates in speaking of a thing's changing from a feature to its contrary "bit by bit" (κατὰ σμίκρον).

[4]But *Philebus* 12d-13a seems to anticipate Aristotle's definition of contrariety as maximum difference within a genus (*Metaphysics* X.4, 1055a5-6).

[5]And elsewhere: see, e.g., *Phaedo* 78e, 100e-101a, 103e; *Parmenides* 130e-131a; and *Republic* 596a6-7. Aristotle attributes the view to Plato at *Metaphysics* I.6, 987b3-10.

[6]Arguably the forms for unity and duality mentioned at 101c are exceptions to this claim. However, Plato has no clear conception of what features are and what features are not contraries, and he may be treating unity and duality as contraries here. Alternatively, they may simply be bad examples. (*Parmenides* 128e-130b is happy to treat unity and plurality as contraries.)

[7]Thus we disagree with a leading idea of Vlastos's "Reasons and Causes" (Vlastos 1981, 91-110). In particular, the mechanism Vlastos invokes to explain, e.g., how adding snow to something can change its temperature (see *Phaedo* 103b-104a) fails to apply to the cases of change the *Phaedo* concerns itself with. Vlastos thinks that the forms of hot and cold are sufficient to determine, respectively, what it is to be hot and what it is to be cold. Perhaps this is so. But Plato wants to explain changes in which, e.g., one thing that is hot in comparison to (hotter than) another thing becomes cold in comparison to (colder than) that other thing. Even if a share in the form of cold is necessary for being colder than a given knish, and a share in the form of hot is necessary for being hotter than that knish, there is no reason to suppose Plato thought that a full description of those forms would tell us what it is for some borsch to be hotter or colder than a knish. Vlastos also believed that an entailment relation between the forms of snow and cold explains why adding snow to something can give it a share in the form of cold. And he appears to have believed that some sort of exclusion relation between the forms of hot and cold explains why making something share in the cold by adding snow will make it cease to be hot (Vlastos 1981, 102-110). But we think that on Plato's view, a share in the form of cold is not sufficient to make one thing colder than another, and a share in the form of hot is not sufficient to make one thing hotter than another. If we are right, then even if adding snow to the borsch gives it a share in the cold, that will not be enough to explain why the soup becomes colder and ceases to be hotter than the knish. On our view, then, however important the forms may be to Plato's thinking about other topics, they do little work in his thinking about change. (We thank J. E. McGuire for helpful discussion of this point.)

[8]There is also reason to believe that the *Phaedo* does not accept the claim that an object's sharing in a form is necessary for its having the corresponding feature. Consider fire, for example. *Phaedo* 103e clearly implies that fire is hot, and 105bc says that we can adequately explain why, e.g., a stove is hot by citing the presence in it of fire. But the *Phaedo* does not bring the hotness of fire within the scope of the explanatory pattern of 100bc; it does not say that fire is hot because it shares in the hot itself. (In fact the *Phaedo* offers no explanation at all of why fire is hot. *Timaeus* 61d-62a does explain this, in terms of structural features of fire itself and not, or not obviously, in terms of sharing.) According to the *Phaedo*, then, fire is hot, but it does not share in the hot itself. The same is true of the rest of the *Phaedo*'s "fancy" explanatory factors (see the end of section V below). The dialogue assumes that three, five, etc.,

are odd while two, four, etc., are even; that snow is cold; that soul is alive; etc.—but it does not explain why these things have the features they do, and, in particular, it does not say that they have them in virtue of sharing in forms.

[9]Σωκράτους ὑπερέχειν ... ὅτι σμικρότητα ἔχει ὁ Σωκράτης πρὸς τὸ ἐκείνου μέγεθος (102c3-4).

[10]Οὕτως ἄρα ὁ Σιμμίας ἐπωνυμίαν ἔχει σμικρός τε καὶ μέγας εἶναι, ἐν μέσῳ ὢν ἀμφοτέρων, τοῦ μὲν τῷ μεγέθει ὑπερέχειν τὴν σμικρότητα ὑπέχων, τῷ δὲ τὸ μέγεθος τῆς σμικρότητος τῆς σμικρότητος παρέχων ὑπερέξον (102c10-d2). (In our discussion below, we ignore the comparison to Phaedo in this explanation.)

[11]The surpassing relation mentioned in the second explanation is a more complicated matter. See n. 14 below.

[12]In this context there may be no significant difference between the two ways of describing the fact. But in general "X is more F than Y" and "X is F relative to Y" will not be stylistic variants of each another.

