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How to build an animal : the metaphysics of Aristotle's ontogeny

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How to build an animal: the metaphysics of Aristotle's ontogeny

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the introduction of maternal movements (as traditionally assumed), but rather from the standard interpretation of the *Generation of Animals* represented here by the first two premises. In the first place, I shall argue that premise (2) is false and must be rejected. Aristotle does not think the father's sperm literally fashions the parts of the offspring out of menstrual blood (the spermatic κινήσεις are not actual *informative* movements of the parent's genetic material). In the second place, I shall argue that premise (1) is false when understood in the broad sense to cover *all* aspects of the offspring's physical appearance, internal anatomy, physiology, and characteristic behaviour. The claim that the male alone provides the form is true only under a certain interpretation of εἶδος which is not co-extensive with the organism's phenotypic nature taken in this broad sense.[10]

Before turning to this, however, it will be instructive to first look at how commentators have traditionally responded to the charge of inconsistency. In what follows I shall take up each argument from within the received interpretation of the *GA*. Most importantly, I shall assume in line with that interpretation that the spermatic "movements" do indeed refer to actual informing movements, movements that literally shape the parts of the offspring into a new individual like a sculptor forming the parts of his statue out of bronze.

§2 Previous responses to the inconsistency charge

For Furth, the sudden appearance of female movements in *GA* 4.3 which are capable of imposing maternal characteristics on the offspring (and thus directly compete with their paternal counter-parts for the privilege of supplying the offspring with form) represents a total collapse of the tidy matter-form theory developed in the earlier books. As Furth sees it, *GA* 4.3 is nothing more than an *ad hoc* attempt on

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[10] Traditionally the form transmitted by the male is identified with the species-form. However, my argument holds whether "all aspects of the offspring's physical appearance, internal anatomy, physiology, and characteristic behaviour" is restricted to species-level properties or whether it is taken to include properties below the level of species as well.

Dedicated to my mother,
Linda Bennett, and to my
father, Bob Henry.

Abstract

How to build an animal: the metaphysics of Aristotle's ontogeny examines various interrelated themes in Aristotle's account of coming-to-be. This includes the concept of the "organism" and its role in the development of the embryo, the mechanisms underlying the transmission of biological form, and whether the fourth book of *Generation of Animals* can be understood as an attempt to formulate a genuine science of inheritance. My central thesis makes two basic claims. First I argue that one of Aristotle's most important insights was to recognise that the replication of biological form crucially depends on an ontological distinction between a creature's fully developed adult form and the underlying source of that form (what has come to be known as the phenotype-genotype distinction). Contrary to virtually all of his predecessors, Aristotle maintained that what is directly inherited by an offspring in the act of reproduction is not the phenotypic characters of the parent themselves but distinct "potentials" for their formation. Second, I argue that the source of an organism's form is part of its deep "hylomorphic" structure. This is contrary to the standard reading of Aristotle which treats artefacts as a suitable model for representing the internal structure of a biological substance: just as a statue is composed from the bronze and the shape, so too a horse is a composite of a material nature and formal nature. I argue that evidence from the biology suggests Aristotle views biological substances as having a more complex structure than artefacts in that the formal side of their nature is itself irreducibly complex.

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Abbreviations

Aristotle

PA	*Parts of Animals*
GA	*Generation of Animals*
IA	*Progression of Animals*
DA	*De anima*
GC	*Generation and Corruption*
De Mem.	*De Memoria*

Ancient Commentators

in. GC	*On Aristotle On Generation and Corruption* (Philoponus)
in Metaph.	*On Aristotle Metaphysics* (Alexander of Aphrodisias)

Introduction

This study is divided into two parts. In the first part I examine Aristotle's concept of the "organism" and its role in his account of embryonic development. In the second part I turn to the question of how exactly an organism's form is passed on to its offspring in the act of reproduction. What are the mechanisms underlying the transmission of biological form? Although I shall draw on several texts in the Aristotelian corpus, the primary focus of this study is Aristotle's ontogeny as presented in the *Generation of Animals*.[1]

Chapter one addresses what has come to be seen as the fatal paradox of Aristotle's natural teleology.[2] The paradox in question is supposed to arise from Aristotle's claim that the "nature" of a biological substance (or organism) is *both* the source *and* end of its development: it is the internal principle of motion that directs the process of development towards the adult form *and* the form of the creature when fully developed. Thus it would appear that one and the same thing ("nature") is the cause of its own existence, which is absurd. By way of introduction to the main project of part one I consider – and subsequently reject – one of the more popular interpretations of Aristotle's ontogeny, what I call "formal preformationism". According to this interpretation, Aristotle holds that the offspring's adult form pre-exists in the embryo in a state of potentiality. On this reading development becomes the gradual actualisation of a pre-existing potential form, which is transmitted to the embryo inside the father's seed.

In chapter two I develop an alternative solution to the paradox of teleology suggested by a key passage in the *Parts of Animals*. There Aristotle divides "nature understood as substantial being" (formal nature) into "nature as mover" and "nature as end" (641a27-33). What I argue is that these two natures are numerically distinct principles that stand to one another as cause and effect. Straightforwardly, nature "as end" is the adult form at the end of development while nature "as mover" is the moving cause that directs the process towards that end. Finally, I argue that by

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[1] The second half of this study is focused almost exclusively on the *Generation of Animals*, while part one is a more general philosophical discussion.

[2] This same paradox has been addressed most recently in King 2001. My own discussion of the paradox of teleology arises in part out of a dissatisfaction with King's solution.

associating these two natures with the creature's substantial being (οὐσία) Aristotle is saying that they are two distinct "parts" of a biological substance hylomorphically speaking. If this is right, then in the biology, at least, Aristotle is working with a *three-dimensional* organism concept. On this reading an organism turns out to be a composite of material nature, nature "as end" (observable form), and nature "as mover" (the genetic source of that form).[3] This is the major conclusion of part one.

In the second half of this study I turn to the question of how exactly biological forms are passed on from one generation to the next. The actual mechanisms behind the transmission of biological form are found in *Generation of Animals* 4.3 in connection with the phenomenon of inheritance. The main discussion of the second part of this study comes in chapters five and six where I discuss Aristotle's account of these mechanisms and how their operation serves to explain various patterns of inheritance (including both individual and species resemblances).[4] In chapters three and four I examine Aristotle's account of sex determination and the problem of maternal inheritance, respectively. In addition to being central topics in Aristotle's ontogeny (and thus necessary parts of any study of the *GA*) they are necessary precursors to the main discussion in chapters five and six. For example, in *GA* 4.3 Aristotle appears to assign a formal contribution to the mother, which many have come to see as being at odds with the strict reproductive hylomorphism set out in the first three books. Assuming the *GA* contains an internally coherent theory, a proper understanding of the mechanisms involved in the transmission of biological form (embodied in the phenomenon of inheritance) must begin with a solution to this problem.

Finally in chapter seven I examine two issues related to the transmission of biological form. The first concerns the on-going debate about whether or not Aristotle believed in so-called particular forms. The literature is somewhat muddled on this

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[3] I shall argue that Aristotle's division between nature "as mover" and nature "as end" prefigures the modern genotype/phenotype distinction. In this way we could express the idea of a three-dimensional organism in terms of a compound of matter, phenotype (nature "as end"), and genotype (nature "as mover").

[4] While some have portrayed *GA* 4.3 as a relatively minor part of the *GA* dealing only with individual resemblances, as we shall see, the mechanisms introduced in that chapter are explicitly connected to the transmission of species-level properties.

issue. Ultimately I think there are two different questions one could ask: Are biological forms universals or particulars? Are the contents of biological forms species- or individual-specific? Eventually I shall come down on the side of the debate which takes the form of each organism to be a particular instance of a form which includes, in addition to those features which are common to all members of the species, those that make it a unique individual. In other words, forms are both particular and individual-specific. The second issue that arises concerns the nature of teleological explanation. As we shall see, Aristotle allows that some phenotypic variation within a species may be due to the activity of an individual's productive nature (it is 'genetic'). This is not incompatible with his views in the *Metaphysics*, however, since he also claims that such differences will be excluded from a definitional account of the creature's substantial being. One of the lessons of *GA* 5 is that intraspecific variation is only subject to explanations in terms of material and efficient causes.[5] Only those features of an organism which are common to all members of the species are subject to explanations in terms of all four causes.

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[5] As we shall see efficient causality can include the activity of an individual's productive nature (its nature "as mover").

Chapter One

The Paradox of Teleology

§1 The Paradox of Teleology

In *Physics* 2.1 Aristotle famously defines a thing's "nature" as "a source and cause of change in that to which it primarily belongs καθ' αὑτό" (*Physics* 2.1, 192b20-2).[1] Again, in *Metaphysics* Δ4 nature is said to be "that whence the primary change in each natural thing originates" which is "in itself *qua* itself" (1014b18-20).[2] In the biological works (especially the *Generation of Animals* and *Parts of Animals*) nature plays a prominent embryological role as the moving cause of growth and development. *Physics* 2.8 is also about nature in this embryological sense. Virtually all the arguments in that chapter concern the development of an embryo into its adult form. For example, at 199b13-18 (cf. *PA* 641b24ff.) Aristotle says:

> Furthermore, among embryos (σπέρμασι) anything must have come to be at random [sc. if Empedocles' account were correct]. But the person who asserts this entirely does away with nature and what exists by nature. For those things are natural which, being moved continuously from a principle inside themselves, arrive at a certain end; but <the end arrived at> from each principle is not the same for every <principle>, nor is it any chance <end>, but <the movement from each principle> always proceeds towards the same <end>, if nothing prevents it.

In this text Aristotle is clearly talking about growth and development; nature is the "principle inside" the organism from which its growth and development proceed.

On the other hand, Aristotle quite often identifies "nature" with the shape and form of the organism when fully developed: it is the form *at the end* of the process of development (τὸ τέλος τῆς γενέσεως).[3] For convenience I shall continue to refer to this nature as "the shape and form" of the creature when fully developed. Determining

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[1] Unless otherwise indicated, all translations are my own.

[2] I shall return to "καθ' αὑτό" and "in itself *qua* itself" later on. I shall argue that both of these mean that the nature in question is partially constitutive of the biological substance itself: it is a "part" of the substance, hylomorphically speaking.

[3] *Metaphysics* Δ4, 1015a3-11 (translated in chapter two below).

precisely what is the form of a biological substance is ultimately subsidiary to my main project, which is an analysis of the hylomorphic structure of biological substance as such. Although strictly speaking biological form is soul, which is to say, the set of characteristic life functions proper to an organism, in the *Parts of Animals* biological form is identified with "the differentiae in the matter" (643a24). This is a much richer conception of biological form than we find in the *De anima* and is meant to include, not only the characteristic functions of an organism (e.g. the capacity to swim, the capacity to fly, etc.), but its functional structures as well (e.g. webbed-feet, wings, etc.).[4] It is in this sense that I shall speak of the nature at the end of a creature's development as its adult "form".[5]

As we shall see, this richer concept of biological form is well-suited to the *Generation of Animals*, which is overwhelmingly occupied with the development of shape and structure rather than simply life-capacities or "soul". In fact Aristotle only considers the question of where the offspring's soul comes from in one chapter, *GA* 2.3, and even then the question only arises in connection with a puzzle about what happens to the physical part of the sperm. Although it is certainly important that the structures that do develop have soul (they are *functional* structures), my point is that Aristotle's embryology is not so much interested in the emergence of different life-capacities as it is in the emergence of complex patterns of structural organisation (the differentiation of the κύημα into various parts).

Many scholars have come to see this dual characterisation of nature as the fatal paradox of Aristotle's natural teleology:

> Form also provides the link between the mature and the immature organism. The growth of an organism is, for Aristotle, a process

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[4] At 644b7-9 Aristotle says that animals are primarily grouped together according to the structure of their parts (τοῖς σχήμασι τῶν μορίων). This suggests that in the biology species-forms are partially morphological in nature rather than strictly functional. Contrast *DA* 2.2, 413b33-414a2 (cf. 414a29ff.) where animals are individuated solely in terms of their different combinations of life-capacities or souls.

[5] In order to avoid any unnecessary complications at this stage I shall postpone the question about whether biological forms are species- or individual-specific. I take this up in chapter seven. The answer to that question will not affect anything I have to say here.

directed toward an end (τέλος): the mature functioning organism. The mature functioning of the organism is 'that for the sake of which' the process of growth has occurred. And yet Aristotle also identifies an organism's nature with the end or the 'that for the sake of which.' Again there is an air of paradox. If an organism relies on its internal principle of change [= nature] in order to reach its end, how could this end, which did not exist during the process of growth, be identified with the organism's nature?[6]

> Now it may be said that despite the close dependence... between nature as principle of change, and the developed structure, Aristotle exceeds his warrant in concluding that the former *is* the latter, since by the very terms of the argument, the latter is the *result* of the former, and is not always actually present at the same time. This indeed is perhaps the main difficulty surrounding the Aristotelian concept of 'form', which in a living thing at any rate is supposed somehow to comprise both efficient and final causes of the substance's natural behaviour. How can what something is to be, which it necessarily is not yet, *be* what brings about the present process towards what is to be? Writers sympathetic to Aristotelianism do not succeed in explaining this to those who are not.[7]

The paradox of teleology is supposed to arise from the fact that an organism's nature is *both* the source *and* end of its development, *both* that which directs the process towards the creature's fully developed form *and* the form of the creature when fully developed. Thus one and the same thing ("nature") becomes the cause of its own existence, which is absurd. Moreover, it seems to imply a sort of finalism where the form at the end of development acts as an efficient cause somehow driving (or

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[6] Lear 1990, 19. See also (same page): "The development of form, as an organism grows to maturity, is a process *internal* to the organism itself. But an organism's internal principle of change is its nature. An object's nature would thus seem to be a developmental force which impels it *toward* the realization of its form. How then can Aristotle identify an organism's nature with its form?" (emphasis Lear's).

[7] Broadie 1982, 65 (emphasis Broadie).

pulling?) the process towards itself so that it terminates in that end. But how can an organism's formal nature influence its development if it does not have that nature until the end of that change (1015a3-11)?[8] Finalism has long since been rejected by philosophers and scientists alike on the grounds that moving causes must come before their effects. From this perspective the charge that is most often levied against Aristotelian teleology is that it involves a strange notion of backwards causation.[9]

Solving the paradox of teleology is not a primary goal of this study. Rather, my project here is to examine Aristotle's concept of a biological substance or "organism" and its role in his ontogeny as presented in the *Generation of Animals*. Resolving the paradox will simply be an upshot of this. I am compelled to deal with the problem in the first place because, historically at least, it has been seen as one of the main reasons for rejecting Aristotelian teleology. I am compelled to introduce the problem *here* because once we appreciate that an organism's formal nature is (so I shall argue) irreducibly complex, the paradox of teleology becomes much harder to motivate. However, by way of introduction, it will be useful to look at an interpretation of Aristotle's ontogeny that some find an attractive way out of the paradox.

§2 Formal Preformationism

As I have said, the main problem traditionally associated with Aristotle's natural teleology is understanding how the offspring's adult form, which he identifies as its nature, can be responsible for the process of its development given that it is not present until the end of that process. One way commentators have tried to reconcile this while attempting to preserve the idea that a thing's formal nature is both the

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[8] King treats finalism as a separate problem from what he calls the problem of the effectiveness of a form which is not present (2001, 23-6). For King the real problem is that the organism's formal nature is not present until the end of development. He argues that finalism is an artefact of our attempt to solve this problem by turning Aristotle's final cause into an efficient cause (24). However, as we shall see, in the biological works especially the formal nature acts as a moving cause. So finalism, if it is a problem at all, is *Aristotle's* problem.

[9] Calow 1967, 17-18. For a good discussion of this charge see Gallop 1988, 257-90 *n.* 1.

source of the process of development and the form in which that process terminates is by denying that the form is not present until the end of development. According to this interpretation, which I shall call "formal preformationism", Aristotle holds that the shape and form of the adult organism pre-exists in the embryo in a state of (unactualised) potentiality. Development on this reading is simply the gradual actualisation or fulfilment of that pre-existing potential form.

The example that is most often associated with this interpretation is the oak tree/acorn example, captured in the following passage by Ronald de Sousa:

> …substances, which is to say *natural objects*, are structured by an inherent teleology (*Met.* Z9, 1034b11). Thus the oak exists potentially in the acorn, and becomes actualized when the acorn grows into the tree; but the actual oak is prior to the acorn in virtue of the general priority of actuality over potentiality (*Met.* Z13, 1038b27). So the nature of any substance involves a natural development in the course of which potentiality flowers into actuality.[10]

Formal preformationism is what you get when you adopt a realist interpretation of the claim that the oak (or, rather, its form) pre-exists in the acorn. The form of the oak tree *really is* in the acorn, only it is in a state of potentiality: it is a latent or not-yet-actualised form. The coming-to-be of the oak is the process in which that potential form "flowers into actuality". This interpretation goes all the way back to Alexander of Aphrodisias.[11] According to Dooley, Alexander "identifies nature, defined as an intrinsic principle of movement, with the enmattered form, i.e. soul, present only in potentiality in the seed of the generator, but actually present in the <adult> animal".[12] More recently formal preformationism has been vigorously defended by Jonathan Lear:[13]

> The form in the young healthy organism is an internal force propelling it toward the realization of its form. This is not as paradoxical as it

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[10] de Sousa 2001, 268. Note, however, that the infamous oak/acorn example is not found anywhere in Aristotle.

[11] See, e.g., Alexander *in Metaph.* 359,30-3; 360,4-6; 9-13; 375,23-5.

[12] Dooley 1993, 132, *n.* 32 (cf. 137 *n.* 79 and 80).

[13] See also Katayama (1999, 91 and 150 *n.* 45) and Witt (2003, 70). According to Witt Aristotle holds that the adult form "really exists in the seed, but only potentially".

might initially appear, for when the organism has reached maturity, its form will no longer be a potentiality. In the mature organism, the form exists as a full-fledged actuality. In the growth of an organism, form is itself developing from potentiality to actuality, and it is directing this process.[14]

Of course, the existence of potential form at the beginning of a developmental process is due to the antecedent existence of actual form. In natural generation, the potential form of the child is due to the actual form of (one of) the parents being passed on in sexual reproduction.[15]

> The form of a man, say, comes from the male parent, and in virtue of the possession of this form we can say of the seed that it is a man (potentially). What we mean by this is that if the seed is implanted in a female's womb it will in ordinary conditions develop into a human being. The form exists antecedently to the generation of the natural substance and endures to become the form of that substance. In the process, though, it changes from being potentially the form of a substance to being actually the form. The matter too persists through this change, yet it cannot be regarded as the subject of change on its own. If the matter which existed in the seed antecedently to the generation were not informed by human nature (as a power or potentiality) it could not change into a human being.[16]

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[14] Lear 1990, 19; cf. 61: "Because change is the actualization of a potentiality, the entire change will be directed toward its fulfilment. And the change will cease as soon as the potentiality has developed to an actuality."

[15] Lear 1990, 40.

[16] Lear 1990, 60. There are several inaccuracies here which I shall largely ignore. For example, Aristotle does not think the father "implants" his sperm in the female which then grows into the offspring like a seed planted in the soil. This naïve "flower-pot" model is inconsistent with the *GA* theory: it is the menstrual blood of the female, not the sperm of the male, that develops into the new organism.

I will take Lear's interpretation as representative of formal preformationism. This interpretation consists of three main claims:

1) Aristotle posits a single "nature" (identified with the shape and form of the adult) which exists at varying levels of potentiality and actuality. At the start of development the offspring's form (or "nature") pre-exists in the embryo in a state of potentiality; at the end of the process the form is no longer in potentiality but exists as a "full-fledged actuality".

2) During development the form itself develops from potentiality to actuality so that at every point along the way there will be a ratio of potential (not-yet-actualised) form to actual form.

3) The potential form which exists antecedently in the embryo is the result of the father's actual form (somehow) being passed on to it in the act of reproduction inside the father's sperm.

This is supposed to resolve the paradox of teleology because the "nature" in the embryo (which is implanted in it by the father) *is* its adult form pre-existing in a state of potentiality.

Although there is a substantial amount of literature already devoted to Aristotle's distinction(s) between potentiality and actuality, it will be useful to begin with an analysis of the concept of potentiality.[17] The reason for this is that both Lear and I take the nature which pre-exists in the seed to be a potentiality of some sort; however, we differ in what kind of potentiality this is. I take the nature in the embryo to be a δύναμις in the sense of an active potential (a causal power). For Lear, this nature is a latent or not-yet-actualised form that flowers into actuality (as de Sousa

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[17] In what follows I shall largely ignore the distinction between levels of potentiality and actuality set out in the *De anima*. The *GA* does not make any use of the distinction between first-potentiality, second-potentiality/first-actuality, and second-actuality (see Balme 1972). Most notably, the key concept of the *DA* model, that of a first-actuality which is also a second-level potentiality, plays no role in the *GA* account of ontogeny. (For an alternative view see Code 1987, 51-9.) In what follows I shall mostly confined myself to the concept of potentiality in the *Metaphysics* (though what I have to say here is compatible with the *DA* account).

puts it).[18] I shall argue that Aristotle's ontology does not countenance such potential forms. The two main sources of this assumption appear to be the analysis of potential-being in *Metaphysics* Θ7 and the definition of change in *Physics* 3.

§3 Potentiality in *Metaphysics* Θ7

Aristotle not only thinks that we can make claims of the form "*x* is an *F*" in the sense that *x* is actually *F*, but also claims of the form "*x* is a potential *F*". According to Frede, the truth of such claims depends on an underlying assumption about reality: Aristotle not only assumes that there are *actual* beings (e.g. actual houses and actual frogs); there are also *potential* beings (e.g. potential houses and potential frogs).[19] These potential beings, Frede argues, form part of the furniture of Aristotle's world. In what does this potential-being consist? That is, in virtue of what do we say of a tadpole that it *is* a frog potentially or that it *is* a potential frog?

Formal preformationism can be seen as one way of answering this question. On this reading, the property that makes the tadpole a potential frog is the very same property that makes the thing at the end of development an actual frog, namely the possession of a characteristic shape and form. And this is the nature of a frog (e.g. Z17, 1041b4-9, 25-31). According to formal preformationism, this same nature exists in the tadpole in potentiality and in the adult frog in actuality. There is a certain intuitive appeal to this answer. If being an actual frog consists in having the actual shape and form proper to a frog, then we might expect Aristotle to say that being a potential frog consist in having that very same shape and form, only in a state of potentiality. One of the places Lear seems to find this is in the discussion of potential-being in *Metaphysics* Θ7.

The question Aristotle asks in Θ7 is when the matter (the subject of change) is potentially *F* and when it is not. The analysis of potential-being in the case of artefacts

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[18] Although Lear sometimes speaks of the nature pre-existing in the embryo as a "power", mostly he takes it to be a latent or not-yet-actualised form. It is the latter idea that I am concerned with. (I think Lear has actually confused the two senses of "potentiality" discussed in *Metaphysics* Θ.) In what follows I shall take Lear as representative of the view I am targeting insofar as he treats the nature that pre-exists in the embryo to be a potential (latent) form.

[19] Frede 1994, 173.

is relatively straightforward. Here the matter is said to be potentially *F* "when nothing has to be added or removed or changed" (1049a10-11). Earth is not yet potentially a statue of Hermes because it still needs to be changed into bronze before it is in a condition where a statue can be directly formed out of it (a17-18). Likewise, cement mix is not yet a potential foundation because we still need to add water before it is in a state where it can be used by the builder to make a foundation. Again the idea is that a foundation comes to be directly out of cement, not cement mix.

What Aristotle wants to say in the case of naturally generated organisms (those cases "where the thing has the source of generation in itself", 1049a13) is much less clear. Is an apple potentially a human being?[20] Aristotle answers: No, but only when it has become human seed (σπέρμα), though perhaps not even then (a1-3). Eventually seed is eliminated as a candidate for being a potential human, since it must undergo a further transformation in another (a15-16). It is potentially a human only when it is in such a condition where, in the absence of anything external impeding it, it will straightaway develop into a human being through its own principle (διὰ τῆς αὑτοῦ ἀρχῆς, a15-16). The difference between the seed in this state and the seed in the previous state (i.e. when it was not yet potentially a human) is said to be the fact that in its previous state it still needed "another ἀρχή".

One of the things that makes Aristotle's analysis of potential-being for organisms rather difficult to follow is that it seems to depend (at least to some extent) on the particular details of the theory of reproduction behind it. For example, "σπέρμα" (in some state) is eventually eliminated as a candidate for being a potential human on the grounds that it must undergo a further transformation in another and acquire "another ἀρχή". The problem is that "σπέρμα" (especially in the biological works) is ambiguous between the father's sperm, the mother's menstrual blood, and the embryo. (I use "seed" as being neutral between these three alternatives.) Likewise "ἀρχή" has several meanings (see, e.g., *Metaphysics* Δ1). And so we cannot be entirely sure what that other ἀρχή is that the σπέρμα must acquire before it counts

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[20] Aristotle uses the example of earth here; however, I think the point is better served using the food a human being consumes which is converted to σπέρμα through a series of changes. For the significance of this see below.

as being a potential human. Any combination of possible meanings for σπέρμα and ἀρχή alone could yield a wide variety of interpretations of Θ7.

However, even without knowing what Aristotle means by σπέρμα, it is easy to see how one might arrive at formal preformationism from reading Θ7. Aristotle says that σπέρμα is not yet a potential human because it still needs to secure another ἀρχή. On one interpretation of this text, it is the possession of this ἀρχή that makes the σπέρμα a potential human. According to Lear, this ἀρχή will be the offspring's potential form: "The form of a man, say, comes from the male parent, and in virtue of the possession of this form we can say of the seed that it is a man (potentially)." Thus, what makes the σπέρμα a potential human being is the possession of a potential form.

One disadvantage of this reading is that Θ7 turns out to be incompatible with Aristotle's position in the *Generation of Animals*. In the *GA* potential-being is cashed out solely in terms of an organism's species-specific matter. In several places Aristotle insists that unfertilised menstrual blood is already potentially an animal of the same kind as the mother herself (e.g. *GA* 737a22-5, 738b3-4, 740b18-20, 741b7-8; cf. 729a32-3). Yet, this is not because menstrual blood already contains a potential form (for one thing the father is supposed to provide the offspring's form). Rather, the female's menstrual blood is potentially the same kind of organism as herself because it is the type of material which is capable of being formed into that kind of organism. On this account each female's species-specific menstrual blood has a determinate potentiality associated with it in virtue of the fact that it can be made into that specific kind of organism and nothing else.

Aristotle's position on potential-being in the *GA* is compatible with at least one interpretation of Θ7. On this reading Θ7 analyses potential-being in terms of necessary and sufficient conditions: under what conditions is *x* capable of being made into an *F* through a single process of change?[21] In the case of art, some matter *x* is

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[21] This reading is suggested by Frede 1994. Frede argues that what counts as a potential *F* is determined in part by what *single* process of change there is that would transform the material subject into an actual *F*. And this in turn is supposed to depend on the presence of an active potential that would govern and explain that change (190; cf. 177).

potentially *F* when it is such that nothing further needs to be added, removed, or changed before the product can be formed directly out of it by the appropriate causal agent. In natural generation, being in a state where nothing further needs to be added, removed, or changed is necessary but not sufficient for being the potential *F*. The material must also have the generative principle in itself, since a naturally generated embryo must be able to develop of its own accord.

It is important to note that Θ7 does not say anymore than this. In particular, it does not tell us *what makes* the matter potentially *F*, only *when it is* potentially *F*. At what point in the causal history of the matter (taken as the underlying subject that persists through several changes) do we have a potential *F*? If this is right, then the way of phrasing the question about potential-being above was in fact misleading. The question is not 'What is that single property in virtue of which a tadpole is a potential frog?' but 'Under what conditions is frog-matter such that it will develop into a frog through its own agency if nothing external impedes it?'.

Reading the text in this way reduces the tension between Θ7 and the *GA*. For the idea that the matter must be in a state where it is capable of being formed into an *F* remains central to both accounts. Θ7 can simply be read as offering a more robust set of criteria for being potentially *F* in which the matter must be in a state where it will *immediately* develop into an *F* of its own accord if nothing external prevents it. As it turns out unfertilised menstrual blood fails this condition, since something must be added, removed,[22] or changed before it is in that state. In this way Θ7 is not antithetical to the *GA* (as it would be on the formal preformationist reading) but simply offers a different answer to the question of when we have a potential human.

Making Θ7 and *GA* compatible does of course require a minor correction to the former. It is fairly certain that "σπέρμα" in Θ7 refers to the male sperm. For instance, at 1049a14-15 Aristotle says that σπέρμα is not yet potentially a human because it must undergo a further change "in another". "In another" here can really only mean "in the female" and so σπέρμα must be male seed. As many commentators have noticed, this is not Aristotle's view in the *Generation of Animals*. The *GA* is categorical that the mother's contribution is the thing that develops into the new organism after being catalysed by the heat in the father's sperm (which then

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[22] cf. 728a26-30.

evaporates). However, I think this inconsistency is much less problematic than commentators have generally made it out to be. What is likely is that Aristotle is arguing dialectically in Θ7; he simply employs what he knows to be the wrong theory of reproduction without actually endorsing it. This flower-pot model, according to which the male implants his seed in the female where *it* grows into the offspring like a seed planted in soil, would have been fairly common at the time. Nevertheless, I think Aristotle's point in Θ7 can be made just as easily by taking σπέρμα there as menstrual blood (in accordance with the *GA* theory). For example, when Aristotle first says that even σπέρμα may not yet be potentially a human we can read this as *unfertilised* menstrual blood (what the *GA* identifies as the potential human). When he later says that even this is not yet potentially a human because it needs another ἀρχή (1049a16-17), he would be saying that only *fertilised* menstrual blood (what we would call the zygote) is a potential human being. The point then is that it is only after being fertilised by the male that the material supplied by the female is such that it will straightaway develop into a human being of its own accord (if there are no external impediments).

When Θ7 is read as offering a set of necessary and sufficient conditions for determining when a thing is potentially *F*, the analysis of potential-being there actually turns out to be much less theory-dependent than previously suggested. For it does not matter what theory of reproduction one actually employs; whatever it is in that theory that satisfies those conditions will count as being *F* potentially. Indeed, when we pull out the criteria from Θ7 and apply them back to the *GA*, we get a very different answer to the question of when something is potentially a human than any offered so far. For example: Is male sperm a potential human being? No, according to the *GA*. For although it contains a principle of generation in itself, it will not *under any conditions* develop into a human. For seminal fluid is not the material out of which the offspring develops. Yet, neither would unfertilised menstrual blood. For although it is the material out of which the offspring eventually develops, it is not yet in a state where it will develop into a human being of its own accord when nothing external is obstructing it. It must still undergo further change before reaching that point. The same applies to fertilised menstrual blood. It is only when the creature's embryonic heart has been differentiated that we now have a potential human. For

according to the *GA* it is then, and only then, that the embryo will develop into a human being *of its own accord*, if nothing external prevents it.[23]

For convenience I shall continue to speak of menstrual blood as the candidate for being a potential *F*. Even if we apply the criteria from Θ7 and call the embryo a potential *F* only when its heart has been differentiated, it will still be in virtue of its material nature (its being composed of a species-specific matter) that it is a potential *F*. Speaking of the menstrual blood as the subject (ὑποκείμενον) of the change emphasises the fact that we are talking about the embryo's material nature.

Taking Θ7 as providing a set of necessary and sufficient conditions for determining when something is a potential *F* also offers a genuine alternative to the formal preformationist reading of that chapter. On this alternative, Θ7 asks under what conditions menstrual blood is potentially a human being. According to Lear, menstrual blood would be a potential human in virtue of (actually) possessing a potential human form, which is implanted in it by the father's sperm. If the menstrual blood were not informed by this human nature, it could not change into a human being.[24] However, the male's formal contribution is a necessary *but not* sufficient condition for being a potential human. Having the principle which comes from the male inside it is necessary if the female's material is going to be able to develop into a human being of its own accord. However, it is also necessary that it be the right kind of material. If the possession of a potential human form supplied by the male were necessary *and* sufficient for being a potential human (as it is on the formal preformationist reading), then the male would be able to generate a human being by fertilising the menstrual blood of any animal whatsoever. Thus, even if we grant that unfertilised menstrual blood still needs to acquire a potential human form from the male sperm before it is potentially a human (assuming this is what Aristotle means by saying σπέρμα needs "another ἀρχή"), it will not be the male's formal contribution *itself* that makes the menstrual blood a potential human. Human-specific matter from the female is also a necessary condition for this. For the human form can only be actualised in the sort of material which is capable of being formed into a human.

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[23] See *GA* 2.1, esp. 735a12ff. I shall have more to say about this important argument in chapter four.

[24] Lear 1990, 60.

The formal preformationist reading of Θ7 is even less plausible than I have so far allowed. The crucial bit of text for this reading is Aristotle's claim at 1049a16-17 that σπέρμα needs another "ἀρχή" before it is potentially a human being. According to the formal preformationist interpretation this ἀρχή is the offspring's potential adult form. Understood this way, Aristotle is saying that σπέρμα is not yet potentially a human being until it secures this potential form from the male. However, there is certainly nothing in the text itself that would suggest that the other ἀρχή the σπέρμα needs before it is a potential human refers to the offspring's adult form in a state of potentiality. In fact, the dialectical nature of Aristotle's argument in Θ7 tells against this reading. What Θ7 actually says is that the father's sperm needs to acquire another ἀρχή before it is potentially a human being. And none of Aristotle's opponents would accept that what the father's sperm still needs to acquire is a potential human form from the female. The flower-pot model assumes that the sperm already possesses all it needs to become a human being except for a suitable environment and a steady supply of nourishment, both of which are supplied by the female.

A much better translation of ἑτέρας ἀρχῆς would be "another starting point" or "another beginning". The idea, then, is that something else needs to happen to the matter (something must be added or removed or changed) before we are at the point from which the process of development commences. This interpretation of ἑτέρας ἀρχῆς makes sense if we consider all of the transformations that an organism's food must undergo before it is finally in a state where it will, without further ado, develop into an organism of the same kind through its own agency.

There is some material out of which a new organism directly comes to be. On the *GA* theory, the offspring is formed directly out of menstrual fluid.[25] Menstrual fluid is in turn formed out of a surplus of the mother's nutritive blood, which is itself the product of another process, namely digestion. And the process of digestion begins from the food the mother consumes. Each process in this chain starts from some raw material which is the product of another process: digestion starts from the apple the mother eats and converts it to blood; spermatogenesis starts from the surplus of blood which is the product of digestion and converts it to menstrual fluid; development

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[25] It makes no difference here whether we take the menstrual blood to be the thing that develops into the new individual (*GA*) or the male sperm (Θ7).

starts from menstrual fluid (in some state) which is the product of spermatogenesis and transforms it into a completely new organism. If I am right, then what Aristotle is suggesting in Θ7 is that unfertilised menstrual blood is not yet potentially a human being because it must still undergo a further change. That is, it needs to reach another *starting point* (ἑτέρας ἀρχῆς). This interpretation makes much better sense of the comparison Aristotle draws with art at 1049a17-18: just as seed is not yet potentially a human being because it needs another starting point, so too, Aristotle says, earth is not yet potentially a statue until it is changed into bronze. This is because the process of sculpting *begins* from bronze not earth.[26]

§4 Two senses of potentiality

Before turning to the other source of formal preformationism (Aristotle's analysis of change in *Physics* 3), I first want to draw attention to the distinction between two senses of potentiality discussed in *Metaphysics* Θ. This distinction is important to the interpretation of Aristotle's ontogeny I am proposing because both Lear and I take the nature which exists antecedently in the embryo (which Aristotle identifies as the source and cause of its development) to be a potential of some kind. On my reading, the embryo's productive nature is an active δύναμις: it is a potential for the formation of an organism of a determinate shape and form. On Lear's reading, the nature in the embryo *is* that shape and form pre-existing in a state of unactualised potentiality. Taking nature to be an active δύναμις versus a potential (not-yet-actualised) form are two very different ways of understanding the concept of potentiality. We do not find anything in *Metaphysics* Θ corresponding to the idea of a potential form that "flowers into actuality" (as de Sousa puts it).

In *Metaphysics* Θ Aristotle distinguishes two senses of potentiality: (1) active and passive potentials; and (2) the sort of potentiality whose fulfilment is change.[27]

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[26] This seems to be Aristotle's point at 1049a21-2 where he says that it is always the last term in the series (τὸ ὕστερον) that is more properly potentially *F*.

[27] The sorts of causal potentials included under (1) are further divided into rational and non-rational δυνάμεις in Θ2. I shall ignore this here. Active and passive δυνάμεις are discussed in *GC* 1.7 and more extensively in *Meteorologica* 4, esp. chp. 8-11. Although I occasionally refer to potentiality (1) as a "causal power", I prefer

This distinction is set out somewhat obscurely in Θ6, 1048b6-9 in terms of how each is related to actuality. The first sense of potentiality, which is discussed in Θ1-2, is "the potential for acting and being acted upon" (1046a19-22; cf. Θ8, 1049b4-11). Here actuality and potentiality are said to be related as building to the art of building or seeing to sight (1048b1), or in general as change to the potential for causing/suffering that change.[28] The other sense of potentiality, which is the primary target of Θ (1045b35-1046a4), is discussed in Θ7.[29] This sort of potential-being is said to be related to actual-being as bronze to the statue formed out of the bronze or wood to the ship built out of the wood (1048b3-5), or in general as a certain sort of matter to οὐσία (b9).[30]

(active/passive) "potential". For one thing Aristotle uses the same word δύναμις for both senses of potentiality (his point in Θ being that the concept has this two-fold meaning). For a good discussion of the causal sense of δύναμις (potentiality (1)) see Gotthelf 1987, 215-17.

[28] Although Aristotle will go on to distinguish an activity (ἐνεργείᾳ) from a process of change (κίνησις) in Θ6, this is not the ἐνεργείᾳ/κίνησις opposition he has in mind here. In *DA* 2.5, for example, Aristotle says that change or motion is a kind of activity (417a17).

[29] Change is defined in *Physics* 3 as the fulfilment of the matter insofar as it is potentially *F*. And what Θ7 tells us is when matter *is* potentially *F*.

[30] The matter in question is the raw material at the start of the process (τὸ ἀνέργαστον, 1048b4), the unsculpted bronze and the pile of wood, whereas the οὐσία is the finished product (τὸ ἀπειργασμένον). It is important to distinguish this sort of potential-being from the passive δυνάμεις that belong to the matter (the potentials it has for being acted upon). To be sure, the materials out of which a ship is built have certain passive potentials associated with them. For example, the iron has a passive δύναμις in virtue of which it is capable of being liquefied when exposed to fire. And each of these causal powers will contribute in some way to the production of the ship. However, the process of ship building (the change) is not the fulfilment of *those* passive potentials but of the materials' (collective?) potentiality to be that product.

Ship building offers a good example for illustrating the distinction between these two kinds of potentiality. The process of ship building (the change) is the actualisation or fulfilment of the wood's potential to be a ship (potentiality (2)).[31] The art of ship building, on the other hand, is an active power in the builder: it is a potential for the formation of a ship (potentiality (1)). Although Aristotle holds that the *actuality* of the builder's potential to build a ship (the art) and the *actuality* of the matter's potential to be built into a ship are "one in being" (*Physics* 3.3, 202a17-21), the potentialities themselves are nonidentical. First, the potential to be a ship belongs to the materials out of which the ship is built; the art is an active potential or causal power in the builder. Second, and more importantly, the potentiality of the matter (the potential to be an *F*) is exhausted at the end of the change whereas the active potential in the builder is preserved through the change.[32]

On my interpretation of Aristotle's ontogeny there is an extremely close analogy between the production of a ship and the development of an organism into its adult form. The potentiality of the menstrual blood to be a human is analogous to the potentiality of the wood to be a ship. This potentiality is the *material* nature of the embryo (see below). The development of the embryo into its adult form – the change – is the fulfilment of *that* potentiality (or rather, of the matter *qua* potentially human). On the other hand, the nature in the embryo that Aristotle identifies as the source of growth and development is an active δύναμις; it is the analogue of the art of ship

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[31] Below I shall argue that it is in fact misleading to speak of change as the actualisation or fulfilment of *a potentiality*. Properly speaking, ship building is the fulfilment of *the wood* insofar as it is potentially a ship. This is not to say that the wood does not have the potential to be a ship. The point is that we must be careful not to mistake this for a separate potential *in* the wood such that change is that actualisation of *that* potential. I shall continue to speak in terms of the matter's potentiality to be an *F* with the understanding that we are not talking about anything over-and-above the matter insofar as it is potentially an *F*.

[32] See Kosman 1984. (Kosman's "kamikaze" potentiality is what I take to be potentiality (2).) The latter distinction underwrites Aristotle's discussion in *De anima* 2.5.

building.[33] If this is right, then there is a nonidentity between the menstrual blood's potential to be a human (the embryo's material nature) and the active δύναμις *in* the menstrual blood which is a potential for the formation of a human (the embryo's productive nature). For unlike the potentiality of the menstrual blood, which is used up in the course of becoming a human, the productive nature that transforms the matter into a human is preserved through that change and eventually transmitted to another embryo in the act of reproduction.[34]

On Lear's interpretation, however, the nature in the embryo that Aristotle identifies as the source of change is simply the offspring's adult form pre-existing in a state of unactualised potentiality. Development is the fulfilment of *that* potentiality. On this model the pre-existing form itself develops from potentiality to actuality. Understood in this way, however, natural generation cannot be assimilated to the craft model in any straightforward way. For there will be no analogue for this nature in the case of art.[35] The nature in the embryo will not correspond to the builder's art. For the builder's art does not pre-exist in the wood and become the form of the ship at the end of the process; the art does not change from being potentially the form of a ship to being actually the form of a ship (the form in the matter). And yet neither will it be analogous to the wood's potentiality to be a ship. For the coming-to-be of a ship is not the actualisation of some latent or not-yet-actualised ship-form implanted in the wood

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[33] cf. Θ8, 1049b8-10. At *Physics* 2.8, 199b26-30 Aristotle compares the nature in the embryo to the ship building art in the wood ("if the ship building art were in the wood, it would produce the same result naturally"). The analogy between the embryo's nature and the craftsman's art is also exploited in several passages in the *GA* (a good example is 740b25-741a3, translated below). In other texts Aristotle compares the father's nature – which I shall argue plays a different role in generation – to the craftsman's art (as at *GA* 730b8ff.).

[34] The relation between the potential for the formation of an organism (the productive nature) and the other active potentials at work in development such as the capacity of heat to solidify certain kinds of material substances is an extremely complex issue. Is the former reducible to the sum of the latter or is it something over-and-above them? I shall remain neutral on this question. For a good discussion of the issue see Gotthelf 1987.

[35] Compare the following with Lear 1990, 60 (quoted above).

by the builder. So if nature is a "potential form" pre-existing in the embryo, then it must be a completely different kind of potentiality than either of the two discussed in *Metaphysics* Θ (both of which are found in the case of art).[36]

§5 Change in *Physics* 3

The other main source for Lear's formal preformationist interpretation is his understanding of how the concept of potentiality figures into the analysis of change. On Lear's interpretation, the development of an organism is the actualisation of a potential form. This way of understanding Aristotle's ontogeny is supposed to be justified by the definition of change in *Physics* 3. According to Lear, Aristotle defines change as the actualisation of a pre-existing potentiality ("the actualizing of potential being as such").[37] When Aristotle's definition is understood this way, it is extremely tempting to think of biological development simply as the actualisation of a pre-existing potential form implanted in the menstrual blood by the father's sperm.

I think Lear has misread the text in an important way. It is misleading to speak of change as the actualisation or fulfilment of *a potentiality* (a separate entity inside the matter). Properly speaking, change is the actualisation of *the matter* insofar as it is potentially *F*. The process of becoming hot provides a good example for illustrating the way potential-being (of the Θ7 variety) figures into Aristotle's account of change.

Something that is actually cold is also potentially hot. Heating is not the actualisation of a distinct potentiality *in* that thing; rather, it is the actualisation *of that thing*, not insofar as it is actually cold but insofar as it is potentially hot.[38] Likewise, sculpting is not the actualisation of a potential form *in* the bronze; rather, it is the actualisation *of the bronze*, not insofar as it is actually bronze but insofar as it is

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[36] It is worth pointing out here that the two senses of potentiality in Θ can be mapped onto the *DA* model. Active and passive δυνάμεις corresponding to first-actualities (capacities), while the sort of potential-being discussed in Θ7 corresponds to a first level of potentiality (which the *DA* identifies with the matter's potential to acquire a capacity).