[13]Similar accounts can be given for Socrates' being smaller than Simmias, Phaedo's being larger than Simmias, and Simmias's being smaller than Phaedo. But as Vanessa DeHarven pointed out to us, if Plato were to give exactly the same explanation, e.g., for Simmias's being larger than Socrates that he gives for Socrates' being smaller than Simmias, he would violate one of his own conditions for adequate explanations. At *Phaedo* 101ab, Socrates rejects such explanations as "Thelonius is larger than Bud, and Bud is smaller than Thelonius, by a head" because they appeal to the same thing in the explanation of contrary features. To avoid explaining being smaller and being larger by appeal to the same thing, Plato should say, e.g., that while the relation between the members of the ordered pair consisting of Socrates' smallness and Simmias's largeness explains why Socrates is smaller than Simmias, what explains why Simmias is larger than Socrates is a relation between members of a different ordered pair–consisting of Simmias's largeness and Socrates' smallness–or a different relation between members of the same ordered pair.

[14]For example, it is far from obvious what the formal properties of the "surpassing" relation mentioned in the second explanation would be, let alone which (if any) relation familiar to us it might correspond to. Moreover, whatever surpassing turns out to be, the following would seem to be an obvious difficulty with the second explanation, at least as stated. Consider the smallness Simmias has in virtue of being smaller than Phaedo and the largeness he has in virtue of being larger than Socrates. We know that Simmias's largeness surpasses Socrates' smallness. Does it surpass his own smallness as well? If it does, then it would seem that he is both larger and smaller than himself. As for the first explanation: it is not clear what it is to say that Socrates' smallness is "something he has relative to the largeness of someone else," let alone whether this involves the surpassing relation mentioned in the second explanation. Finally, it is hard to say whether the two explanations tell two different stories or the same story in two different ways.

[15]Regrettably Socrates does not raise the question whether there are beings relative to whom even the gods are ugly or—to put the issue sharply—whether there are limits to the series (presumably a partial ordering) his examples imply.

[16]A useful discussion of individual and sortal comparison is Wallace 1972.

[17]Note in particular 100e2-3: τῷ καλῷ τὰ καλὰ καλά.

[18]See also *Theaetetus* 154cff.

[19]Indeed, *Republic* 479b6-7 goes on to ask a question about largeness and smallness analogous to 479b3-4's question about double and half.

[20]See *Republic* 479aff., where anything that has a feature will also appear to have the contrary feature, and *Hippias Major* 289, where participation in beauty makes something *appear to be beautiful*.

Someone may object, e.g., that to be what we are calling beautiful by Perceiving Subject is not to be beautiful at all, but simply to *appear* to be beautiful. This seems to be Plato's view at *Sophist* 235e-236a. There, a sculptor produces a work that is so large that the lower parts will seem larger than they really are and the upper parts smaller than they really are from a normal viewing position. If the sculptor used "the true proportions of beautiful things," the statue would look ugly, and so he uses "proportions that are not but will seem to be beautiful" (οὐ τὰς οὔσας συμμετρίας δοξούσας εἶναι καλάς. But at *Republic* 479b, things that "appear" to be beautiful will also "appear" to be ugly, just as things that "appear" to be doubles will also "appear" to be halves—and similarly for large and small, light and heavy, etc. The verb φαίνομαι, here translated in the language of appearance, is sometimes used to talk about how things appear as opposed to how they really are. But it is also used in connection with what is manifestly the case. The example of doubles and halves indicates that in our passage Plato uses "appears" in the second of these senses: 6 really is double relative to 3, and really is half relative to 12. Plato thinks the sights and sounds that delight the φιλοθεάμονες don't just appear to be beautiful, but *are* beautiful when perceived by some perceivers (or in some settings) and ugly when perceived by others (or in other settings).

[21]These examples all involve qualified predication. Whether compresence is possible for some cases of unqualified predication is a question on which the *Phaedo* is silent. As we shall see, the *Republic* implies a negative answer.

[22]Notice that this does not give us a condition for contrary forms. To get such a condition from Contrariety, we would have to add conditions that appeal to the role of those forms in the qualified and unqualified predication of the features involved.

[23]The claim that each contrary has only a single contrary is used at *Protagoras* 332a-333b as a premise in the argument that wisdom and temperance are a single thing, each being the contrary of folly.

[24]Aristotle's characterization of contrariety as maximum difference within a genus (*Metaphysics* X.4, 1055a5-6) improves on Contrariety in not being subject to either of these criticisms.

[25] Plato presents a similar puzzle for a case involving a group of six dice: that group is more by half relative to a group of four and less by half relative to a group of twelve without undergoing a change in number (154c). This puzzle is introduced by a general assumption—a close relative of (3) above—whose acceptance would generate similar puzzles for heat, color, and other features in addition to size (154b).

[26]He says as much at *Theaetetus* 154c.

[27]See, e.g., *Republic* 349a.

[28]We suppose that with the last phrase Plato has in mind, e.g., presenting a student with more principles of grammar than he can deal with.

[29]In light of Plato's views on the centrality of crafts in human life, an adequate theory of the crafts would articulate what is foundational to the proper conduct of all practical affairs.

[30]For a brief discussion, see DuMond and Cohen 1960, 145.

[31]The units on the scale the surveyors used were themselves fractions of a circle (Klein 1988, 114).

[32]See Klein 1988, 115.