[37] Lear 1990, 60.

[38] Note that the cold thing is not potentially hot because there *really is* heat existing in the cold thing in a state of potentiality (some kind of latent or not-yet-actualised heat). Cold is the privation or absence of heat (*GA* 743a36).

potentially a statue. Applied to natural generation, the development of a horse is not the gradual actualisation of a potential equine form implanted in the menstrual blood by the sperm; rather, it is the actualisation *of the menstrual blood*, not insofar as it is actually menstrual blood but insofar as it is potentially a horse. What Θ7 provides is a set of necessary and sufficient conditions for determining when equine menstrual blood *is* potentially a horse.

Taking development to be the actualisation of the menstrual blood rather than a potential form implanted in the menstrual blood makes much better sense of the association between matter and form, on the one hand, and potentiality and actuality, on the other. For Aristotle, matter *is* potentiality: it is the potentiality to be and not-be (Z7 1032a20-2, *GC* 2.9 335b5).[39] In contrast to this, Lear associates form with both actuality and potentiality. For even if Lear accepts that it is the matter which is potentially an *F*, he insists that it is the possession of a potential form that makes it a potential *F*. But there is no evidence that Aristotle's ontology even countenances such potential forms. In fact, the very idea of a *potential* form is unintelligible in Aristotle's metaphysics. Throughout *Metaphysics* H, for example, it is argued that form is actuality.[40] This alone is enough to make formal preformationism an extremely implausible interpretation of Aristotle's ontogeny. Nevertheless, it has exegetical value for making my own interpretation explicit by way of contrast. Thus I shall continue to draw on it throughout this study at various junctures.

§6 Summary conclusions

I began this chapter by pointing to the paradox of Aristotle's natural teleology: the idea that the creature's "nature" is both the source (ἀρχή) and end (τέλος) of the process of its development. As we can see, the paradox only arises if one assumes that Aristotle is referring to numerically the same principle (the shape and form of the adult). In that case a thing's nature turns out to be the source and cause of its own existence, which is absurd (nothing can stand to itself as both cause and effect). The

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[39] The distinction between the potentiality to be, on the one hand, and the potentiality to not-be, on the other, seems to be significant for the distinction between generation and destruction.

[40] This is explicitly stated in *Metaphysics* H6, though form and actuality are used almost interchangeably throughout H.

formal preformationist solution denies that there is this causal relation and instead identifies nature with one ontological item – the creature's adult form – in two states of being. This form exists in the embryo *in potentiality* and in the adult *in full-fledged actuality*. In the next chapter I shall propose an alternative solution to the paradox. I shall argue that when Aristotle says that "nature" is both the source *and* end of development he is referring to two numerically distinct principles (both of which are called φύσις). In that case there would be nothing strange in identifying the principle that initiates and controls the embryo's development into its adult form with its "nature". For nature in this sense does not refer to that fully developed adult form. This reading preserves the causal relation between nature in the sense of inner principle of change and nature in the sense of fully developed adult form (the former is the productive source of the latter) and simply denies that "nature" refers to numerically the same principle. In the course of setting out this solution we shall gain deeper insight into the metaphysical structure of a biological substance.

Chapter Two

The Structure of a Biological Substance

§1 Three senses of "nature"

In "Material and Formal Natures in Aristotle's *De Partibus Animalium*" James Lennox draws our attention to several key passages in the *PA* where Aristotle divides the nature of a biological substance into its material nature (640b28-9, 641a26) and its formal nature (640b27). The latter is eventually identified with nature understood as substantial being (641a27), which is then distinguished into nature "as mover" and nature "as end".[1] This is set out explicitly in *PA* 1.1, 641a22-33:

> The natural scientist will state both what the soul or that very part of the soul is, and speak about the attributes it has in virtue of the sort of being it is, especially since the nature of something is spoken of and is in two ways: as matter and as substantial being (οὐσία). And nature as substantial being is both nature as mover and nature as end (καὶ ὡς ἡ κινοῦσα καὶ ὡς τὸ τέλος). And it is the soul—either the whole soul or some part of it—that is of this sort in the case of animals. So in this way it will be requisite for the person studying nature to speak about the soul more than the matter, inasmuch as it is more that the matter is nature because of soul than the reverse; for indeed the wood is a bed or a stool because it is potentially these things. (Lennox transl. with modifications)

In this text Aristotle elaborates on the hylomorphic structure of a biological substance. Generalising to all living things, a biological substance (or organism) is a composite of a material nature and a formal nature. However, the formal nature is said to be both nature "as mover" and nature "as end". I shall not deal with the concept of material nature in any direct manner here.[2] My interest is rather with the hylomorphic structure of a biological substance as such, more specifically, with the (real or apparent) two-

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[1] Lennox 2001b, 182-304. Note all references to Lennox 2001b are to essays reprinted in that volume.

[2] Lennox 2001b, 182-304 offers an excellent discussion of the relation between the material nature and the formal nature as mover in the *PA*. See also *GA* 743a36-b5 (translated below).

fold structure of its formal nature. The question to ask is whether, by saying nature understood as substantial being (formal nature) is *both* nature as mover *and* nature as end, Aristotle is identifying one thing under different descriptions or two different things.

Traditionally, views on the relation between the material nature and formal nature of an organism have been divided into two main camps. On the one side there are those who take these to be distinct "parts" of the unified whole. On the other side are those who argue that material nature and formal nature are merely conceptual abstractions from something that is metaphysically simple.[3] Eventually I shall side with the former view. Thus, in what follows I shall assume that the first distinction in our text between the organism's material nature and its formal nature is a real distinction. Although this involves a number of (ultimately ancillary) problems, in the interest of advancing the argument I shall simply take this for granted. The danger otherwise is that we will become quickly entangled in the intricacies of Aristotle's metaphysics before getting started.

It should be kept in mind here that the traditional debate surrounding the relation between the matter and form of an Aristotelian composite substance cannot be perfectly mapped onto the division in *PA* 641a22-33. For discussions of Aristotle's hylomorphism generally only take into account the matter and the form actualised in the matter, which in our text is "nature as end". This leaves "nature as mover" unaccounted for. I am assuming that Aristotle's hylomorphism is to be understood on the part-whole model; the two approaches to *PA* 641a22-33 that follow thus represent two ways of dealing with "nature as mover" from this perspective. On one view nature as mover and nature as end pick out numerically the same "part" of an organism's hylomorphic structure (the adult shape and form) under different descriptions. On the other view (the one I shall defend) nature as mover and nature as end pick out two numerically distinct "parts" (making three in total).

§2 Nature ὡς τὸ τέλος and nature ὡς ἡ κινοῦσα

On the standard reading of the *Metaphysics* all composite substances, including biological substances, have the same basic two-fold structure (matter and form). The problem facing this reading is what to do with the contrast between formal

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[3] For more on this see below.

nature "as mover" and formal nature "as end". The most obvious strategy would be to collapse the two into a single principle under different descriptions, thereby preserving the apparent two-fold analysis of the *Metaphysics*.[4] Here we would take the first division between the material nature and the formal nature as a real distinction yielding two parts of the composite and the second division between nature as mover and nature as end as a mere '*qua*' distinction. On this reading both nature as mover and nature as end refer to the shape and form of the organism. The latter is the form when actualised in the matter; the former is that same shape and form (somehow) acting as the efficient cause of the process leading up to it.

Formal preformationism offers a way to make sense of this in the context of generation. On Lear's account, for example, nature as end and nature as mover will both refer to a single nature in two states of being: the former is the shape and form of the creature when fully developed (the actualised form); the latter is that numerically same shape and form pre-existing in the embryo in a state of potentiality (the potential form).

However this first reading is cashed out, it is extremely difficult to square with Aristotle's Greek. The suggestion would be that the distinction Aristotle makes between nature as mover and nature as end is not a genuine sub-division of the formal nature into two distinct principles but simply picks out a single nature under different descriptions. Thus we are talking about the nature *qua* mover and the nature *qua* end. The obvious problem with this is that Aristotle does not employ the '*qua*' (ᾗ) locution here. Rather, he refers to nature ὡς ἡ κινοῦσα and nature ὡς τὸ τέλος. This is the same word used to distinguish the material nature from the formal nature: nature ὡς ὕλης versus nature ὡς οὐσίας. And these are said to be ontologically distinct (641a26: διχῶς οὔσης). This interpretation would thus require taking the same word "ὡς" in two different ways. In the first instance it expresses a distinction between two parts of a biological substance, matter and form, and in the second instance a mere

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[4] I say the *apparent* two-fold analysis here, since it is not clear whether the *Metaphysics* actually does see biological substances as having a two-fold nature (as traditionally assumed) or whether this is simply a by-product of Aristotle's reliance on the artefact model there. The current strategy is only attractive if one insists on this standard way of reading the *Metaphysics* (which I shall not).

'*qua*' distinction (one thing under different descriptions). And nothing in the Greek warrants this.[5]

In contrast to this first reading, I shall defend the view that nature "as mover" and nature "as end" refer to numerically distinct parts of a unified whole.[6] Nature "as end" refers to the shape and form of the creature when fully developed while nature "as mover" refers to a distinct potential for its formation (an active potential). On this reading, nature as mover stands to nature as end as the art of ship building stands to the form of the ship when fully constructed (the form in the matter). The force of what I shall call the nonidentity reading derives from its explanatory power. It explains how Aristotle can consistently hold that the formal nature of an organism is *both* the principle that initiates and controls the embryo's development *and* the shape and structure of the thing when fully developed. For unless Aristotle takes these to be (numerically) distinct, we end up with the paradox that one and the same thing is the cause of its own existence.

My argument for this reading will proceed in two steps. First I shall introduce several texts to show that Aristotle at least recognises a *conceptual* distinction between formal nature as mover and formal nature as end.[7] I shall then offer three sets of arguments to show that this must be understood as a *real* (as opposed to a mere

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[5] Of course this is not a problem for a reading that takes the distinction between material nature and formal nature to be a mere '*qua*' distinction as well. There are several reasons for rejecting this view (see below). However, even without those reasons, our text tells against this reading insofar as Aristotle says that material nature and formal nature are not only two ways in which nature is *spoken of* but also two ways in which it *exists* (they are different in being). And the standard way of expressing the idea that *A* and *B* are one thing under different descriptions is to say that they are *the same in being*, though different in account (e.g. *Physics* 202a20-1).

[6] I address the problem of unity (H6) further below. This reading is also endorsed by Lennox 2001b, 189.

[7] This first step may seem trivial given that this is at minimum what 641a22-33 is telling us. However, some commentators deny that there is even this conceptual distinction. For example, Sarah Broadie argues for what she calls a "conceptual coincidence" between these two senses of formal nature. I discuss Broadie's view further below.

'*qua*') distinction. If I am right, then nature "as mover" and nature "as end" cannot be collapsed into a single nature. For example, they do not refer to the shape and form of the organism in two states of being (potentiality/actuality).

§3 Some terminology

Before beginning, it will be helpful to introduce some terminology. In what follows I shall designate formal nature as mover (ὡς ἡ κινοῦσα) by "genetic nature" and formal nature as end (ὡς τὸ τέλος) by "phenotypic nature". My choice of terminology here is certainly not arbitrary. For I shall argue that when Aristotle distinguishes between nature "as end" and nature "as mover" he is drawing roughly the same distinction modern biology makes between an organism's phenotype and genotype.[8] Although these two concepts are not clearly defined even within modern biology, the basic distinction is between the organism's fully developed morphology, physiology, and behaviour (what we might call its observable form), and the sum of underlying genetic factors (whatever these turn out to be) which are in some sense productive of those phenotypic characters.[9] To be sure, the extent to which genes are

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[8] This insight has also been recorded by Morsink 1982, 167. However, Morsink is drawing on *GA* 4.3 rather than *PA* 641a22-33. For a discussion of Morsink's account see chapter five below. Gutiérrez-Giraldo 2001 makes the reverse claim that I am making here. He argues, not that Aristotle made a distinction akin to the modern phenotype/genotype distinction, but that the modern concept of the genotype counts as an Aristotelian ψυχή. I shall not evaluate this interesting claim here.

[9] My use of "phenotypic nature" is intended to be neutral with respect to the *kinds* of features it includes and their *level of specificity* (whether they are species- or individual-specific). Thus, in the first place, it makes no difference whether phenotypic nature is restricted to species-level properties or whether it is taken to include properties below the level of species as well (though I shall eventually argue for the latter). In the second place, supposing we take phenotypic nature to be identical with the species-form, it makes no difference whether we take this to include *all* aspects of an animal's physical appearance, internal anatomy, physiology, and behaviour characteristic of the species (cf. Furth 1988, 72: "Fact 2") or whether we restrict it to certain aspects of its observable form. (One might even wish to restrict

causally responsible for the phenotype is very controversial.[10] What is important for my purposes is simply the fact that modern biology recognises a fundamental ontological distinction between the phenotypic characters of an organism, on the one hand, and the genes that underlie them, on the other.[11] It is in this way (so I shall argue) that the phenotype/genotype distinction provides a good model for understanding the relationship Aristotle envisions between nature ὡς τὸ τέλος and nature ὡς ἡ κινοῦσα and the role he assigns to each in his ontogeny. As we shall see, one of Aristotle's most important insights in this respect was to appreciate that the replication of biological form (embodied in the phenomenon of inheritance) requires that these two kinds of formal nature pick out two distinct parts of an organism.

The structure of the genetic nature is explored in detail in later chapters (see esp. chapter five). I shall argue that an organism's genetic nature is comprised of different active potentials (or δυνάμεις), each of which is causally responsible for producing a different part of its phenotypic nature. However, there is still a good deal of exegetical work to be done before we can appreciate this. The first step in the argument is to show that Aristotle at least recognises a conceptual distinction between what I am calling an organism's phenotypic nature and its genetic nature. And the best way to do this is to look at the text itself.

§4 Phenotypic nature

The idea that an organism's "formal nature" is its adult form (or phenotypic nature) is relatively uncontroversial. The following two texts should be sufficient to illustrate this:

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phenotypic nature to (parts of) the organism's soul, though in what follows I shall use the concept in the much richer sense of "the differentiae in the matter".)

[10] To what extent the phenotype is a product of the interaction between the genotype and the cellular and extra-cellular environment is still extremely controversial. For a good discussion of this see Sterelny and Griffiths 1999, chp. 5.

[11] See Laubichler and Wagner 2000. The claim that there is an ontological distinction here should not be taken to imply a substantial dualism, that genes and their expressions are two different *kinds* of substances (as mind and body are for a Cartesian). It need not amount to anything more than the idea that genes are one thing, their phenotypic expressions another, which is sufficient for my purposes.

For it is not enough to say from what things they [sc. animals and their parts] are constituted, e.g. from fire or earth. It is just as if we were speaking about a bed or any other such thing; we would attempt to define its form rather than its matter, e.g. the bronze or the wood. And if we could not do this, we would at least attempt to define the matter of the composite; for a bed is a 'this-in-that' or 'this-such', so that we would have to mention its configuration as well, and what its visible character is. For the formal nature (ἡ κατὰ τὴν μορφὴν φύσις) is more important than the material nature (τῆς ὑλικῆς φύσεως). (*PA* 640b23-8, Lennox transl. with one modification[12])

Even Empedocles occasionally stumbles on this [sc. nature is more of a principle than the matter], led by truth itself, and is forced to say that substantial being, i.e. nature, is the ratio (τὸν λόγον), for example when he gives an account of what bone is. He does not say that bone is any one of the elements or two or three or all of them together, but rather that it is a ratio of the mixture (λόγον τῆς μίξεως) of these. And it is clear that he would explain what flesh is and each such part in the same way. (*PA* 642a17-24)

I shall pass over without comment Aristotle's suggestion in the first passage that in those cases where we cannot define the form by itself (i.e. in the case of sensible substance), we should instead define the matter of the composite. My interest is in the use of the concept of formal nature (nature understood as substantial being).

By associating the formal nature with a thing's "configuration" (σχήματος) and "visible character" (ποῖον τὴν ἰδέαν) the first passage is clearly picking out the phenotypic nature of an organism. In the second passage we find Aristotle praising Empedocles for 'stumbling' upon the concept of nature understood as substantial being and for recognising that nature in this sense is more of a principle of things than the matter. However, *PA* 641a22-33 shows us that the association with οὐσία alone is not sufficient for determining whether Aristotle is picking out the genetic nature

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[12] Lennox translates ἡ κατὰ τὴν μορφὴν φύσις literally as "the nature in respect of shape". I have translated this simply as "formal nature" for consistency. Other constructions include ἡ κατὰ τὸ εἶδος φύσις and ἡ κατὰ τὸν λόγον φύσις.

(nature "as mover") or the phenotypic nature (nature "as end"). As such, context will always play an important factor. In the present context it is fairly certain that the nature in question is the phenotypic nature, which Empedocles believed could be adequately expressed in a chemical formula.

Aristotle praises Empedocles' account of nature (understood phenotypically) for two reasons. First, according to Lennox, although Empedoclean accounts of the nature of biological tissues are not the preferred functional accounts employed in the *Parts of Animals*, they at least take us in the right direction. For saying that the substantial being of bone is a ratio expressed by the formula $E_2W_2A_0F_4$ (DK fr. 96; cf. *DA* 410a4-7) goes beyond merely stating its constituent materials and instead focuses our attention on their precise organisation.[13] Second, Aristotle praises Empedocles not just for recognising the concept of substantial being, but for refusing to reduce the substantial being of each thing to its material nature (even if he was forced to concede this): "He does not say that bone is any one of the elements or two or three or all of them together, but rather that it is a ratio of the mixture of these."

Our working definition of phenotypic nature is the shape and form into which an embryo develops. Here, "nature" picks out the actualised form of the individual at the end of the process (its observable form or visible character). However, this requires qualification. Calling the adult form nature ὡς τὸ τέλος suggests that Aristotle is talking about the form that is *supposed to* result from development and not simply the form that actually results. Thus, Aristotle will exclude from the phenotypic nature those characteristics of an organism that result from any accidental changes that might occur during and after its development (e.g. birth defects, battle scars).[14] I shall take this normative qualification as implicit in our use of the concept of phenotypic nature: the phenotypic nature is the form into which the embryo is *supposed to* develop.

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[13] Lennox 2001a, 151. Note that only this first observation about the current passage is suggested by Lennox.

[14] To be sure, identifying which features are accidental (not supposed to happen) will not be straightforward, since Aristotle thinks both environmental and material factors (e.g. diet) can contribute to the normal pattern of development (*GA* 5).

§5 Genetic nature

No one (I think) would object to the suggestion that the concept of formal nature, or nature understood as substantial being, picks out the form of an organism when fully developed. However, the same concept is quite often used to pick out the productive agent at work in the development of the organism that is causally responsible for that form. The *Generation of Animals* provides a wealth of examples of this use of formal nature:

> And just as the products of art are formed by means of the artist's tools, or to speak more accurately just as they are formed by means of the movement of these (for this movement is the activity of the art and the art is the form of the products in another), so too with the power of the nutritive soul. Just as at a later stage in the animals and plants themselves this soul effects growth out of the nourishment using heat and cold like instruments (for the movement of this [sc. growth] is in things of that sort and each thing comes into being according to a certain formula), so too it [the power of the nutritive soul] constructs the naturally generated organism at the beginning. For, since the material out of which the organism grows and that out of which it is originally constructed are the same, the active potential (ἡ ποιοῦσα δύναμις) is also identical with the one which is operative in the beginning (but greater than it). If, then, this is the nutritive soul, it is also that which generates – and this is the nature of each organism, being present in all plants and animals alike. But the other parts of the soul, while they are present in some living things, are not present in others. (740b25-741a3)

Like a good household manager (οἰκονὸμος), the nature <of an organism> is not accustomed to throw anything away if something useful can be made out of it. In home economics the best of the food available is reserved for the free men; the surplus from this as well as the inferior food goes to the servants, and the worst of all goes to the domestic animals. Here, then, is an instance of a mind external to them acting so as to provide for their growth. Likewise, the nature is at work within organisms that are coming to be and constructs the flesh and the

somatic parts of the other sense-organs out of the purest material, while it constructs bones and sinews and hair out of the residues, which means they must wait until the organism's nature has some residue at hand – and that is why they are the last to be formed. (744b16-27; cf. 740a3ff.)

For nothing occurs contrary to nature with respect to what is everlasting and necessary (τὴν ἀεὶ καὶ τὴν ἐξ ἀνάγκης) but in the case of things that happen in a given way for the most part but can also happen in another way. In fact, even in the case of monstrosities, what occurs is contrary to this particular order, indeed, but it never takes place in a merely random fashion; and it therefore seems to be less of a monstrosity because even that which is contrary to nature is in certain sense according to nature, namely when the formal nature (ἡ κατὰ τὸ εἶδος φύσις) fails to master the material nature (τὴν κατὰ τὴν ὕλην <φύσιν>). (770b11-17)

We can ignore the first sense of nature in the last text which is used as shorthand for the statistical frequency of natural phenomena (cf. *GA* 777a18-21, *PA* 663b27-9). Again my interest is in Aristotle's use of formal nature.[15] In each of these three texts the formal nature is the principle that constructs the organism (genetic nature) rather than the shape and form of the organism when fully constructed (phenotypic nature). This use of the concept of formal nature stands in stark contrast with its use in the other two passages looked at earlier.

This is most explicit in the third passage where "the formal nature" acts on "the material nature". Although Aristotle insists that the origin of a monstrous form is the material nature of the embryo (770a4-7), it is ultimately caused by a failure of its formal nature to impose the parent's shape and form on the matter (cf. 768b10-15, 769b8-13). Here formal nature is the genetic nature of the embryo, the productive agent; the phenotypic nature would be the shape and form that this nature fails to impose on the matter. This text gives us a clear picture of the role played by each of

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[15] Although only the last text uses the full expression ἡ κατὰ τὸ εἶδος φύσις, it is clear that "the nature" in the other two refers to the formal nature and not the material nature.

these natures in Aristotle's ontogeny. Development is a process in which the *genetic* nature transforms the *material* nature into an organism with a certain *phenotypic* nature.

In both of the other texts the formal nature also picks out the organism's genetic nature rather than its phenotypic nature. Although there is a good deal to say about the second passage, all that is important here is the generative role it assigns to the formal nature: it is a teleological principle inside the developing embryo that is causally responsible for the formation of its adult structures. In the first passage Aristotle explicitly refers to organism's formal nature as the active potential (ἡ ποιοῦσα δύναμις) that is responsible for generating (ἡ γεννῶσα) the new individual.

A caveat is necessary here. The two stages Aristotle is referring to in the first text are morphogenesis (the differentiation of the organism's primary structures out of menstrual blood) and the subsequent growth of those structures in the period following morphogenesis. Aristotle's point is that the genetic nature regulates both of these two processes. It is important that the growth "at a later stage" which the genetic nature governs is the augmentation of the immature structures and *not* the day-to-day metabolic activities that maintain the mature organism's body through the course of its adult life. We can see this clearly by comparing the first text with 777a3-8: "It is clear, then, that milk has the same [material] nature as the secretion out of which each part is formed, as has been said earlier." Here, Aristotle is contrasting the mother's breast milk (the matter used to grow the parts of the baby) and her menstrual blood (the matter used to build those parts). The "earlier discussion" to which Aristotle refers here is presumably 740b25-741a3. If this is right, then "the material out of which the organism grows and that out of which it is originally constructed" (in 740b25-741a3) refer to the mother's milk and the menstrual blood, respectively.

In *PA* 640b23-8 and 642a17-24 Aristotle used the concept of formal nature to pick out the shape and form of an individual when fully developed (its "configuration" and "visible character"). However, as our second set of texts clearly shows, Aristotle is quite willing to use that concept to pick out the productive agent at work inside the developing embryo which is responsible for generating that shape and form. Indeed, this is its primary application in the *Generation of Animals*.

§6 The distinction between the natures

Each of the texts I have introduced so far deals with one or the other of these uses of formal nature. However, there are several places where Aristotle is explicitly concerned with the distinction itself. One such place is *Metaphysics* Z7. What is interesting here is that Z7 appears to articulate the very same three-fold distinction between an organism's material nature, phenotypic nature, and genetic nature that we find in *PA* 641a22-33. At 1032a15-25 Aristotle identifies three principles of natural generation. The first two – that "out of which" biological substances are generated and that "according to which" they are generated – correspond to the matter and the form (or phenotypic nature), respectively. The third principle, the moving cause of natural generation, is explicitly identified with the creature's formal nature (a24-5). Aristotle's Greek here is quite difficult:

> καὶ ὑφ' οὗ ἡ κατὰ τὸ εἶδος λεγομένη φύσις ἡ ὁμοειδής (αὕτη δὲ ἐν ἄλλῳ. ἄνθρωπος γὰρ ἄνθρωπον γεννᾷ).

Ross translates this text as, "...and so is that by which they are produced—the so-called 'formal' nature, which is specifically the same as the nature of the thing produced (though it is in another individual); for man begets man".[16] Tredennick renders it, "And that by which they are generated is the so-called 'formal' nature, which has the same form as the thing generated (although it is in something else); for man begets man".[17] Neither of these seem to capture Aristotle's point.

The central idea is packed into the phrase ἡ κατὰ τὸ εἶδος φύσις ἡ ὁμοειδής. A literal translation of ἡ κατὰ τὸ εἶδος φύσις (standardly translated simply as "the formal nature") would be "the nature with respect to the form" or "the nature according to the form". Since Aristotle is talking about the moving cause of natural generation ("that by the agency of which" (ὑφ' οὗ) an organism comes to be), we can be sure that he means the genetic nature. Thus ἡ φύσις should be read in the sense of an internal source of motion or change. Substituting "internal source of motion" for "nature", Aristotle is saying that the moving cause of natural generation is an internal source of motion according to the form, where "according to the form" (κατὰ τὸ εἶδος) specifies the kind of motion for which the genetic nature is a source.

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[16] Translation from Barnes 1995.

[17] Tredennick 1996.

This rather odd-sounding phrase can be understood by way of contrast. For Aristotle, a developing embryo changes according to what it is (i.e. according to its form). In contrast to this his materialist rivals claimed that an embryo changes according to what it is made out of (i.e. according to its matter). But if the materialists are right, then we should expect an embryo to separate into its constituent elements, its fiery constituents moving upwards, its earthy constituents moving downwards, and each of its other elements moving according to their own natures. However, this is not what we find. When left to its own an embryo does not break down and separate into its constituent elements (contrast a paper cup). Rather, it undergoes a complex series of movements and changes that collectively transform the matter into a organism of a determinate kind – indeed the same kind as its parents – whose functioning parts all work together in ways that contribute to its ability to survive and flourish within its particular environment. Clearly this complex change does not originate from the simple natures of the materials themselves.[18] The fact that an embryo does not break down into its constituent matter but instead undergoes a series of complex transformations that build it into an organism of the same kind as its generating parents suggests that there is something else at work inside the embryo that regulates its development according to that form. For Aristotle, this principle is the creature's genetic nature: it is an internal principle of motion or change that organises the matter according to the pattern of its adult form (ἡ κατὰ τὸ εἶδος φύσις).

As I understand Aristotle's point, ἡ ὁμοειδής further modifies the kind of motion initiated by the organism's genetic nature. What he is saying, then, is that the moving cause of natural generation is an internal principle of change whose activity organises the embryonic materials according to *the same form* as the generating parent (the form which is "in another").

The introduction of the genetic nature at 1032a24-5 underwrites Aristotle's attack on Forms as paradigmatic causes in Z8:

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[18] cf. *GC* 2.9. As Lennox notes (2001b, 191-2), most of the changes that take place inside an organism are in fact *contrary* to its material nature. Lennox points to *PA* 663b25-36 where earthen material in the organism is said to 'flow *upwards* of necessity', whereas the natural, unconstrained motion of Aristotle's element earth is downwards.

Obviously, then, the cause which consists of the Forms—as some are wont to speak of the Forms, if they are something over-and-above (παρά) the particular things—is useless (οὐθὲν χρήσιμα), at least with respect to coming-to-be and being. Nor for this reason should these Forms be regarded as self-subsistent entities (οὐσίαι καθ' αὑτάς). Indeed, in certain cases it is even obvious that the generator is of the same kind as that which is generated, not, however, identical or one in number, but one in form, e.g. in the case of natural things (for man begets man).... Thus, it is obvious that it is not necessary to set up a Form as a pattern, for we should have looked for Forms in these cases especially, since <natural things> are substances in the strongest sense, but the thing which generates is sufficient to produce, and be a cause of, the form in the matter (ἱκανὸν τὸ γεννῶν ποιῆσαι καὶ τοῦ εἴδους αἴτιον εἶναι ἐν τῇ ὕλῃ). (1033b26-1034b5)

Aristotle's point here is about ontological economy. In the case of biological substances, we do not need to introduce separately existing Forms as models to explain how particulars come to be *F*. The reason is that organisms contain the source of a specific organism-building motion in themselves, what we might call a developmental 'programme'. For Aristotle this heritable programme is the creature's genetic nature. The force of this argument will become clearer when we turn to the analysis of the mechanisms of inheritance in *Generation of Animals* 4.3. For now we will have to make do with an analogy. Fire does not need a map to get to the upper cosmos because (in Aristotle's physics) it contains a source of upward motion in itself. The activity of its nature carries it there automatically. A horse's genetic nature is like the nature of fire, except it is the source of a much more complex horse-building motion. Aristotle's point, then, is that because the embryo contains a source of horse-building motion in itself, it does not need a model or blueprint (a separate παράδειγμα) of its adult form in order to achieve that end. The activity of its nature generates the form in the matter automatically.

The final bank of texts that I want to draw attention to here in order to make explicit the conceptual distinction between genetic nature and phenotypic nature

comes from *Metaphysics* Δ4.[19] Once again we find Aristotle deploying the concept of formal nature in both ways:

> [In one sense nature means] that whence the primary change in each natural being originates [which] is in itself *qua* itself. (1014b18-20)

> Hence as regards the things that are or come to be by nature, though that out of which they naturally come to be and are [sc. the matter] is already present, we say they do not yet have their nature until they have their shape and form. Therefore, that which is composed from both of these (e.g. animals and their parts) exists *by* nature, while both the primary material… and the form (i.e. the substantial being) *are* natures;[20] and the latter is the end of the process of development (τὸ τέλος τῆς γενέσεως). (1015a3-12)

> From what has been said, the primary and chief sense of nature is the substantial being of those things that have a principle of change in themselves *qua* themselves; for the matter is said to be nature in virtue of being receptive of this, and development and growth are said to be nature in virtue of being changes from it. And nature in this sense is the source of the changes of natural beings, which is somehow inherent in them either potentially or actually. (1015a13-19)

The first two texts are fairly straightforward. The first picks out the creature's genetic nature; "the primary change" is the growth and development of the new individual that proceeds from this nature (1015a13-19). The second opposes the material nature

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[19] I have chosen *Metaphysics* Δ4 rather than *Physics* 2.1 because it makes the distinction between the three senses of nature (material nature, phenotypic nature, genetic nature) more explicit. There do not appear to be any major philosophical differences between the two discussions.

[20] This is a slightly liberal translation of the Greek; however, it captures the contrast Aristotle is after more effectively than a literal translation. The contrast in question is between φύσει (μέν), "by nature", and φύσις (δέ), "a nature". The point is that the organism, which is a composite of matter and form, exists *by* nature (φύσει), whereas the matter and the form of which it is composed do not exist *by* nature but each of them is *a* nature (φύσις, note the absence of the definite article).

(that out of which the organism naturally comes to be) with the phenotypic nature (the form at the end of the process of development). The third text is more complicated. For Aristotle makes two references to what we would identify as the formal nature.

The reference to nature in the final sentence is quite clearly genetic nature (the source of change). Alexander takes Aristotle's statement that this nature is "somehow inherent" in natural beings "either potentially or actually" to mean that the adult form pre-exists in the embryo in potentiality and in the adult in actuality.[21] However, Aristotle does not say that *the (adult) form* is somehow inherent in natural beings either potentially or actually but *the source of the change that produces that form*. And unless one already accepts that nature in the latter sense *is* nature in the sense of fully developed adult form, there is no reason to accept Alexander's reading of this text. As I read the text, growth and development are called "nature" in virtue of proceeding from the genetic nature, which is nonidentical with the shape and form in which those processes terminate.

On the other hand, the opening reference to nature understood as substantial being (which is nature "in the primary and chief sense") is ambiguous given Aristotle's remarks in *PA* 641a22-33. For it could refer to genetic nature or phenotypic nature. Having said that, it is fairly certain that Aristotle is picking out the organism's phenotypic nature. For it is in virtue of being receptive of this that matter is said to be "nature" (cf. 1050a15-16), and it does not receive that form until the end of the process of development (1015a3-12).[22]

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[21] Alexander *in Metaph.* 360,9-13. See Dooley 1993, 137 *n.* 80 (cf. *n.* 79).

[22] My way of reading 1015a13-19 requires that we take the reference to the formal nature of which matter is receptive (= τῷ ταύτης δεκτικὴ) to point backwards to phenotypic nature (= nature in the primary and chief sense) and the reference to the formal nature from which growth and development proceed (= τῷ ἀπό ταύτης) to point forward to genetic nature (the source of change in natural beings). This is not at all unreasonable, though. For the point of Δ4 is that "nature" is said in many ways. And it would certainly add rhetorical effect if the sentence in question was seen to be trading on that very ambiguity.

Thus, ignoring nature in the sense of the process of growth and development (which is more properly said to be *according to* nature rather than *a* nature).[23] 1015a13-19 countenances the same three-fold division that we find in our main text at *PA* 641a22-33.

Like the other texts we have looked at so far, *Metaphysics* Δ4 demonstrates Aristotle's willingness to use the concept of formal nature in two different ways. In the one case it refers to the form which is actualised in the matter, in the other it refers to the principle inside the embryo that is causally responsible for that form (insofar as growth and development proceed from it). However, there is another way to read 1015a13-19 that would suggest there is not even a conceptual distinction between these two natures. On this reading the fully actualised form of an adult organism is both the nature from which development proceeds (genetic nature) and the nature towards which it advances (phenotypic nature). This reading is suggested by Sarah Broadie.

According to Broadie, Aristotle argues for a "conceptual coincidence" between phenotypic nature and genetic nature:

> But the natural process of growth denoted by the word 'φύσις' (in the sense in which it means 'genesis') does result in a state that in turn gives rise to such processes, and this state is also called 'φύσις'. Evidently Aristotle is thinking of the fact that man generates man: i.e. that a full-grown man is a source of processes (in offspring) identical in kind to that by which he developed. ...Thus a kind of conceptual coincidence obtains between (a) the concept of the developed natural state and (b) the concept of the source of the process that gives rise to that state....[24]

The suggestion is that, contrary to what I have been arguing, Aristotle's twin concepts of phenotypic nature and genetic nature coincide in the fully developed adult form which is actualised in the matter. On this reading, to talk about the organism's fully

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[23] cf. *Physics* 193a1. "According to nature" is properly applied to motions and changes. In this sense the development of an embryo is on a par with the natural motion of fire towards the upper limit, which is the example Aristotle uses in the *Physics* passage as something that is "according to nature" rather than "*a* nature".

[24] Broadie 1982, 64.

actualised form as "phenotypic" nature is to talk about that form as the end of that creature's development; to talk of the "genetic" nature is to pick out that same actualised form in its role as the source and cause of its offspring's development.[25]

It is important to appreciate how this reading differs from a reading like formal preformationism, which accepts there is a conceptual *distinction* between two senses of formal nature (insofar as there is a conceptual distinction between potentiality and actuality). Formal preformationism takes the genetic nature which pre-exists in the embryo to be the offspring's potential form and the phenotypic nature to be that same form when fully actualised in its adult body. The current reading denies there is even this distinction. Instead it takes the fully developed adult form actualised in the matter (Socrates' visible shape and form) to be both phenotypic nature and genetic nature.

There are three major problems with this interpretation. First the form in which the parent's own development terminates – *its* developed form – will count as a source of change "in another" whereas (genetic) nature is supposed to be a source of growth and development "in the thing itself *qua* itself". Second the idea that the

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[25] Broadie is not commenting on, nor even seems to be aware of, the distinction in 641a22-33. Her evidence for conceptual coincidence is drawn exclusively from *Physics* 2 (specifically 193b8-18). Broadie gives two conflicting versions of conceptual coincidence. In the above passage she is saying that (what 641a22-33 calls) nature as end and nature as mover both pick out the parent's fully actualised form under different descriptions: the parent's shape and form is both the end of its own development and the source of its offspring's development. However, in the argument deployed immediately after this (pp. 65-6, §20: see further below) Broadie claims that the conceptual coincidence obtains between the offspring's fully developed form and its internal principle of change. On this version of conceptual coincidence an organism's shape and form is both the end and source of its own development. Here genetic nature refers, not to the parent's developed form *qua* source of motion for its offspring, but to the principle of motion inside the developing embryo itself (which Broadie argues is also its nature in the sense of its fully developed structure). The present section is targeting Broadie's first version of conceptual coincidence (nature as mover and nature as end pick out the parent's own fully developed form under different descriptions).

offspring's growth and development proceed from the parent's actualised form is extremely difficult to square with Aristotle's views on reproduction in the *Generation of Animals*. The idea that the fully developed structures of the parent organism play a direct role in reproducing those structures was one of the prevailing theories at the time (so-called pangenesis). Given the amount of time devoted to undermining that theory in the *GA* (see esp. 1.17-18), it is extremely unlikely that the nature Aristotle says is the source and cause of development refers to the parent's fully developed structures. Third, even if this were the case, we still end up with a *conceptual* distinction between the source of biological development and the end in which that development terminates (even if they turn out to be numerically the same thing).

§7 Arguments for nonidentity

I now want to turn to the arguments in favour of the nonidentity reading of *PA* 641a22-33. I shall argue that Aristotle does not just think there is a conceptual distinction between an organism's phenotypic nature and its genetic nature; they are two distinct principles of an organism. Some of the most compelling evidence for this comes from Aristotle's general treatise on coming-to-be, *Generation and Corruption*.

§7.1 The ontological argument

The strongest argument comes from *Generation and Corruption* 2.9 where Aristotle's ontology of coming-to-be is said to include three numerically distinct items. As in Z8, *GC* 2.9 focuses on the problem of ontological economy. However, in this case the problem is not one of proliferation (as it was in Z8) but deficiency:

> The principles <of coming-to-be> are equal in number to, and identical in kind with, those in the sphere of the eternal and primary things. For there is *one* in the sense of matter, and a *second* in the sense of form; and there must be a *third* principle present over-and-above (ἔτι προσυπάρχειν) these. For the two [sc. matter and form] are not sufficient (οὐ ἱκαναί) for coming-to-be any more than they are sufficient in the case of the primary things. (335a28-32, translated after Joachim)

> This [sc. the potentiality of each thing to be and not-be] is a cause in the sense of matter for the things which are such as to come into being, while the cause in the sense of that for the sake of which <they come to

be> is the shape and form; and this is the formula of the substantial being of each thing (ὁ λόγος ὁ τῆς ἑκάστου οὐσίας). But there must be the third principle in addition (προσεῖναι), which was vaguely dreamed of by all our predecessors but definitely stated by none of them. On the contrary, some amongst them thought the nature of the Forms was adequate for coming-to-be. Thus, Socrates in the *Phaedo* first blames everyone else for having given no explanation, and then lays it down (ὑποτίθεται) that some things are Forms, others participants of the Forms (τὰ δὲ μεθεκτικὰ τῶν εἰδῶν), and that while a thing is said to be in virtue of the Form, it is said to come to be and pass away in virtue of sharing in and losing the Form. So that he believes if these are true, the Forms must be causes of coming-to-be and passing-away of necessity. On the other hand, there were others who thought the matter alone was sufficient for coming-to-be, since the movement derives from (ἀπό) the matter. (335b3-17, translated after Joachim)

In the second passage Aristotle targets the theory of Forms in the *Phaedo*. According to Lennox, this is also Aristotle's target in Z8.[26] However, it is more likely that the argument in Z8 is directed at the theory of Forms in the *Timaeus*. For Aristotle's complaint against the *Phaedo* is that it does not posit enough ontological items to account for natural generation, whereas in Z8 Plato is criticised for introducing too many. In both Z7 and *GC* 2.9 Aristotle insists that natural generation involves *three* principles: matter, form, and a productive cause which supplies the motion that organises the matter according to that form. The *Timaeus* introduces a *fourth* ontological item: separately existing Forms that serve as models after which the productive agent (the Demiourge) patterns its movements.[27]

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[26] Lennox 2001b, 141ff.

[27] The four ontological items of the *Timaeus* are matter (the receptacle), sensible forms ("the copies", e.g. 29BC, 48E-49A), a productive agent (the Demiourge), and separately existing Forms that serve as models. I have argued that Aristotle's genetic nature makes separately existing models unnecessary since it is a source of motion according to the parental form.

In *GC* 2.9 Aristotle argues that none of his predecessors managed to posit all three principles. Specifically, they failed to recognise a distinct moving cause. While "Socrates in the *Phaedo*" recognised the importance of forms in natural generation, he went wrong in taking them to be productive causes. Philoponus interprets this as suggesting that Plato actually identified the moving cause with the Forms themselves:

> For some rendered the Form as moving cause, as Plato in the *Phaedo*.
>
> He [Plato]... says that the Form produces that which is endowed with form by being present. But [Aristotle] criticises him, saying that the Form is not sufficient for production: for neither is the image (ἡ εἰκών) said to produce what comes to be in relation to it but rather the craftsman, nor does health heal the one who is ill without there being a doctor. ...In this way he [Aristotle] refutes those who say that forms are productive causes. (*in GC*, 281,25-282,2)

In this respect Aristotle thinks the materialists offered a much better account of natural generation than the Platonists:

> For to say that matter generates owing to its movement would be, no doubt, more naturalistic (φυσικώτερον) than to make such claims as are made by the thinkers we have been criticizing. For that which brings about alteration and structural change is more explanatory (αἰτιώτερον) of coming-to-be, and in everything (in both nature and art alike) we are more accustomed to speak of what is capable of initiating motion (κινητικόν) as the productive cause (τὸ ποιοῦν). (335b26-30)

However, the materialists went too far in attempting to reduce natural generation to matter and its intrinsic motions.[28] Even if we accept that matter is a source of motion, those simple motions could not be responsible for producing complex living organisms which are functionally adapted to their particular environments except by chance – and it is too regular for that.[29] The generation of these substances must be

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[28] cf. Philoponus *in GC* 282,2-20, Joachim 1999, 249-50.

[29] Aristotle makes a similar point against Empedocles in *GC* 2.6 (see Sorabji 1980, 179; Joachim 1999, 231).

traced to a goal-directed productive activity, which Aristotle thinks is supplied by a separate principle (the creature's genetic nature).[30]

While Aristotle's account of natural generation in Z7 makes explicit the conceptual distinction between phenotypic nature and genetic nature, *GC* 2.9 emphasises their nonidentity. In both accounts natural generation is said to require three principles: matter, form, and a source of motion that puts the matter together according to that form. These correspond to the three senses of nature identified in *PA* 641a22-33: material nature, phenotypic nature, and genetic nature.[31] What is not explicit in Z7, however, is that the third principle is something distinct from the other two. This is unmistakable in *GC* 2.9. First, Aristotle tells us that the principles of natural generation are three *in number* (335a28). Thus, material nature, phenotypic nature, and genetic nature are not only conceptually different, they are *numerically* different as well. Second, and more importantly, Aristotle says that matter and form are "not sufficient" for generation (οὐ ἱκαναί); there must also be a moving cause "over-and-above" these two principles (ἔτι προσυπάρχειν; cf. 335b7, προσεῖναι). Indeed, the point of *GC* 2.9 is that previous attempts to account for natural generation failed precisely because they did not posit a *distinct* moving cause: the materialists identified it with the matter while "Socrates in the *Phaedo*" identified it with the form.

§7.2 The causal argument

The idea that an organism's phenotypic nature and genetic nature are numerically distinct principles can also be established by appealing to their different causal roles in the generation of an organism. One of Aristotle's objections to the *Phaedo* account of coming-to-be in *GC* 2.9 is that, while forms exist (they are real ontological items), they are not productive of anything. It is the doctor who produces health in the patient and the scientist who produces knowledge in the student, not health and knowledge themselves (335b20-4). This objection appears to be a restatement of an earlier argument from *GC* 1.7 against turning forms into moving causes:

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[30] *GC* 335b30-4, 336a8-12; cf. *GA* 734b24-735a4.