[33]We are indebted to B. Goldstein for pointing this out to us in discussion. For examples, see Heath 1981, ch. 4.

[34]See Heath 1981, 308ff. Although we have no space to discuss it here, it is worth noting that this sort of emphasis on qualified predications of magnitude is by no means peculiar to ancient science. Newton's *Principia* contains many examples in which the determination of proportionalities takes priority over the determination of absolute magnitudes. P. K. Machamer tells us that the assignment of numerical values to physical constants doesn't seem to have been a major theoretical concern until well into the 18th century.

[35]He does not give any general specification of what taxonomic level or levels contain these kinds.

[36]In discussion at the University of Pittsburgh in 1994. Cp. Lennox 1987, 341ff.

[37]Compare Porphyry, *In Aristotelis categorias*, 124.16-125.4.

[38]This anticipates points that would become central to early 20th century discussions of what P. Geach called "Cambridge change" (Geach 1979, 90-91). Russell (1964, 469) defined change as

> the difference, in respect of truth and falsehood, between a proposition concerning an entity and a time T and a proposition concerning the same entity and another time T', provided that the two propositions differ only in the fact that T occurs in the one where T' occurs in the other.

Of course this definition is inadequate; the change in the truth value of a proposition like "Socrates is taller than Theaetetus" requires nothing more than a change in Theaetetus. We have seen that Aristotle is well aware of this. And it is remarkable that when one thing loses or gains a relative feature simply because of facts about what it is compared to, Aristotle says something comes (or ceases) to be true, instead of saying that any genuine (non-incidental) change (μεταβολή) has taken place:

> ἐνδέχεται γὰρ θατέρου μεταβάλλοντος ἀληθεύεσθαι καὶ μὴ ἀληθεύεσθαι θάτερον μηδὲν μεταβάλλον, ὥστε κατὰ συμβεβηκὸς ἡ κίνησις αὐτῶν (*Physics* V.2, 225b11-13).

In this passage Aristotle uses the notion of change in truth-value—by means of which Russell tried and failed to define all change—as part of a characterization that *distinguishes* Cambridge from genuine changes.

[39]For some details, see Bogen 1991 and 1992.

[40]What we have to say about quantitative is of course not a complete account of Aristotle's treatment of quantitative contraries, let alone of the contraries involved in any of the other categories with respect to which things change.

[41]At the very least, the size of a millet seed or a mountain must fall between the sizes of things that are large relative to it and things that are small relative to it. Aristotle needs intermediates to distinguish pairs of relatives that are contraries from pairs of relatives that are not (see *Metaphysics* X.4, 1057a37ff).

[42]A similar condition is required for intermediates, and analogous conditions must be required for contraries and intermediates in other categories. We need not and will not try to formulate any Aristotelian definiteness requirements here. Non-Aristotelian requirements of definiteness can be found in Ellis 1966 or any other standard treatise on measurement.

[43]See Bogen 1992, 17ff.ogen 1992.

[44]This is the way people define contraries according to Aristotle in *Categories* 6, 6a17-18. (Cp. *Generation and Corruption* I .7, 323b29-324a1.)

[45]For further discussion see Bogen 1991 and 1992.

[46]According to *Metaphysics* X.4, 1055a10-22, both uniqueness (7) and definiteness (8) can be secured for any sorts of contraries for which "modes of completeness" can be determined. On our reading, for any pair of contraries (quantitative, qualitative, or spatial) whose members can be possessed by things of some kind or kinds, the "mode of completeness" that secures uniqueness and definiteness for the pair is constituted by the capacities of normal members of the kind or kind in question to have features of the genus (e.g., colors, sizes, weights, etc.) to which the contraries belong. For some discussion of this, see Bogen 1992.

[47]It is not clear, however, that Aristotle's program of identifying quantitative contraries by appeal to the maximal largeness and smallness of natural kinds will succeed. In the first place, it is hard to see how appeal to natural kinds will help at all in dealing with the quantitative changes that would emerge in crafts like carpentry or weaving, say, which do not involve natural kinds in any obvious way. But there are problems even in the sphere in which Aristotle's proposal might be thought to have its best chance of

success—the growth and development of natural organisms. *History of Animals* V.15, for example, notes that the murex attains its full growth within a year (547b23-25); this sort of case fits Aristotle's proposal quite well. But it is not easy to see how the yearly increase in the convolutions of the murex's shell (547b9-11) could be explained in terms of maximal sizes: Aristotle does not suggest, for example, that the murex dies because its shell becomes too large or too heavy. Similar difficulties would be involved in dealing with the growth of so-called moles in human females discussed in *History of Animals* X.7 and *Generation of Animals* IV.7. Finally, it would be a bad joke to suppose that Aristotle could account in terms of maximal and minimal viable sizes for the growth of horns in deer (*History of Animals* IX.5), for the development of breasts in the human female (*History of Animals* VII.1, 581a31-b6), and for the enlargement of the male sexual organ during arousal (*History of Animals* II.1, 500b20-22).

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