[31] It is important to note here that this moving cause (in natural generation) will not be the parent organism but the embryo's own nature. For natural generation requires an *internal* source of motion.

> The productive agent is a cause in the sense of that from which the change begins, but the end for the sake of which it takes place is not productive. That is why health is not productive, except metaphorically. For when the productive agent is present the patient *becomes* something; but when states are present the patient no longer *becomes* but now *is* <that thing>, and forms (i.e. ends) are a kind of state. (324b13-17)

This passage supplies us with two different ways to establish the nonidentity of a particular organism's genetic nature and phenotypic nature.

One argument appeals to their teleological relation. Consider the following passage from *GA* 2.6:

> While both [sc. heating and cooling] are employed by the nature, having a capacity for making one thing into this and another into that from necessity, in the generation of organisms it is certainly for the sake of something that the heating and cooling of these things takes place and that each of the parts is formed, the flesh being made soft, heating and cooling making it such on the one hand from necessity and on the other hand for the sake of something, while the sinews are made solid and elastic, the bones solid and brittle. (743a36-b5)

Given the active role assigned to nature here, it is certain that Aristotle is talking about the embryo's genetic nature. Flesh, bone, and sinew, on the other hand, as well as their functions are taken as being partially constitutive of the end for the sake which this nature acts (they are part of its phenotypic nature). Aristotle is categorical in *GC* 324b13-17 that the end for the sake of which change occurs (the form at the end of the process) is *not* the thing that produces that change: "The productive agent is a cause in the sense of that from which the change begins, but the end for the sake of which it takes place is not productive."[32] It follows from this that the offspring's genetic nature must be distinct from its phenotypic nature. For the nature that "uses" heating and cooling is the productive agent – it is a cause in the sense of that from which the change originates – while nature in the sense of adult form is the end for the sake of which it acts. And this nature is not productive of anything.

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[32] cf. 335b5-7.

We can put the current argument in more formalised terms. What *GC* 324b13-17 is saying is that for any two things *A* and *B*, if *A* is the productive agent and *B* is the end for the sake of which it acts, then *A* and *B* must be different things, since the end is not productive of anything. In this case *A* is the genetic nature (the nature that "uses" heating and cooling as instruments) and *B* is the phenotypic nature (the end for the sake of which that heating and cooling takes place). Therefore, genetic nature and phenotypic nature must be different.[33]

§7.3 The temporal argument

The second half of 324b13-17 suggests a third means for establishing the nonidentity of an organism's genetic nature and phenotypic nature. The basic form of this third argument is straightforward. The genetic nature and phenotypic nature cannot be the same principle since an embryo has its genetic nature but lacks its phenotypic nature. In more formalised terms, the argument consists of three premises:

(1) A developing horse has the genetic nature of a horse.

(2) A developing horse does not have the phenotypic nature of a horse.

(3) One and the same thing cannot be both present and absent in the embryo at the same time.

It follows from this that the genetic nature and phenotypic nature cannot be one and the same thing, since the former is present in the embryo during development while the latter is not. That Aristotle holds premise (1) it is sufficiently clear, both on textual grounds and on logical grounds. For the productive nature must be present in the embryo during the process of its development, since it is the source of the change. We can offer different formulations of this argument by offering different reasons for accepting premise (2).

One version of the argument can be obtained from 324b13-17 itself. Aristotle says that the productive agent must be present during coming-to-be, since it is the source of change. However, when the form is present the matter is no longer *becoming* a thing but now *is* that thing. This establishes the nonidentity I am after: the nature which is present in a developing horse cannot be the phenotypic nature (the adult form). because when that nature is present it is no longer *becoming* a horse but already *is* a horse (cf. Z17, 1041b4-9).

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[33] A similar argument can be found in Lennox 2001b, 185.

This same conclusion can also be established on slightly different grounds. The genetic nature must be present in the embryo before it begins to develop, since development proceeds from that nature (nature is an internal source of growth and development). On the other hand, Aristotle insists that a thing does not acquire its phenotypic nature until *the end* of that process (1015a3-12, translated above).[34] Thus, since the developing embryo has its genetic nature before it acquires its phenotypic nature, they must be numerically distinct natures.

A third version of this argument can be obtained by looking at *Physics* 193a31-b6. Here Aristotle uses the example of flesh and bone rather than complete organisms, but the point is the same:

> For just as what is in accordance with art and what is manufactured (τὸ τεχνικόν) are called 'art', so too what is in accordance with nature and what is natural are called 'nature'. But we would not say in the former case that there exists (ἔχειν) anything in accordance with art, if it is a bed only potentially, not yet having the form of a bed; nor would we call it manufactured. The same is true of things formed by nature. For what is flesh or bone potentially does not yet have its proper nature (τὴν ἑαυτοῦ φύσις); nor does it exist by nature, until it acquires the form specified in the definition, which we name in defining what flesh or bone is.

Generalising the point in this passage to horses, what is potentially a horse does not yet have its proper nature until it acquires the form specified in the definition of a horse (phenotypic nature). And it acquires this form at the end of the process of its development. As we have seen, Θ7 tells us that a thing is potentially a horse only when it is in such a condition where, in the absence of anything external impeding it, it will straightaway develop into a horse through the agency of its own generative principle (cf. 1049a13). Therefore, *by definition*, a potential horse already has the

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[34] cf. Θ8, 1050a3-9: "the adult is prior to the child, and the human being to the embryo, *because the one now has the form while the other does not*". See also *GA* 736b1-b5, translated below.

genetic nature of a horse but not the phenotypic nature (which comes at the end of development), and so the two must be distinct.[35]

The foregoing discussion introduced three basic arguments in favour of the nonidentity reading of *PA* 641a22-33 (that genetic nature and phenotypic nature are numerically distinct principles and not one principle under different descriptions). First, Aristotle's ontology of coming-to-be posits three *numerically* distinct entities: matter, form, and an internal principle of change that organises the matter according to that form. The nonidentity of these three entities is most explicit in *GC* 2.9 where Aristotle insists that generation requires there to be a moving cause present *over-and-above* the matter and the form. Second, *GC* 324b13-17 argues for a nonidentity between the end and the productive agent of change. In this way the nonidentity of phenotypic nature and genetic nature simply falls out of their different causal roles in natural generation. The genetic nature is the productive agent while the phenotypic nature is the end for the sake of which production takes place but is not itself productive of anything (*GA* 743a36-b5, *GC* 335b5-7). Third, I argued that genetic nature and phenotypic nature cannot be one and the same thing on the grounds that a developing embryo has the one but lacks the other. I offered three variations on this basic argument. One appeals to Aristotle's claim in *GC* 324b13-17 that "when the productive agent is present the patient *becomes* something; but when states are present the patient no longer *becomes* but now *is* <that thing>, and forms (i.e. ends) are a kind of state". Another appeals to *Metaphysics* Δ4 where Aristotle insists that an organism does not have its phenotypic nature until the end of development, though it must already have its genetic nature at the start since development proceeds from that nature. Finally, I argued that the genetic nature cannot be the phenotypic nature on the grounds that a potential *F* has the former but lacks the latter by definition (Θ7).

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[35] Recall that Θ7 provides the criteria for determining when we have a potential *F* so that anything that meets those criteria is a potential *F*. The current point is that having the genetic nature of an *F* and not already having the phenotypic nature of an *F* are necessary conditions for being a potential *F*. Indeed, *GC* 324b13-17 has just said that when a thing has its phenotypic nature it is not becoming an *F* but is now an actual *F* (cf. Z17).

§8 Broadie's objection

I now want to turn to an objection raised by Broadie against the nonidentity reading being defended here. Broadie argues for a "conceptual coincidence" between nature in the sense of fully developed structure (phenotypic nature) and nature in the sense of inner principle of change (genetic nature). Broadie is inconsistent on what exactly this conceptual coincidence amounts to.[36] In the version considered earlier Socrates' fully developed structure is both the end of his own development and the source of the process that terminates in those same structures in Menexenos (his offspring). In the following argument, however, Broadie claims that Menexenos' fully developed structure *is* the source of his own development. This is why Broadie thinks Aristotle's natural teleology generates a paradox. In what follows I shall be concerned only with this second formulation of conceptual coincidence and ignore the inconsistency.

Broadie's objection to the nonidentity thesis targets the third pattern of argument offered above. According to this argument, genetic nature and phenotypic nature cannot be the same principle since an embryo has the one when it lacks the other. At the start of development the embryo already has its genetic nature but not its phenotypic nature. Broadie objects to this on the grounds that refusing to identify these two principles leads to consequences which are unacceptable to Aristotle. Her argument for this is quite complicated, and so it will be helpful to reproduce it in its entirety here rather than attempting to summarise it.[37]

> But however paradoxical the equation of final with efficient cause, consider the consequences of denying it, i.e. refusing to identify nature as principle of change or development with nature in the sense of fully developed structure. Suppose that we reject this, on the ground that the developing creature has one but lacks the other. It follows that when the creature attains developed form, it has a property which earlier it lacked. If this developed form is, as Aristotle always holds it to be, that in virtue of which the creature is a substance of the kind that it is, it follows that the still developing creature was not a substance of that

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[36] See note 25 above.

[37] This passage is a continuation of the passage quoted at the outset of chapter one in which Broadie sets out the paradox of teleology.

kind. Either [1] it was of a different kind, or [2] it was no substance at all. In either case, it is impossible that developing and developed should be the same individual substance at different phases in its history, for the same individual Aristotelian substance must, for as long as it exists, be of a single nature throughout all changes, including development. But if developing and developed are not the same individual, the developed never did develop, and there is no such thing as development. [3] The alternative, for Aristotle equally absurd, would be to deny that the fully developed structure is an essential property of the creature which attains it. In that case, the developing creature lacked nothing in virtue of which the developed is the kind of substance that it is. But then what is the essential or substantial nature that was present throughout? The only likely candidate is the property of being a source of development (or developments) into such and such a type of structured object. This property is common to the developing and also to the developed (the latter being a potential parent of like offspring). This implies that being endowed with a source of development into mature structure F is of the essence of the object, even though having F itself is not of the essence; from which it follows that the substance might itself cease to be characterized by F (e.g. the structure of a mature human being) while retaining the essential power of giving rise to developments towards F: thus what is no longer a man (of human structure) could nonetheless generate man. To conclude: if a developing thing is a substance of the kind it is on account of the principle within it of development, and if a developed one is of the kind *it* is on account of its fully structured form, then these two natures, *natura naturans* and *natura naturata*, must be and all along have been in some sense identical, or else the same individual substance has different substantial essences.[38]

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[38] Broadie 1982, 65-6 (§20). The numerical notations are my insertion. For consistency with my own discussion I have also changed Broadie's "C" to "F" (e.g. "This implies that being endowed with a source of development into mature structure C [F] is of the essence of the object").

The argument in this passage is a *reductio ad absurdum*: (1) – (3) represent the consequences of refusing to identify genetic nature ("nature as principle of change") and phenotypic nature ("nature in the sense of fully developed structure") which Aristotle is supposed to find unacceptable.

I think Broadie is too quick to dismiss these three alternatives. As we shall see, each represents a viable position and thus three possible escape routes from the dilemma. Now it would certainly be enough for avoiding Broadie's objection if it could be shown that at least one of these alternatives is a live option for Aristotle and is not (as Broadie suggests) an absurd consequence of refusing to collapse genetic nature and phenotypic nature into a single principle. However, it will strengthen my position enormously if I could show that all three of them are acceptable in this way. Since the three alternatives represent mutually exclusive positions, I shall not insist on any one of them but simply offer them up as three possible ways to respond to Broadie's objection. This will be enough to show that her objection is in fact no objection at all.

Before beginning, it will be useful to isolate what appear to be the two main philosophical assumptions driving Broadie's argument. I shall call these two assumptions the substance criterion and the unity criterion, respectively. Stated negatively, the substance criterion holds that x cannot be said to be an F unless it possesses the essential property that makes something an F. According to the unity criterion, embryo (x_1) and adult (x_2) must be the same individual F at different points in its ontogenetic history in virtue of a single common substantial nature (i.e. they both have the essential property that makes a thing an F). This is necessary for saying that the embryo *develops into* the adult, which I take to be what is really at stake.

The satisfaction of the unity criterion is parasitic on how the substance criterion is filled out. For example, on Broadie's reading an organism is an F just in case it possesses the characteristic shape and form proper to an F. Thus embryo and adult will be (numerically) the same F at different points in its ontogenetic history in virtue of possessing (numerically) the same phenotypic nature. Obviously this would require something like formal preformationism to work. For the claim being made is that nature in the sense of inner principle of change (the nature which pre-exists in the embryo) *is* nature in the sense of fully developed structure. And Aristotle denies that the undifferentiated embryo possesses any *actual* structures proper to its adult form

(e.g. 734a16-25, 741b22-4). However, I think the substance criterion is still open at this point.

The general structure of Broadie's argument is a two-horned dilemma (with the first horn dividing into two consequences identified here by (1) and (2)). These two horns represent two alternative readings of the substance criterion. The first takes the property in virtue of which *x* is an *F* to be the fully developed structure of an *F* (phenotypic nature). The second horn takes the property in virtue of which *x* is *F* to be the productive source of that structure (genetic nature). Broadie wants to force us into accepting the identity of these two properties on the grounds that their nonidentity leads to absurdity. My strategy in answering Broadie's objection will be to show that each of the three alternatives is an acceptable conclusion for Aristotle and so do not force us to identify the two senses of formal nature. The first two solutions both involve accepting Broadie's reading of the substance criterion – *x* is a substance of kind *F* in virtue of possessing the phenotypic nature proper to an *F* – but rejecting the unity criterion. (As we shall see, there are two ways to reject the unity criterion.) The third solution accepts Broadie's unity criterion – embryo and adult are the same substance in virtue of possessing a single formal nature – but rejects her reading of the substance criterion. On this alternative, embryo and adult are the same individual substance at different points in its ontogenetic history in virtue of possessing (numerically) the same *genetic* nature. (This is numbered (3) in the above passage.)

§8.1 First Horn

The first horn of Broadie's argument takes phenotypic nature as the substance criterion: it is the possession of a characteristic shape and form that makes an organism a substance of kind *F* (e.g. a horse or a human being). This seems to be Aristotle's position, for example, at 1015a3-12. If, as I hold, the embryo does not have this nature until the end of development, then the developing embryo will not be an *F* until the end. Thus, either it was a different kind of substance than the thing at the end of the process or it was not a substance at all. In either case, Broadie argues, it is false to say that embryo and adult are the same individual substance at different points in its ontogenetic history. And if they are not the same individual, then it is false to say that the embryo *developed into* the adult and there is no such thing as development. This is supposed to force us into accepting that, if phenotypic nature is the essence of an *F*, the genetic nature and the phenotypic nature "must be and all

along have been in some sense identical, or else the same individual substance has different substantial essences".

One response to this would be to accept that embryos are not substances at all (numbered (2) in the above passage) and simply deny that this is an absurd consequence of nonidentity. Indeed, at *PA* 641b31-2 Aristotle tells us that an embryo is a γένεσις (a process) while the adult at the end is the οὐσία (the entity). What Aristotle seems to be saying here is that the embryo is not an *F* but the coming-to-be of an *F*. In other words, pace Broadie, a tadpole is not a developing *frog* but *the development of* a frog. Admittedly, this is the only text where we find Aristotle making this interesting claim; he certainly never argues for it.[39] However, the point is simply that denying an embryo is a substance at all would not be as absurd a consequence as Broadie makes it out to be. For Aristotle himself entertains that idea (whether or not he can be shown to hold it consistently).

Another way to avoid Broadie's objection would be to accept that a developing organism is a substance but deny that Aristotle thinks it must be the same kind of substance at every point in its ontogenetic history (consequence (1) in the above passage). Broadie rejects this alternative on the grounds that the same individual substance will have different substantial essences, which violates the unity criterion. However, when we turn to the *Generation of Animals* we find that Aristotle does not actually accept this criterion:

> It is as they develop (προϊόντα) that embryos acquire the capacity for sensation, in virtue of which a creature is an animal. For it is not the case that an animal and a human being are formed at the same time, or an animal and a horse, and likewise for the other animals; for the end is formed in the final stage, and what is distinctive (τὸ ἴδιον) is the end of the process of development. (736b1-5)

Aristotle's denial that when an embryo comes to *be* an animal it also comes to *be* a human or horse or any other particular kind of animal exposes a critical weakness in Broadie's argument. Broadie claims that "the same Aristotelian substance must, for as long as it exists, be of a single nature throughout all changes, including development" and that the consequence of refusing to collapse the genetic nature and phenotypic nature is that "the same individual substance" will turn out to have "different

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[39] Though see Freeland 1987.

substantial essences", which Aristotle is supposed to find absurd. Yet, Aristotle is categorical in this text that the same individual substance *does* have different substantial essences at different points in its ontogenetic history.

Aristotle's point here is that as soon as an organism develops the parts of its sensory system, while it is now true to say of that creature that it *is* an animal ("animal" can be truly predicated of it), it is false to say that it *is* a horse or human being or any other particular kind of animal ("it is not the case that an animal and a human being are formed at the same time, or an animal and a horse, and likewise for the other animals"). The reason is that it does not yet have the shape and form proper to any particular kind of animal. So, pace Broadie, it is not true to say of the tadpole that it *is* a frog anymore than it is true to say that it *is* a horse or *is* a human being. Since the tadpole does not acquire the distinctive phenotypic nature of a frog until the final phase of its development, it will not *be* that particular kind of organism until that phase.

Of course there is a sense in which Aristotle thinks it is true to say of the tadpole that it "is" a frog: it is a *potential* frog. However, his point in 736b1-5 turns on the claim that it is not an *actual* frog until it has the characteristic shape and form proper to that type of creature. This exposes another presupposition of Broadie's argument that Aristotle would not accept. Broadie assumes all along that it is true to say of the embryo that it is an *F* at every point in its ontogenetic history. More importantly, she assumes that embryo and adult are both actual *F*s (indeed numerically the same *F*) and that *F* is predicated of them both in virtue of (numerically) the same nature.[40] As such, Broadie argues, the nature which pre-exists in the embryo (nature in the sense of inner principle of change) must be its nature in the sense of the fully developed adult form. For this is the property in virtue of which we predicate *F* of the adult.[41] However, Aristotle would object to this on the grounds

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[40] cf. 64: "...when we ask... what the growing thing is, i.e. what sort of growing thing it is, the answer is given by predicating *of that object* the same word as is used of it in the developed state" (emphasis Broadie).

[41] cf. 65: "Putting all this together, we may say (i) that both *qua* developing and *qua* developed, the natural substance is endowed with an inner principle of change; and (ii) that if 'F' is the predicate expressing the shape or form when fully developed, the creature both *qua* developing and *qua* developed is to be defined as an F. From this

that *F* is not predicated of embryo and adult in the same way.[42] It is predicated of the embryo *potentially* and of the adult *actually*. More importantly, it is not predicated of them in virtue of the same property. For something is an actual *F* in virtue of its actual shape and form (Z17) but a potential *F* in virtue of the fact that its matter is capable of developing into that form when acted on by the appropriate causal agent (Θ7; cf. Θ8, 1050a15-16).

The main point is that Aristotle is categorical in the *GA* that the still developing embryo is not an actual *F* until it acquires the distinctive property that makes something an actual *F*. And it does not acquire that property until *the end* of its development. Thus, since the embryo is not an actual *F* (even if it is a potential *F*), Broadie's consequence (1) does not force us into identifying genetic nature and phenotypic nature.[43]

There is one outstanding issue that needs to be addressed before moving on to the third solution to Broadie's dilemma. It has to do with the unity criterion itself. *If* the possession of a distinctive phenotypic nature is the criterion for being a substance of kind *F*, then Aristotle's insistence that the embryo does not acquire this property until the end of its development does lead to the two consequences that Broadie highlights. Either a developing embryo is not a substance at all or it is a different kind of substance than the thing at the end of the process. I have argued that both of these alternatives would be acceptable conclusions for Aristotle and so do not pose a problem for the nonidentity thesis. However, Broadie argues that in either case it will still be false to say that embryo and adult are the same individual substance at different points in its ontogenetic history. And thus it will be false to say that the embryo develops into the adult – which *is* an absurd conclusion. Thus, one might object that neither of our first two solutions actually manages to escape Broadie's dilemma.

The crucial move here is the claim that if the embryo is not a substance (consequence (2)), or if it is a different kind of substance than the thing at the end of

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Aristotle concludes that nature in the sense of inner principle of change *is* the developed form."

[42] That is, assuming *F* is predicated of the embryo at all (641b31-2).

[43] Unless otherwise stated, I shall continue to speak of something's being an *F* in the sense of being an actual *F*.

the process (consequence (1)), then it cannot be identified with the adult at an earlier stage in its ontogenetic history. However, this does not follow. What Broadie has in mind is diachronic unity, being the same individual over time. And she sees this as being bound up with substantial unity, being the same *kind* of substance over time. What *GA* 736b1-5 makes perfectly clear, however, is that (in the *GA* at least) diachronic unity is severed from substantial unity in Aristotle's mind. For Aristotle, being numerically the same entity over time does not necessarily require being the same *kind* of entity: "For it is not the case that an animal and a human being are formed at the same time, or an animal and a horse, and likewise for the other animals." Given the divorce of diachronic unity from substantial unity, all we would need to show in order to be able to say the embryo *develops into* the adult is that they are numerically the same individual, that the embryo *is* the thing at the end of the process (diachronic unity), not that they are the same individual *F* (substantial unity).

It is entirely possible that when it came to biological development Aristotle simply did not find questions about diachronic unity very puzzling (which is not to say he was not interested in questions of identity at all: see the problem of Siamese twins at 773a5-13). He may have simply taken it as obvious that the embryo is the same individual as the thing at the end of the process.[44] We can explain this, I think, by remembering that for Aristotle the process of development is one continuous change (cf. 741b9: συνείρεται τὸ ἐφεξῆς). For, being one and continuous, there is nothing to threaten the diachronic unity of the developing organism. Diachronic unity

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[44] Here I am talking about Aristotle's mature theory of biological development as presented in the *GA*. The *Physics*' preoccupation with the question of diachronic unity is noticeably absent from the *GA*, whose underlying metaphysics must be assumed to supersede those of the *Physics* on the question of substantial coming-to-be. The *Physics* is mainly concerned with diachronic unity in the context of accidental changes such as Socrates coming to be healthy from being sick. Here there is a clear subject that persists through the change, Socrates, who simply exchanges one accidental property for another. However, in biological development things are radically different. Here the properties acquired along the way are constitutive of the thing's substantial being (understood phenotypically). What the underlying subject is in this case (what I have been calling the "embryo", though properly speaking it is the material nature) is not as clear.

only becomes a problem if one thinks development is composed of discrete stages. Consider the modern labels "zygote", "blastula", and "gastrula". Each of these represents the embryo in different stages of development. If we imagine these to be like actual points on a line, then the question naturally arises: In virtue of what can we say of the zygote, blastula, and gastrula that they are all the same entity at different points in its ontogenetic history? In this case we might (as Broadie does) look for a single property which is common to all three entities. However, for Aristotle, as indeed for modern developmental biology, this is simply the wrong way to think about development and (for Aristotle at least) the wrong way to think about lines. Just as Aristotle denies that a line is composed of actual points, so too he denies that development is composed of actual stages. Now the distinction between a developing embryo and the development *of* an embryo is deceptive here. For the process of development *just is* the embryo in the process of developing into its adult form. Thus, the analogy with Aristotelian continuous lines equally applies to the embryo itself considered as a temporally extended being (though one that is undergoing transformation).[45] Thus, since development is one continuous change or, alternatively, since it is the coming-to-be of one thing, there is nothing to threaten the diachronic unity of the developing organism. And so the question of whether embryo and adult are the same individual simply does not arise.

Having said that, I think we can offer a third solution which allows for Broadie's unity criterion. The first two solutions to Broadie's dilemma involved accepting her reading of the substance criterion (*x* is a substance of kind *F* in virtue of possessing the phenotypic nature proper to an *F*) but rejecting the unity criterion, either by denying that embryo and adult must be the same kind of substance or by denying that the embryo must be a substance at all. In either case, there is no reason to insist that the embryo must already have the phenotypic nature proper to an *F* and thus no reason to identify this with its genetic nature (the nature it does have). The

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[45] In modern biology, zygote, blastula, and gastrula are not three distinct entities either but conceptual abstractions from what is essentially one temporally continuous entity. "Zygote", "blastula", and "gastrula" are simply names we give to the embryo at arbitrary points in its continuous development (cf. Maienschein 2000, 124-5). It is as if we were to give a name to three arbitrary (potential) points on an Aristotelian continuous line.

third solution would involve accepting Broadie's claim that embryo and adult must be the same individual *F* in virtue of possessing (numerically) the same formal nature and simply deny that this is the phenotypic nature. In that case the embryo will not lack any essential property in virtue of which the adult is an *F*. The only alternative, Broadie says, is to take the property in virtue of which they are both *F* as "the property of being a source of development (or developments) into such and such a type of structured object". In other words, the substantial nature which is common to embryo and adult is the genetic nature. On this reading, although the embryo does not yet have its fully developed adult form, it will still be the same individual substance as the thing at the end of the process in virtue of possessing (numerically) the same genetic nature.

§8.2 Second Horn

On the current reading of the substance criterion it is the possession of a characteristic genetic nature ("the property of being a source of development (or developments) into such and such a type of structured object") that makes a creature an organism of kind *F*. Again, Broadie dismisses this alternative as absurd:

> This implies that being endowed with a source of development into mature structure F is the essence of the object, even though having F itself is not of the essence; from which it follows that the substance might itself cease to be characterized by F (e.g. the structure of a mature human being) while retaining the essential power of giving rise to developments towards F: thus what is no longer a man (of human structure) could nonetheless generate man.

By the structure of a mature human being Broadie means (what I am calling) the phenotypic nature of a human and by the source of development into that mature structure its genetic nature. I have argued that a human being's phenotypic nature and genetic nature are numerically distinct on the grounds that the developing human has its genetic nature but lacks its phenotypic nature. Moreover, as we shall see, only the former is passed on to the offspring in the act of reproduction. As Broadie rightly points out, it follows from this that a mature human being could (at least in principle) lose its phenotypic nature whilst retaining its genetic nature.[46] However, it doesn't

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[46] cf. 722a11-14.

follow in this case that what is no longer a human can nevertheless generate a human. For to say that the human ceases to *be* a human when it loses its phenotypic nature simply assumes that it was the possession of that nature that made it a human being in the first place. And this is precisely what is being denied here. On the current reading of the substance criterion it is the possession of a characteristic *genetic* nature that makes something a human being, not the possession of a characteristic phenotypic nature. And since the organism in this example retains the genetic nature of a human being, it follows that what *still is* a human generates a human.

§9 Genetic nature as οὐσία?

In the end Broadie does not present a convincing case against this third alternative, since her objection merely begs the question. But is there any reason for thinking that Aristotle would accept this alternative reading of the substance criterion (that what makes a creature an organism of kind *F* is the possession of a characteristic genetic nature)? Pace Broadie, Aristotle does not always take phenotypic nature to be the property in virtue of which an organism is a substance of the kind it is. As we have seen, the *Parts of Animals* also identifies the creature's genetic nature with its substantial being: nature understood as substantial being is *both* genetic nature *and* phenotypic nature. It is not entirely clear how we are supposed to understand this. On Broadie's (and Lear's) reading there is just one ontological item (the shape and form of the adult) which is the creature's substantial being; genetic nature and phenotypic nature are this one ontological item under different descriptions. However, I have already presented several arguments in favour of taking genetic nature and phenotypic nature to pick out two numerically distinct parts of an organism. Given this nonidentity, we need to find a way to understand Aristotle's claim that both of these two natures count as substantial being.

Aristotle could simply be saying that genetic nature and phenotypic nature both qualify as substance whereas material nature does not. However, in Zeta/Eta the matter is also said to be substance; it is just that the form is substance in the primary sense. In that case *PA* 641a22-33 may be read as suggesting that both phenotypic nature and genetic nature are proper candidates for being the substance of an organism in the primary and chief sense while remaining silent (or neutral) on which of them this is.

Is there any evidence outside *Parts of Animals* 1.1 for thinking that what makes a creature an organism of kind *F* is the possession of a characteristic genetic nature? Is there any reason besides this one statement for thinking that Aristotle ever entertained the idea that *both* phenotypic nature *and* genetic nature are proper candidates for being the substance of a biological organism in the primary and chief sense? I shall argue that Aristotle's view in the *Parts of Animals* (as expressed in 641a22-33) is consistent with at least one interpretation of the central books of the *Metaphysics*. On the one hand, it is almost universally agreed that Z17 reaches the conclusion that an organism's substantial being is to be identified with its phenotypic nature (its fully developed adult form). On the other hand, H6 seems to suggest that an organism's substantial being can also be identified with the productive agent (τὸ ποιῆσαν, 1045a31) or moving cause (ὡς κινῆσαν, 1045b22) of its generation. I want to argue that this productive agent is the creature's genetic nature, what Aristotle calls its nature "ὡς ἡ κινοῦσα".

The account of substantial being in Z17 is well-rehearsed in the literature and its conclusions are relatively uncontroversial with respect to what it identifies as substantial being. At the outset of Z17 Aristotle announces a "fresh start" in his search for οὐσία by introducing a new criterion for determining what the substance of a thing is. According to this new criterion, substantial being is whatever it is that is primarily responsible for making the matter (the subject or ὑποκείμενον) an individual of such-and-such a kind: What makes this body a horse? What Aristotle is after here is "the cause of the matter in virtue of which it *is* a definite thing", which is identified with the indwelling form (1041b4-9). In the case of biological substances this turns out to be the formal nature (1041b25-31). Here formal nature is clearly meant to pick out the organism's phenotypic nature. In the second part of the chapter phenotypic nature is said to also be the thing responsible for the unity of the adult body. The connection between substantial being and unity is made explicit in H6. There Aristotle tells us that asking what makes *x* an *F* is the same as asking what makes *x* one *F*.[47] Thus, according to Z17, phenotypic nature turns out to be the cause of a thing's membership in its kind (insofar as it makes this body an *F*) and the cause of its unity (insofar as it makes this body *one F*).

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[47] 1045b19-21. Cf. Charles 2000, 297.

When the question of substantial unity arises again in H6, we appear to get a very different answer. In this case the cause of a thing's unity (and thus its substantial being) is identified with its producing agent or moving cause:

> But if, as we say, one is matter and the other form, the one potentially and the other actually, then what is being sought would no longer seem to be a puzzle. For this puzzle would be the same even if the definition of *X* were 'bronze sphere'. For this name would be an indication of the account. So that the cause we are searching for is what it is that causes the bronze and the spherical to be one. But it is apparent that this is no longer a puzzle, because the one is matter and the other form. What, then, is the cause of this – of what is potentially *F* being actually *F* – except the productive agent (τὸ ποιῆσαν) in those things which admit of coming-to-be? For there is no other thing that causes the potential sphere to be an actual sphere. And this is the essence of each thing. (1045a23-33)

H6 is an extremely controversial chapter. In what follows I shall attempt to develop a reading of the text which supports the view that the substance of a thing is to be identified with its genetic nature.

There is no clear consensus as to what exactly "this" (in the final sentence) is supposed to pick out. According to one reading, "this" refers back to the "thing that causes what is potentially spherical to be actually spherical", namely the productive agent (τὸ ποιῆσαν).[48] On this reading, Aristotle's point is that the productive agent is the essence of each thing that comes into being.[49]

Aristotle has already cleared the way for this idea back in Z17. There we are told that the object of inquiry is "the cause" and that this is the essence of each thing (1041a27-8). In some cases, Aristotle says, this will be the end for the sake of which a thing exists. But in other cases the essence will be the primary source of motion (a30). We look for the final cause in those cases where we are interested in being and the

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[48] Charles also reads "this" as referring to "the cause" but takes the cause to refer to some other cause and not the productive agent (2000, 295 *n.* 40). For more on this reading see below.

[49] This is how I read the final sentence of the text (see also Gill 1989, 169). For an alternative reading see Burnyeat et al. 1984, 41; Harte 1996 (esp. 292 *n.* 42 and 43).

moving cause when we are interested in coming-to-be (a30-4). I would construe Z17 and H6 as pursuing these two alternatives, respectively.

We can ignore most of the details of 1045a23-33. What is important for my immediate purposes is the suggestion that the cause of unity (what it is that makes a potential *F* into an actual *F*) is the productive agent. Aristotle reiterates this idea in the closing lines of the chapter when he says that in the case of substances that contain matter "there is no cause [of unity] except whatever it is that causes development [lit. the cause "as mover" (ὡς κινῆσαν)] from potentiality to actuality" (1045b21-2). Now the productive agent here cannot refer to the Unmoved Mover.[50] For one thing, the Unmoved Mover is not an efficient cause. What we are talking about is the particular moving cause of an individual's development. Looking at Z7, this could refer either to the parent organism itself (1032a15-17) or to the creature's genetic nature (1032a24-5). However, given the connection between a thing's substantial being and the cause of its unity, taking the productive agent in H6 (the cause of unity) to be the parent organism would imply that the substance of a thing is another individual distinct from itself. It follows from this that a thing's substantial being could pass out of existence before it does (unacceptable for Aristotle). Taking the productive agent to be the creature's own genetic nature avoids this consequence.

On my reading, then, the productive agent which is primarily responsible for changing the potential *F* into an actual *F* is the thing's own genetic nature (what *PA* 641a22-33 calls nature ὡς ἡ κινοῦσα). It is fairly easy to see why this nature should be responsible for unifying the organism's matter and form. For it is the principle that is responsible for the matter supplied by the female developing into its adult form. The idea that the matter *develops into* its adult form is significant insofar as it avoids the model of production where two entities (a matter and a form) are compounded together to make a third entity (the composite). In this case one might seriously wonder why the thing compounded from them is not a mere aggregate of matter and form. The idea that the one *develops into* the other avoids the problem, especially when the things in question are one and the same *F* in two states of being (viz. potentiality and actuality).

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[50] Contrast Rist 1989, 239-41.

Gill also takes H6 to be identifying the cause of a thing's unity with the moving cause of its generation.[51] However, she takes this cause to be necessary because material compounds are unstable. On this reading the productive agent is a cause of a thing's unity in virtue of being responsible for its material elements holding together at the chemical level:

> The simpler matter is a source of difficulty because the elements are most [sic] themselves, not in combination, but in simple separation—because they tend to be recreated and thereby to destroy the higher object that they compose. The elements must therefore be controlled and coordinated when the object is generated and must still be controlled while the construct lasts. A controlling cause is required precisely because the unity of a composite substance is so easily destroyed. Given the recalcitrance of the lower level material properties, composite bodies must be preserved as unities or they will simply degenerate into something simpler. Aristotle appeals to the [moving] cause in H.6 to explain why composites *come to be* unities and why they *remain* the unities that they have become.[52]

Gill's reading, though clever, seems to go well beyond anything that is given in H6. Nothing in that chapter suggests that the explanadum is the structural integrity of highly unstable material substances (unity at the chemical level). Moreover, although Aristotle is certainly asking about how things *come to be* unified in H6, I do not see him asking the further question about how they *remain* unified.

On my reading of H6 the genetic nature (Gill's controlling cause) is responsible for the unity of matter and form in virtue of being the cause of development from potentiality to actuality. This also provides a clue as to why an organism's genetic nature, as the moving cause of its development, should count as its essence or substantial being. The key lies in the fact that the development of an embryo into its adult form is precisely the development of a potential *F* into an actual *F*.

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[51] Gill's characterisation of this moving cause (below) strongly suggests that she also takes it to be a principle internal to the developing organism itself (the creature's own genetic nature) rather than the parent organism. (Though see Harte 1996, 293 *n.* 44.)

[52] Gill 1989, 170.

Recall that according to Z17 the substance of an *x* (where *x* is the matter in the sense of ὑποκείμενον) is whatever it is that is primarily responsible for making that *x* an *F*: What makes this body a horse (let us call him 'Sir Desmond')? Z17 and H6 offer different answers to this question by exploiting an ambiguity in the word "make".[53] In Z17 the phenotypic nature "makes" Sir Desmond's body a horse by being present in it as form (1041b4-9). If the phenotypic nature of a frog came to be present in that same body, that is, if Sir Desmond's body suddenly came to be organised according to a frog's formal nature, then Sir Desmond would now *be* a frog. When Aristotle turns to the context of generation in H6 it is the genetic nature which is primarily responsible for "making" the matter (into) a horse. However, it does not do so by being present in the matter as its form but by bringing it from a state of potentiality to actuality. It is in this sense that Sir Desmond's genetic nature can be said to be the cause of his *being* a horse.

This reading of H6 has two advantages. First, the substantial being of an organism turns out to be an internal structural component of the thing. For its genetic nature will be the source and cause of its growth and development "in itself *qua* itself". Second, and more importantly, it provides us with an explanation for why Aristotle thinks both phenotypic nature and genetic nature are proper candidates for the substantial being of an organism. Since there are two ways in which something can be said to "make" this matter a horse – either by being present in it as form or by turning what is potentially a horse into an actual horse – there will be two answers to the question, What is it that is responsible for Sir Desmond's *being* a horse?

Before leaving H6 I should say a few words about a competing interpretation of the text. The crucial lines for my reading are the last few sentences of 1045a23-33:

> What, then, is the cause of this – of what is potentially *F* being actually *F* – except the productive agent (τὸ ποιῆσαν) in those things which admit of coming-to-be? For there is no other thing that causes the potential sphere to be an actual sphere. *And this is the essence of each thing.*

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[53] The ambiguity I have in mind is present in both the English "make" and the Greek "ποιεῖν".

Charles reads the first sentence as an earnest (as opposed to rhetorical) question.[54] He sees Aristotle asking: What is the cause of unity *besides* the productive agent? That is, setting the efficient cause aside, what *else* causes the potentially *F* to be an actual *F*? Charles reads "this" in the last line as referring to that *other* cause (namely the essence) and not the efficient cause. The point (on this reading) is that both matter and form share the same cause (e.g. they have the same teleological goal) which determines what it is to be each of them.

This seems wrong to me. Charles is concerned with avoiding what he calls the nonexplanatory or dissolutionist reading of H6. According to this reading, if one excludes the efficient cause, there is no cause of substantial unity at all; the unity of a composite substance is basic and needs no further explanation.[55] In an attempt to avoid this reading, Charles takes *para* at 1045a31 to mean something like "in addition to": In addition to the efficient cause, what *else* is the cause of a thing's substantial unity in those things that come into being? But Aristotle clearly means to say there is no other cause of substantial unity *except for* the efficient cause. This is confirmed by the closing lines of the chapter: "Thus, there is no other cause [of unity] except (πλήν) whatever it is that causes development from potentiality to actuality."[56]

Charles recognises that this last line is inconsistent with his reading of H6 and attempts to explain it away as follows:

> The explanatory interpreter, by contrast, can avoid this inconsistency if he can show that the final sentences of H.6 mean only that (if one excludes the efficient cause) there is no cause of unity of substance *distinct* from the relevant actuality and potentiality (since these encapsulate all the causal features required to explain the unity of the composite substance).[57]

There is no inconsistency when the text is read my way. The problem is that Charles ignores the efficient cause.[58] As a result he sees the reading of the text where Aristotle says there is no other cause of substantial unity except the efficient cause as

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[54] Charles 2000, 295. See also Lewis 1996.

[55] Charles 2000, 297.

[56] 1045b21-2.

[57] Charles 2000, 297-8 (Charles' emphasis).

[58] This is fairly common in the literature on H6.

nonexplanatory or dissolutionist. But why ignore the efficient cause? Aristotle is clearly not a dissolutionist here, since he says explicitly that there *is* a cause of substantial unity, namely the efficient cause. And *this* (the efficient cause) is the essence of each thing. The idea that "essence" might pick out the efficient cause does not seem to occur to Charles. However, we have already seen that in cases of coming-to-be the essence is identified with the source of motion (1041a27-32).

Like Charles, Lewis also reads Aristotle as merely brushing aside the moving cause in H6, which is "relevant only in cases of becoming, which are not his target here".[59] Thus Lewis reads the text as saying that when we ignore the efficient cause it turns out that there is no other cause of substantial unity *beyond the form and matter themselves*. But that is clearly not what Aristotle says. He says there is no other cause *beyond the moving cause* (1045a31, b21-2). Straightforwardly, then, the only thing that accounts for the unity of the matter and the form of a composite substance is the moving cause. Thus, either Aristotle thinks there is no cause of unity for the kind he is interested in here (if Lewis is right that moving causes are irrelevant) or there *is* a cause and it is the moving cause. There is no third option.

The main problem with Lewis' reading is his claim that moving causes are irrelevant in H6 since Aristotle is not interested in cases of becoming. As a consequence Lewis is forced to downplay any attention to coming-to-be in the chapter. For example, he says: "Aristotle does not use the language of becoming in the chapter except to bracket such cases at [1045]a31 (ἐν ὅσοις ἔστι γένεσις)."[60] On my reading Aristotle *is* interested in coming-to-be and so this is not an attempt "to bracket such cases". The strongest evidence in favour of this again comes in the closing lines of the chapter, which summarise the discussion: the cause of substantial unity is whatever it is that causes development *from* potentiality *to* actuality (ἐκ δυνάμεως εἰς ἐνέργειαν, 1045b22).[61] Far from setting aside such cases, Aristotle's language here strongly favours talk of becoming: the cause of substantial unity is whatever it is that causes the potential *F* to become an actual *F*. And according to Θ7

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[59] Lewis 1996, 54.

[60] Lewis 1996, 73 *n.* 36.

"the potential *F*" is the matter when it is in a state where it will immediately develop into an actual *F* of its own accord if nothing external prevents it (embryonic matter).

My reading of H6 supports the idea that an organism's genetic nature is a proper candidate for its substantial being. This is consistent with Aristotle's remarks in *PA* 641a22-33 that an organism's phenotypic nature and genetic nature both count as nature understood as substantial being. In the end, however, phenotypic nature will most likely turn out to be the substance of an organism in the primary and chief sense.[62] For it is prior to the genetic nature both in account and in being. First, the phenotypic nature is the end or τέλος specified in the account of the genetic nature insofar as the genetic nature is a potential for the formation of just that shape and form. Thus, the genetic nature of a horse is not identifiable independently of the phenotypic nature for which it is a potential (whereas the phenotypic nature is independently identifiable). Second, although the genetic nature is prior in coming-to-be,[63] Aristotle insists that the τέλος of development (which is the phenotypic nature towards which the genetic nature directs the process) is always prior in being (646a25-7). Indeed, for Aristotle, the genetic nature is present in an organism for the sake of reproducing its phenotypic nature rather than vice versa.[64]

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[61] This is supported by Ross' view that in moving from Z to H Aristotle "passes from the static consideration of substance to the dynamic consideration of change" (Ross 1924, cxxiv).

[62] *Metaphysics* 1015a13-19.

[63] Eventually I shall argue that Aristotle's analysis of natural generation entails that the reproduction of the phenotypic nature (the observable form) must be preceded by the reproduction of the genetic nature (the source of that form). This is consistent with the argument for nonidentity above according to which the offspring acquires its genetic nature *before* its phenotypic nature.

[64] Some modern philosophers of biology think that this gets things the wrong way round. For example, Dawkins (1976) takes the 'real' entities to be the genes which make use of the phenotype in order to replicate themselves. On Dawkins' view, then, the organism's phenotypic nature exists for the sake of its genetic nature.

§10 The three-dimensional organism concept

Up to this point I have been arguing that genetic nature and phenotypic nature pick out two numerically distinct principles of an organism rather than the same principle under different descriptions. Aristotle's remarks in the *PA* that both of these count as nature understood as substantial being imply that these two principles are both internal structural components of the biological substance itself (hylomorphically speaking). If I am right, then in the biology at least Aristotle is working with a three-dimensional organism concept.[65] On this reading, a biological substance is a composite of material nature, phenotypic nature, and genetic nature. To make this clearer it will be useful to say a word about Aristotle's hylomorphism.

The traditional interpretation of the *Metaphysics* takes all sensible substances, including biological substances, to be composites of matter and form. Aristotle's hylomorphism is set out, for example, at the outset of Z3:

> In one sense we say matter is of this sort [sc. the subject], in another the form, and in a third that which is composed from these. By matter I mean, for example, the bronze; by form, the configuration of the outward appearance (τὸ σχῆμα τῆς ἰδέας); and by that which is composed from these – the composite (τὸ σύνολον) – the statue. (1029a2-5)

In Z8 we are told that hylomorphic substances are not only composed from (ἐκ) matter and form but, conversely, they are also divisible (διαιρετόν) into them. For example, a statue is divisible into the bronze and the shape. Of course this does not mean that the bronze and the shape can be physically pulled apart so that I can hold

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[65] In what follows I shall use the term "dimension" interchangeably with "part". ("Principle" is intended to be neutral on the question of internal structure.) This is mainly for stylistic reasons. For example, "three-part organism concept" may sound too much like I am saying *the concept itself* has three parts to it, which is not my point. It may turn out that dimensions are a better way to characterise the components of a hylomorphic substance than parts. However, exploring this possibility would take us too far outside the scope of my current project. For my purposes I shall simply treat dimension talk and part talk as equivalent.

the matter in one hand and the form in the other.[66] Rather, the statue can be analysed into those two constituents.

Where commentators on the *Metaphysics* disagree is how best to characterise the relationship between matter, form, and composite. Answers to this question have tended to fall into two main camps. On one side are those who argue that matter and form are (in some sense) "parts" of a unified whole.[67] On the other side are those who treat matter and form as mere conceptual abstractions from something which is in itself simple and atomic.[68] On this interpretation hylomorphic substances are incomposite and have no genuine internal structure. Their being "composite" is simply an artefact of our way of looking at them. Thus, at best, we are justified in talking about statues and horses *qua* matter and *qua* form.[69]

There are several reasons for thinking that Aristotle treats matter and form as proper "parts" of a hylomorphic substance and that such compounds are therefore irreducibly complex. I will mention three here.

First, the view that hylomorphic compounds are metaphysically simple and atomic is difficult to square with the fact that throughout Zeta and Eta we are constantly reminded that sensible substances are *composed from* and *divisible into* matter and form. Talk of composition and division is extremely ill-suited for an ontology whose paradigm objects are essentially incomposite.

Second, in the closing lines of H6 Aristotle distinguishes substances that contain matter (hylomorphic compounds) from those that do not (e.g. essences: 1037a1) by saying that in the former case there is a cause of unity (namely, the moving cause) while the latter are one without qualification (ἁπλῶς).[70] The implication is that being composed of form and matter makes a thing complex and

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[66] This might be one area where "dimensions" has an advantage over "parts".

[67] Haslanger 1994, Charles 1994, Lewis 1994, Loux 1995a, Lewis 1996, Charles 2000.

[68] Ackrill 1972-3, Rorty 1973, Kosman 1987, Balme 1987b, Halper 1989, Gill 1989, Scaltsas 1994. Witt 2003. Loux (1995a) offers an excellent and fairly exhaustive treatment of the different versions that fall into this camp.

[69] Lewis (1996) refers to this view as the "constructivist" or "projectivist" interpretation.

[70] At 1045b3 the latter are said to be "immediately one" (εὐθὺς ἕν).

only "one" in a qualified sense (e.g. it is one *human* or one *horse*). I shall return to this again below.

Finally, matter and form are listed among the several senses of "part" in *Metaphysics* Δ25:

> Again [part means] that into which a thing is divided or from which the whole is composed, either the form or that which contains the form [the matter]; for example, of a bronze sphere or cube, the bronze is a part (this is the matter in which the form is induced) and the angle [the form] is a part. (1023b19-22; cf. *Physics* 4.3, 210b30-1)

Although Aristotle does not tell us exactly what being a part amounts to here, the passage is clear that the relation of matter and form to the composite shares some essential feature with other types of part-whole relations.[71]

On the standard reading of the *Metaphysics* all composite substances are alike in having the same *two*-fold hylomorphic structure. Dogs, horses, statues, houses, and even mountains, are all composites of matter and form. What I am arguing is that in the biological works organisms are treated as *three*-dimensional objects.[72] On this conception of an organism the genetic source of its form is included in its hylomorphic make-up. Thus, dogs and horses (unlike statues, houses, and mountains) are composites of material nature, phenotypic nature, *and* genetic nature.

As I have said, one of the primary reasons for thinking that Aristotle treats the genetic nature as a third dimension of a biological substance (hylomorphically speaking) is the fact that in the *Parts of Animals* it is explicitly identified with the οὐσία of an organism along with its phenotypic nature: "And nature as substantial being is *both* nature as mover *and* nature as end." Taking the productive source of an organism's form to be a part of its internal hylomorphic structure provides us with a way to understand Aristotle's claim that (genetic) nature is a source and cause of development in that to which it primarily belongs "καθ' αὑτό" (*Physics* 192b20-2) or "in the thing itself *qua* itself" (*Metaphysics* 1014b18-20). This does not simply mean

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[71] For a good discussion of parts and wholes in Plato and Aristotle see Harte 2002.

[72] Below I shall consider the question of whether or not the three-dimensional organism concept is peculiar to the biological works. There I confront an objection to my thesis which points to the apparent absence of any three-fold hylomorphic analysis of organisms in the *Metaphysics*.

that a naturally generated organism has the source and cause of its form in itself in the spatial sense. It has that principle as part of its ontological make-up. In other words, the genetic nature of a living thing is partially constitutive of the substance itself.

An upshot of this is that it provides Aristotle with a much more robust distinction between genuine organisms and mere artefacts. Houses and statues are clearly two-dimensional objects in the relevant sense: they are composites of matter and form only. Here the generative principle is located in something else (the builder and sculptor, respectively). However, this also holds for cases where the generative principle is in the thing itself. In these cases Aristotle says that the productive source of the artefact's form (the art) is in the thing itself "*qua* other" (e.g. *Metaphysics* 1049b7). The idea of being "in itself *qua* other" is significant. For it suggests that "in itself *qua* itself" is a much stronger sense of being "in" something than simply being inside it in the spatial sense. To be "in itself *qua* itself" must mean being part of that thing's ontological make-up. If this is right, then the idea that an organism's genetic nature is a source and cause of development "in itself *qua* itself" means that it is partially constitutive of that object (it is a "part" of the substance, hylomorphically speaking).[73]

Another interesting implication of the three-dimensional organism concept is that spontaneously generated organisms will not count as biological substances in the strict sense.[74] For the genetic source of their form is not part of their internal

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[73] This is also suggested by the alternative phrase, "in that to which it primarily belongs καθ' αὑτό". Consider the case where patient and doctor happen to be the same individual (e.g. Hippocrates). *Physics* 192b16ff. says that in this case the art of healing is in the patient not καθ' αὑτό but κατὰ συμβεβηκός. Here body (matter), health (form), and art (source of change) are only accidentally unified in the same individual (Hippocrates). Just as in the case of the statue, to pick out Hippocrates as the product of healing (to pick out the artefact in this case) is to identify him as a two-dimensional object composed of body and health.

[74] Spontaneously generated organisms (abiogenetic kinds) are discussed in *GA* 3.11 and throughout *HA*. It is important to keep in mind here that by saying these creatures are the result of "spontaneous" organisation (ἀπό συστάσεως αὐτομάτου) Aristotle does not mean they are in some way the product of chance. For one thing it

hylomorphic structure. For example, spontaneous generation is characterised in *Metaphysics* Λ3 as generation in the absence of a nature (1070a6-9). The idea is that the development of, say, a sea urchin counts as "spontaneous" in the sense that the process is not initiated and controlled by a principle of change in the thing itself *qua* itself. In this case the various material forces, including environmental conditions such as the place where the 'foetus' develops, are sufficient for producing the kinds of motion and change that genetic natures bring about in biological substances (Z9, 1034b4-7).[75] This means that spontaneously generated creatures are only *two-dimensional* organisms consisting simply of a material nature and phenotypic nature (or visible form). Unlike genuine biological substances, these organisms have an external rather than internal source of form.

Thus an important corollary of my thesis is that biological substances are neatly marked off from all other non-biological substances in terms of having a unique three-dimensional hylomorphic structure. And most notable among these are artefacts and spontaneously generated creatures, both of which are two-dimensional objects consisting of matter and visible form alone. For Aristotle, a biological substance differs structurally from these other kinds of substance insofar as the genetic source of an organism's shape and form is partially constitutive of the substance itself.

§11 Objections to the three-dimensional organism concept

I want to close the first part of this study by confronting two potential objections to the idea that biological substances are composites of material nature, phenotypic nature, *and* genetic nature. The first draws attention to the apparent absence of any three-dimensional organism concept in the central books of the *Metaphysics* where Aristotle's hylomorphism is at the fore. The second argues that introducing the genetic nature as an additional constituent (hylomorphically speaking) makes organisms complex in ways that are unacceptable to Aristotle.

It is certainly true that throughout the central books of the *Metaphysics* biological substances are continually analysed as composites of matter and form, in

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is far too regular in Aristotle's view to be a mere coincidence (Aristotle thinks entire kinds come into being spontaneously). See Henry 2003.

[75] I discuss this in detail in Henry 2003, 197-201.

each case form picking out what I am calling the organism's phenotypic nature. Not once are they said to be composites of material nature, phenotypic nature, and genetic nature.[76] How do I account for this? I think we can offer two different stories here using the transition from the *Categories* to the *Metaphysics* as our model.

One thing that stands out about the analysis of substance in the *Categories* is the total absence of the hylomorphism characteristic of the *Metaphysics*. There are two ways one might account for this. According to Furth, the concept of substance underwent an evolution between the *Categories* and the *Metaphysics* marked by an increase in complexity of the sort I have in mind.[77] The substantial individuals of the *Categories* (e.g. Socrates) lack any internal structure. Once we get to the *Metaphysics*, however, substances are no longer viewed as one-dimensional subjects of predicates but as two-dimensional composites (σύνθετα) of matter and form.[78] Furth puts this rather colourfully by saying that moving from the *Categories* to the *Metaphysics* "is like travelling from the complex surface of a solid into its multiply-complex interior".[79]

Wedin offers a different story. According to Wedin, although the analysis of primary substances in terms of matter and form is absent from the *Categories*, this is not because Aristotle thought they were devoid of internal structure. The *Categories* is simply not interested in the structure of its primary entities:

> From the point of view of the *Categories*, primary substances… are taken as unanalysed primitives. Although some find in this evidence that Aristotle did not yet have the idea of hylomorphism, according to the basic idea of this essay the *Categories* exhibits no interest in the structure of its fundamental entities because this is irrelevant to their role in its theory of underlying ontological configurations for standard categorical statements. *Metaphysics* Z, on the other hand, is consumed by the question of structure precisely because of the specific nature of

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[76] Z7-9 is a potential exception to this (though see note 81 below). There Aristotle countenances *three* principles of coming-to-be: material nature, phenotypic nature, and genetic nature.

[77] Furth 1988, 50ff.

[78] Furth 1988, 50, 67; cf. 38, 60.

[79] Furth 1988, 49.

> its explanatory project. In particular, it undertakes to explain the nature of those entities that are the fundamental primitives of the theory of the early treatise. It has no interest in replacing them with something better suited to perform their function.[80]

On this second story, the substantial individuals of the *Categories* are the same composite substances of the *Metaphysics*. It is only when Aristotle undertakes to explain the nature of the being of those entities in the *Metaphysics* that their hylomorphic structure becomes salient.

These two competing accounts of the relation between the *Categories* and the *Metaphysics* with respect to Aristotle's hylomorphism offer us different ways to explain the apparent absence of the three-dimensional organism concept from the *Metaphysics*.

As in Furth's story, we could accept that the organisms of the *Metaphysics* are in fact two-dimensional composites of matter and form (or material nature and phenotypic nature) and simply argue that the three-dimensional organism concept is a further evolution in Aristotle's thinking about substance. On this story the concept of substance will have undergone yet a further evolution in the biological works analogous to the one that marks the transition from the *Categories* to the *Metaphysics*. However, in this case it is only the concept of a biological substance that evolves; artefacts and other non-biological substances remain the same two-dimensional objects that they were in the *Metaphysics*.

According to the second story, Aristotle already has the three-dimensional organism concept in the central books of the *Metaphysics*. It is simply that the specific nature of his explanatory project there (the causes of *being* a substance) does not require it. For the study of being it is sufficient to treat organisms like any other material object, namely, as two-dimensional composites of a certain matter together with a characteristic shape and form. On this story Aristotle does not replace the biological substances of the *Metaphysics* with something better suited to perform the functions required of them in the biology (as the first story implies). Rather, although he has the same organism concept throughout, it is only when he turns to the subject

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[80] Wedin 2000, 4 (cf. 5).

of biological generation that its full three-dimensional structure becomes salient.[81] The advantage of this second story, then, is that it allows us to account for why we do not seem to find a three-fold hylomorphic analysis of biological substance in the *Metaphysics* without having to retreat to claims about the development of Aristotle's thought.

There are perhaps other ways to account for the apparent absence of the three-dimensional organism concept from the *Metaphysics*. Whatever the correct story turns out to be, I do not think this poses a significant challenge to my thesis.

The second objection is more serious. One might argue that taking genetic nature and phenotypic nature to be two nonidentical constituents of a biological substance makes organisms complex in ways that are unacceptable to Aristotle.[82] I think there are two ways that my interpretation might suggest this.

Consider Aristotle's statement at the end of H6 where we are told that "the ultimate matter and the shape are the same and one, the one potentially the other actually" (1045b18-19). On one reading of this text Aristotle is saying that at the moment of actualisation the matter and the form of a substance are numerically the same.[83] This solves the problem of unity (according to this reading), since hylomorphic substances turn out to be essentially incomposite: they have no genuine internal structure. Since I am claiming that the genetic nature cannot be collapsed into either the material nature or the phenotypic nature, biological substances would turn out to be irreducibly complex. As such (the objection goes) organisms would not be genuine substance, since they will not count as genuine unities.

If being a genuine unity means being one in the unqualified sense (ἁπλῶς), then this is no objection at all. For even after saying that the matter and the form are "the same and one", hylomorphic compounds are still distinguished from substances

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[81] When Aristotle does turn to the causes of becoming in Z7-9 we actually do find him appealing to the three principles in question (material nature, phenotypic nature, and genetic nature). Admittedly, these chapters may have been a later insertion and not part of the original treatise.

[82] I am grateful to MM McCabe for pressing me on this.

[83] See, for example, Balme: "But a solution appears in the next book; at the moment of actualization matter is identical with the form realized in it, so that the composite is a definable unity (*Metaph.* H.6)" (Balme 1987b. 295).

which do not contain matter in that only the latter count as being one in the unqualified sense. At 1045b21 Aristotle qualifies the unity of a composite substance by saying that potentiality (matter) and actuality (form) are one "in a sense" (πώς).

Moreover, there are several readings of 1045b18-19 that do not involve eliminating the complex structure of a hylomorphic substance by collapsing matter and form into each other.[84] For example, Lewis argues that the claim that matter and form are "the same and one" is not a claim about their numerical identity. Rather, Aristotle is saying that the matter and the form are one and the same *F*, the one picking out what is potentially *F* the other what is actually *F*.[85] This idea picks up on H2 where Aristotle had said that in asking what a house is those who say it is bricks and timber (the matter) only tell us what is *potentially* a house whereas those who say it is a receptacle for containing goods and persons (the form) tell us what is *actually* a house (1043a14ff.).

As I read Aristotle's point in H6, the puzzle about the unity of a composite substance disappears, not because the matter and form of the composite are numerically identical so that what at first appeared to be composite turns out to be incomposite on closer inspection, but because the relation between potentiality and actuality (and thus matter and form) is not especially puzzling. For the actuality is the actuality *of* the potentiality. On this reading, matter and form are one and the same individual *F* at different points in its ontogenetic history.[86] And so to ask for the cause of their unity is to ask what is responsible for the development of the potential *F* into the actual *F*.[87]

A caveat is necessary here. An important part of my interpretation of H6 is that the matter Aristotle is talking about is embryonic matter (the matter at the beginning of the process of development). One might object to this by pointing to 1045b18-19 where Aristotle makes reference to the "ἐσχάτη" matter. The general

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[84] For examples see note 67 above.

[85] Lewis 1994, 254-5 *n.* 20 (cf. Harte 1996, 296).

[86] Lewis calls this being "genidentical" (1996, 77 *n.* 59). Lewis rejects this idea because he needs to play down the emphasis on coming-to-be in H6 (see above).

[87] *If* Aristotle thinks we need some further account of the unity of the phenotypic nature and genetic nature, then this could easily be cashed out teleologically: the genetic nature is a potential *for* that phenotypic nature.

assumption among commentators is that this picks out the constitutive or "proximate" matter of the fully developed body (the material substratum of the adult form). Indeed, this is one of the primary reasons for thinking that 1045b18-19 is saying that at the moment of actualisation the matter and form of a thing are numerically one and the same so that a hylomorphic substance is essentially incomposite.

In the first place, there is a problem with taking ἡ ἐσχάτη ὕλη to refer to the constitutive matter of the adult body. For it leads to the puzzling notion that constitutive matter is somehow both potentially *F* and actually *F* at the same time.[88] Some commentators have tried to account for this by appealing to the different levels of potentiality and actuality in the *De anima*.[89] The only thing from the *DA* model that would help in this situation is the level of first-actuality, which is also a potentiality. However, the *DA* is categorical that it is the form (i.e. the soul) that occupies this level, not the matter. The soul is both an actuality relative to the body and a potentiality (capacity) relative to the exercise of a capacity.

On the other hand, there are strong reasons for taking ἡ ἐσχάτη ὕλη as the embryonic matter. 1045b18-19 identifies the matter with the potential *F*. And according to Θ7, the matter is an *F* potentially only when it is in a state where it will develop into an *F* of its own accord if nothing external impedes it. Here Aristotle is definitely talking about embryonic matter (σπέρμα in some state). Moreover, using ἐσχάτη to refer to the matter out of which the product is directly formed is common practice in the biological works. For example, an animal's nutritive blood is "ultimate" (ἐσχάτη) matter because the parts of its body are formed directly out of it.[90] Blood in this state is not the informed matter of the body but the material at the start of the nutritive cycle *before* it gets distributed to the parts. It is the matter *before* the body's shape has been imposed on it (the equivalent of unsculpted bronze).

The other reason one might think that my interpretation makes organisms complex in ways that are unacceptable to Aristotle has to do with my reading of 641a22-33. Aristotle is explicit in that passage that nature understood as substantial

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[88] 1045a23-33 identifies the bronze as an actual sphere.

[89] This strategy is pursued in Kosman 1987 and Witt 1989b.

[90] e.g. 725a11-18, 726a26-8, b1-3. This is fully consistent with the analysis of potential-being in Θ7.

being includes *both* phenotypic nature *and* genetic nature. On the reading suggested above Aristotle is saying that the phenotypic nature and the genetic nature are both proper candidates for being the substance of an organism. One might object to this on the grounds that it raises problems of competing classification which the *Metaphysics* desperately tries to avoid. For in that case an organism will turn out to have two substantial beings, which would seem to make it not one but *two* kinds of thing. The problem I have in mind here is captured by Lewis:

> In the latter case [sc. questions about the unity of the compound material substance], Aristotle himself believes that the bronze sphere, for example, has two constituents, its matter and its form. each of which is a nature and is a candidate for the nature *of* the thing. Does it follow that the sphere is equally bronze, thanks to its matter, and (a) sphere, thanks to its form?[91]

But the suggestion that an organism's genetic nature and phenotypic nature *both* count as nature understood as substantial being (even substantial being in the primary and chief sense) is not a problem here. For the contents of the phenotypic nature and the genetic nature will be identical. The phenotypic nature is the form of a horse; the genetic nature a potential for the formation of a horse. There is no problem of competing classifications, then, since Sir Desmond is (a) horse, thanks to his phenotypic nature, and (a) horse, thanks to his genetic nature.[92]

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[91] Lewis 1996, 51-2.

[92] Talk of "content" is Lewis'. The claim that the phenotypic nature and genetic nature are identical in account (i.e. they share the same content) actually depends on the level at which definition is sought. For a difference in content *is* revealed by a more precise account of a thing's phenotypic and genetic natures. This has to do with the problem of resemblance to ancestors (atavism). Briefly stated, in order to explain why Menexenos has his grandfather's straight nose, Aristotle posits a "movement" in Socrates' sperm that transmits that property. And this "movement" is said to be derived from a corresponding potential (δύναμις) of Socrates' genetic nature. (For this discussion see especially chapter five below.) A more precise account of Socrates' genetic nature will thus include a reference to a snub nose, which is a part of his phenotypic nature. and a straight nose, which is not part of his phenotypic nature. So at this level a definition of Socrates would be different depending on whether we

In the end, I do not think the addition of a third dimension to an organism's hylomorphic structure generates any special problems of unity that do not already arise simply from the claim that biological substances are complex. For example, the problem of competing classifications is a problem even for the standard reading of the *Metaphysics* according to which organisms are simply composites of matter and form (or material nature and phenotypic nature). At most the addition of a further dimension to an organism's hylomorphic structure exacerbates this problem; it certainly does not generate it.

§12 Some concluding remarks on biological structure

In the first part of this chapter I argued that an organism's genetic nature and phenotypic nature are distinct principles, not the same principle under different descriptions. The three-dimensional organism concept can be seen as falling out of this nonidentity. For in the *Parts of Animals* Aristotle tells us that both phenotypic nature *and* genetic nature are proper candidates for being the substance of a thing. It follows from the nonidentity of these two principles that they are both partially constitutive of an organism's hylomorphic structure: they are the two formal dimensions of an organism which, together with the material nature, make up the biological substance itself. There *may* be room here for one to accept the idea that an organism's genetic nature and phenotypic nature are nonidentical without accepting the stronger claim that the genetic nature adds a further dimension to its hylomorphic make-up. On this reading only the phenotypic nature of an organism would be partially constitutive of the biological substance itself. Here one might simply wish to treat the genetic nature as a mechanism or tool that the substance (the two-dimensional entity) has for reproducing its phenotypic nature. However, in that case one would have to explain away the fact that in the opening Book of the *Parts of Animals* Aristotle brings both phenotypic nature *and* genetic nature under the heading of substantial being. And given the strength of the evidence in favour of their nonidentity, it is unlikely that one can simply retreat to some sort of conceptual coincidence here.

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took his phenotypic nature or his genetic nature as the object of definition. This gives us good reason for keeping definitions at the level of species. For that way Aristotle can avoid problems of competing classifications. I shall return to all of this later on.

Introduction to Part Two

In the second part of this study I shall explore the question of how exactly an organism's form is passed on to its offspring in the act of reproduction. I shall argue that, for Aristotle, an organism does not directly transmit its form but only the source of that form. In the language of the first part of this study, an organism reproduces its phenotypic nature indirectly by directly reproducing its genetic nature. The actual mechanism behind the transmission of biological form is set out in *Generation of Animals* 4.3. Although that chapter is primarily about the inheritance of individual differences below the level of species, I shall argue that the mechanism at work there is meant to explain the transmission of all phenotypic resemblances including the common species resemblance.

In order to properly understand *GA* 4.3, however, two preliminary issues need to be addressed. The first is Aristotle's account of sex determination from *GA* 4.1-2. Although Aristotle's account of inherited resemblances in *GA* 4.3 is clearly an extension of this discussion, the two accounts actually employ different (albeit related) causal mechanisms. This is something that is not sufficiently appreciated by commentators on the *GA*. The second is the controversial issue of the mother's contribution to inheritance. The problem is that *GA* 4.3 appears to assign a *formal* contribution to the mother, which many have come to see as being at odds with the strict reproductive hylomorphism set out in the first three books. I take up these two issues in chapters three and four, respectively. This will clear the way for the central topic of this part of my study: the transmission of biological form as embodied in the phenomenon of inheritance.

Chapter Three

Sex Determination

§1 The generation of the sexes

Book four of the *Generation of Animals* opens with the following programmatic remarks:

> The coming-to-be of animals has now been dealt with, both in general and with respect to them all separately. But since in the most perfect of animals the female and the male are separate, and since we have said these capacities are principles of all animals and plants alike (though in the latter these are not separated while the former have them separated), we must first of all speak about the generation of the sexes; for the embryo is differentiated into male and female while it is still imperfect in its kind. However, it is not generally agreed whether one animal is male and another female even before the difference is evident to our senses, <and if so whether> the difference is acquired within the mother or even earlier. (763b20-9)

The stated aim of *GA* 4.1 is to investigate "the generation of the sexes". Aristotle's dissatisfaction with the answers given by his predecessors was due to the way they understood the difference between male and female. Clearly how one answers the question of why one animal becomes male and another female depends on what one takes males and females to be.

In order to understand Aristotle's account we first need to recognise the subtle distinction he makes between an animal's sexual identity and its sexual morphology. An animal's sexual identity is that property in virtue of which it is ultimately male or female, while its sexual morphology refers to the parts, traits, characteristics, etc. proper to its sexual identity.[1] Thus to ask "whether one animal is male and another

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[1] I have chosen the term "sexual identity" for the lack of a better term. "Gender" is too broad and is believed by many to be socially constructed, whereas the property Aristotle is targeting is something fundamentally biological. As we shall see, sexual identity is linked to a particular function or capacity whose physiological basis is the principle of natural heat in the animal's heart. Moreover, although Aristotle treats sexual identity and sexual morphology as primary and secondary sexual

female even before the difference is evident to our senses" is to ask whether the offspring's sexual identity is determined before it develops its sexual morphology.

If one takes sexual morphology to be constitutive of sexual identity, that is, if being male and female is simply a matter of having certain parts, then one will answer this question negatively. At the other extreme are those among Aristotle's predecessors who held that the difference between males and females is reducible to a quantitative property. For example, Empedocles is said to have held that being male or female is simply a matter of being hotter or colder (764a1-6, 12-15). On this theory embryos that enter a hot womb are males while those that enter a cold womb are females. Anaxagoras is also said to have reduced the differentiation of animals into males and females to the causal history of the seed from which the organism develops. On this theory, seeds that come from the father's right testicle are males while those that come from his left testicle are females (763b31-764a1). For Empedocles, then, the difference between males and females is "acquired within the mother" while for Anaxagoras it is acquired "even earlier", namely back in the father's body.

Modern biology can be seen as occupying the middle position. While having certain parts is an important part of an organism's sex, what ultimately makes one animal a male and another a female is its sex chromosomes (e.g. in mammals male = *XY*, female = *XX*). As we shall see, this is closer to Aristotle's own views.[2]

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characteristics of an animal, this cannot be mapped onto *our* modern distinction between primary and secondary sexual characteristics. According to modern biology, primary sex characteristics are those phenotypic characters proper to males and females that are directly involved in reproduction (e.g. the male gonads), while secondary sex characteristics are those specific to males and females but are not directly involved in reproduction (e.g. pitch of voice, patterns of body hair).

[2] One way Aristotle's views differ from modern biology is that for him the distinction between sexual identity and sexual morphology is not divided along genotype/phenotype lines. What I call an organism's "phenotypic" nature (taken in the broad sense) will include its characteristic sexual morphology; its "genetic" nature will include a set of active potentials (or δυνάμεις) for the formation of that sexual morphology. However, those potentials *do not* constitute the animal's sexual identity.

Although both the reductionists and modern biology hold that an organism's sexual identity is determined before it develops the morphology corresponding to that identity, the difference between them is significant. One of Aristotle's major complaints against the reductionists is that they completely ignore the importance to being male or female of having certain parts.[3] This is highlighted in Aristotle's dialectical argument against Empedocles at *GA* 764a12ff. On the one hand, Empedocles is a preformationist, and so he thinks the parts of the offspring are already there preformed inside the seed. On the other hand, he held that males differ from females in virtue of hot and cold alone, so that a seed which enters a hot womb is a male and one that enters a cold womb is a female. But this means that if a seed containing female parts were to enter a hot womb, the offspring would be a male despite the fact that it had a uterus and other such parts. For Aristotle, as for modern biology, although sexual identity can be traced to something more primary, we cannot ignore the importance of sexual morphology in determining whether an animal is a male or a female.

§2 Anatomical versus functional definitions of sex

The main philosophical issue in *GA* 4.1 is the question, In virtue of what is one animal male and another female? Aristotle offers two candidates for this property, both of which must be included in an adequate account of the generation of males and females. The first (which most of Aristotle's predecessors neglected) is the obvious anatomical difference (sexual morphology). From this perspective one animal is male and another female in virtue of having certain parts. However, Aristotle also holds that "male" and "female" in the primary sense refer to the ability and inability to produce sperm (respectively). For Aristotle, it is this second, functional property which is constitutive of an animal's sexual identity. It is the presence and absence of this function that *ultimately* makes one animal male and another female.[4]

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[3] Later I consider Aristotle's other major complaint against Empedocles and Anaxagoras, that they fail to demonstrate any necessary connection between sexual identity and sexual morphology.

[4] Note (I) Aristotle treats the ability to produce sperm or γονή as a natural function of all sexual reproducing organisms. This will be important for Aristotle's notorious claim that a female *qua* female is a "πεπηρωμένον" male (see below). (II) The

A caveat is necessary here. The ability to produce sperm would be the form specified in the definition of a male animal (the inability being the privation). However, the *Metaphysics* denies that male-animal is a proper object of definition. There are several reasons for this, but all of them come down to the fact that male stands to animal as snub stands to nose (Z5). So, for example, the definition of a male-animal would be an account formed from an additional term (ἐκ προσθέσεως). And Aristotle denies that such accounts are proper definitions. Again, just as 'snub-nose' expands to concave-nose nose, so too 'male-animal' expands to animal-with-the-ability-to-produce-sperm animal. However, Aristotle does allow that definitions can be applied in a secondary way to all those attributes which belong to substance *per se* and cannot be defined apart from it. It is in this secondary sense that males are definable (since 'male' cannot be defined apart from animal).

Generation of Animals 4.1-2 is primarily concerned with the generation of males and females in the functional sense. *GA* 4.1 is a classic Aristotelian opening chapter. It begins with Aristotle reviewing the theories of sex offered by his predecessors before turning to his own account of the mechanism behind the generation of males and females. *GA* 4.2 goes on to provide empirical evidence to support the account set out in *GA* 4.1. Finally, *GA* 4.3 introduces the theory of inheritance and the mechanisms behind regular patterns of formal resemblance. I shall argue that Aristotle treats the inheritance of sexual morphology as a special case of resemblance and so is governed by the same mechanisms that explain standard familial resemblances. What is important is that in *GA* 4.3 "male" and "female" generally refer, not to the ability and inability to produce sperm (sexual identity), but to the parts of the offspring's sexual morphology.[5] I shall have more to say about this

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functional definition of male and female *qua* male and female (= the capacity and incapacity to produce sperm) must be distinguished from the functional definition of them *qua* father and mother (= the capacity to generate "into another" (εἰς ἕτερον) and the capacity to generate "into itself" (εἰς αὑτό)). For the latter see Book 1, esp. 716a17ff.

[5] Eventually I shall argue that the spermatic κινήσεις (or "movements") that Aristotle refers to in *GA* 4.3 are the genetic factors responsible for the transmission of those morphological characters. For example, "the movement of the male" (768a28) is the

later. First I focus on the account of sexual identity in *GA* 4.1 in order to set out the causal mechanism responsible for the generation of males and females functionally defined (what we would call sex determination).

§3 Sexual Identity

According to *GA* 4.1 an animal is ultimately male or female insofar as it is capable or incapable of fully concocting its nourishment and converting it to sperm (γονή).[6] Whether or not a particular animal has this ability, and thus whether or not it is male or female, depends on its source of natural heat. The stronger the animal's principle of natural heat, the greater its ability to effect concoction and so produce sperm.[7] Since an animal's sexual identity is determined by the relative strength of its natural heat at its source, Aristotle concludes that the source of an animal's sexual identity must lie in its heart (or its analogue).[8] For that is where the source of its natural heat resides:

> If, then, male is a certain principle[9] and cause, and one animal is male in virtue of a certain ability and the other female in virtue of a certain inability, and the line of determination between the ability and inability is whether it concocts or does not concoct the nourishment (which in the blooded animals is blood and in the bloodless ones the analogue of

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vehicle through which the parts of the male's sexual morphology are physically transmitted to the offspring in the act of reproduction. I discuss this mechanism in detail in chapter five.

[6] In Aristotle's biology, an animal's reproductive material (its "σπέρμα") is produced by concocting a portion of blood left behind in its heart after the nutritive cycle. Menstrual blood (καταμήνια) and sperm (γονή) are the two kinds of animal σπέρμα. The latter is fully concocted σπέρμα while menstrual blood is only partially concocted (or inconcocted) σπέρμα. The "ability" in question is thus the ability to fully concoct the nutritive blood and convert it to γονή (male sperm). For more on this see below.

[7] See note 27 below.

[8] See 788a5ff. (cf. 716b3-12, 788a13-16).

[9] The "principle" (ἀρχή) in question is the principle of natural heat in the male's heart (cf. 766b12-14).

> blood) in the final stages, and the cause of this is in the heart and the part which contains the principle of natural heat, then it follows *of necessity* that a heart must be formed in the blooded animals (and in the other [sc. bloodless] kinds where males and females come to be present, the analogue of the heart) and the offspring will be either male or female. (*GA* 766a30-b3)

The idea that the individual members of those species that contain males and females must *necessarily* possess a heart (or its functional analogue) is interesting. The reason is that the property that ultimately makes an animal male or female is located there. I will call this the heart-based model of sex determination. According to this model, the differentiation of animals into male and female can ultimately be traced to a difference in their hearts and the principle of natural heat contained therein.[10]

Aristotle's account of sex determination is underwritten by his account of spermatogenesis, which is the process in an organism responsible for the production of σπέρμα (its genetic material).[11] In the case of animals, this material is generated by concocting the portion of nutritive blood left behind in the heart after the nutritive cycle. For Aristotle, both males and females produce σπέρμα of some form.[12] So just

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[10] The heart-based interpretation is also endorsed by Peck 1990, lxvi-lxvii (§68). For an alternative interpretation see Coles 1995 (cf. Deslauriers 1998). I will not address this alternative interpretation here, since I do not think it is a viable reading of the text.

[11] With the following see *GA* 1.18-20.

[12] Female σπέρμα is explicitly mentioned at (e.g.) 728a26-7, b21-2, 767b16-17, 771b20, b22-3. Aristotle does say at 728a31 that "the female does not emit σπέρμα"; however, he is being careless here. Sometimes (as in the present case) Aristotle will simply refer to "σπέρμα" when he really means male sperm, γονή. A more carefully qualified statement is made at 727b7 where Aristotle says the female does not emit the *same kind* of σπέρμα as the male (cf. 728a26-7: the female emits a less purified form of σπέρμα). We should note two further things about the female's σπέρμα. First, properly speaking, the material cause of the offspring is not the female's entire blood-like discharge. Aristotle saw the menstrual discharge as having two components: the fluid, which is the useless portion of the menstrual discharge, and the

like the male, the female has the ability to concoct the surplus of blood left behind in her heart after the nutritive cycle and turn it into σπέρμα. And she does this by means of her own principle of natural heat. The difference is that her principle is weaker than the male's (she is colder), which accounts for her inability to produce γονή (sperm, which is fully concocted animal seed). This is easy to miss. For it requires a proper understanding of the difference between Aristotle's concepts of "concoction" (πέψις) and "inconcoction" (ἀπεψία).

§4 Spermatogenesis: concoction and inconcoction

During nutrition the animal's blood or "ultimate" nourishment gets distributed from the heart to the various parts of its body. σπέρμα is what results from concocting the surplus of undistributed blood left behind in the creature's heart.[13] Menstrual blood (καταμήνια) and sperm (γονή) are the two kinds of σπέρμα produced by animals. Male sperm is fully concocted σπέρμα. Menstrual blood is inconcocted σπέρμα (728a22). Being *in*concocted (ἄπεπτον) is quite different from being *un*concocted (μὴ πέπτον).[14] Things which are inconcocted have undergone partial concoction (*Meteorologica* 379a1-2). This is significant because an inconcocted substance, unlike one that is unconcocted, will still have undergone some level of concoction and so contains some degree of heat. It has just not undergone the level of concoction needed to produce the change that would have resulted had that

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σπέρμα, which is the useful part that resides in it (739a7-10; cf. 728b21-2). The parts of the offspring are formed out of the latter. Second, Aristotle refers to the female's contribution using the plural τὰ καταμήνια. This is because he thinks there are several bits of spermatic material in the fluid discharge. During conception the heat in the sperm draws these bits of σπέρμα together and forms them into one solid mass (= the κύημα; see 739b20-7). I will continue to use "menstrual blood" generally for both the entire blood-like discharge and for its spermatic contents. Nothing I have to say here turns on this.

[13] 725a21-8, 726b9-15.

[14] Peck mistranslates ἄπεπτον at 774a2 as "*un*concocted". This is significant for the current point, since Aristotle is describing the state of the female's σπέρμα there: it is an *in*concocted (or partially concocted) residue.

process been carried to completion. In this case the process of concoction ends prematurely. And the reason for this, Aristotle says. is a failure on the part of the concocting agent due to a lack of sufficient heat.

The concept of inconcoction as partial concoction (as opposed to not being concocted at all) is reflected in the definitions of "concoction" and "inconcoction" from *Meteorologica* 4.[15] Concoction is defined as a perfection of the undetermined moisture in a natural body by means of its internal heat (379b17); inconcoction is the corresponding imperfection that results from a deficiency in that same heat (380a5-6). In other words, inconcoction is *incomplete* concoction owing to a deficiency of natural (or proper, οἰκεία) heat. This is important because substances which are only partially concocted are necessarily colder, greater in volume, and more fluid than those which are more fully concocted.[16] And these are characteristics of the menstrual blood.

It is evident from this that the difference between male and female σπέρμα is not a difference in what is being concocted—both forms of animal σπέρμα are a residue of the same substance (nutritive blood)—but the stage at which the residue is produced.[17] Male sperm (γονή) is what results when the process of concoction is brought to completion (it is the end of the production of animal seed). Female menstrual blood is what results when that same process falls short of the end owing to a deficiency of natural heat (it is the result of an incomplete concoction).

The point of this excursion into the nature of concoction was to show that the line of determination between males and females (functionally defined) is not a general capacity and incapacity to concoct the surplus of blood left over after the nutritive cycle. Aristotle thinks both sexes have the ability to concoct this blood and turn it into σπέρμα of some form. Rather, the ability and inability that defines males

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[15] See esp. *Meteorologica* 4.1-3.

[16] 726b30-2. This follows from Aristotle's chemistry. Concoction is inversely proportional to bulk and fluidity and directly proportional to heat and density (380a4-5). Therefore something that is more concocted will be hotter and more compact (and thus smaller in bulk) than something that is only partially concocted (which will be colder. more fluid, and greater in bulk). This will be important later on.

[17] cf. 725a11-18.

and females has to do with concocting the blood in the final stages of spermatogenesis (τῆς ὑστάτης, 766a31-3). For Aristotle, the female is female in virtue of her inability to produce sperm (γονή), which is the type of residue produced in the final stages of spermatogenesis.[18] And the source of this inability is a deficiency in natural heat, which is the physiological basis of her sexual identity. It is the property that defines females *qua* female. So the female does have the ability to produce σπέρμα; it is just that the kind of σπέρμα she produces is a partially concocted or inconcocted residue (menstrual blood). Male sperm is fully-concocted σπέρμα, which is the form of genetic material that is produced when spermatogenesis is carried to completion.

Before leaving the discussion of spermatogenesis I want to make one final point. Aristotle often says that the female is "colder" and that her principle (of natural heat) is "weaker" than that of her male counterpart.[19] The terms "colder" and "weaker", like "hotter" and "stronger", must be understood in relation to the capacity to concoct the surplus blood left over from nutrition.[20] Females are "colder", not in the ordinary sense of being colder to the touch, but in the sense that they lack the capacity to fully concoct the surplus of nutritive blood owing to a deficiency in (or "weakness of") natural heat.[21] It is in this sense—and *only* in this sense—that the female *qua* female is a "πεπηρωμένον" male.[22]

πεπηρωμένον is usually translated as "deformed". However, this is an extremely loaded word and is inappropriate for Aristotle's point. In Greek it implies the lack of a capacity or function that a thing would otherwise naturally possess. The function in this case is the ability to produce sperm, or fully concocted σπέρμα. A

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[18] cf. 728a18-25.

[19] e.g. 726b30-727a2, 775a14-15.

[20] The connection between "strength" and the ability to concoct nourishment is explicit throughout the *GA* (see, e.g., 725b8-726a16).

[21] In *PA* 2.2 Aristotle distinguishes several senses of "hotter" and "colder". The ordinary sense of being warmer and colder to the touch is only one sense. At 648b25-6 "hotter" and "colder" are also defined in terms of the relative capacity to produce a certain effect.

[22] e.g. 737a25ff. By female "*qua* female" Aristotle is picking out the creature's sexual identity.

female *qua* female is a πεπηρωμένον male only in the sense that she lacks this ability owing to her deficiency of natural heat. By analogy, if the natural function of fire was to produce steel, then an orange flame would be a "πεπηρωμένον" white flame in this same sense on account of its inability to get the iron hot enough to convert it to steel.

It helps to realise here that Aristotle thinks of concoction as a kind of refining process (cf. 728a28: διηττημένη). For example, in several places spermatogenesis is compared to the process of refining fruit.[23] The idea is that the process starts from a large bulk of material and refines it, removing its impurities (the fluid portion), until what results is a pure form of concentrated animal seed (γονή). From the assumption that concoction is a process of refinement Aristotle inferred that menstrual blood must be a residue produced at an earlier stage of spermatogenesis than male sperm on account of its greater bulk and fluidity (it is a less purified form of σπέρμα that lacks the concentration and potency of pure seed). This seems to be the empirical basis of Aristotle's view that the female is colder than the male: we can see from the state of her σπέρμα that she lacks the level of natural heat necessary to bring the production of σπέρμα to completion.[24]

§5 The mechanism of sex determination

We are now in a position to understand Aristotle's account of the mechanism behind the generation of males and females (functionally defined). According to Aristotle's chemistry, undergoing concoction increases a thing's heat (since heat is always transferred from agent to patient in the process). And the hotter something is, the more it is capable of effecting concoction.[25] Thus, the ability of a thing to effect concoction is directly proportional to the level of concoction it has itself undergone (assuming it is something whose proper heat derives from being concocted). It follows from this that whether or not an animal is able to concoct the residue of blood in the final stages of spermatogenesis—and thus whether or not it is male or female—

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[23] See. e.g., 728a26-30, 765b15ff. (cf. 725a11-18).

[24] The empirical inference from the quantitative differences in male and female σπέρμα to their differences in natural heat is explicit at 765b19ff.

[25] *Meteorologica* 4.2. 380a4-5.

ultimately depends on the level of concoction the menstrual blood undergoes when it is being formed into an embryo.

For Aristotle, the father's sperm (or rather the heat which is present in it) is the causal agent responsible for making the embryo male or female (functionally defined). And it does this by concocting the material supplied by the female which increases its level of natural heat.[26] If the embryo is fully concocted by the seminal heat, then it will be formed with its own source of natural heat above the threshold for being male. If the seminal heat is deficient in any way and only manages to partially concoct the matter, the embryo will be formed with a source of natural heat somewhere below that threshold. In this case the embryo is female.[27]

This deficiency in seminal heat, however, is in relation to the coldness of the material being concocted. Menstrual blood that is excessively cold to begin with will be further away from the threshold and thus require a substantially greater amount of

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[26] This is a rather simplified version of the theory. More specifically, the sperm concocts the embryonic heart in the area where its principle of natural heat is located (the centre cavity, according to *PA* 665b34-666a3).

[27] The threshold in question represents the amount of concoction the embryo must undergo in its heart such that it *will eventually* be able to concoct its σπέρμα into γονή. For obviously embryos do not actually have this capacity. In what follows I will assume that we are talking about the potential presence of this capacity in the embryo and that this is determined by the current level of natural heat in its heart. This is where the idea of a threshold comes in. All sexually mature males have the right level of natural heat which enables them to convert their σπέρμα into γονή. Now at *GA* 766b30-1 Aristotle describes the principle of natural heat in an immature male as heat that is not yet "perfected" (τέλειον). This suggests that the creature's heart continues to undergo concoction right up to the point of sexual maturity, which gradually increases its level of natural heat. Thus we can imagine some starting level of natural heat that an embryo must have such that, through the steady concoction of its heart, it will eventually reach the level where it is sufficient for producing γονή. It is this threshold that defines male and female embryos. A male embryo is one whose starting level of natural heat is above that threshold, a female one whose starting level is below that threshold.

concoction to turn it into a male embryo than menstrual blood which is warmer (cf. *GA* 775a17-18). What this means is that the ability of the sperm to make the embryo male is not an intrinsic property of the sperm itself. It is not a function of how hot the sperm is in itself but how hot it is *in relation to* the menstrual blood at the time of conception. Hotter sperm may still produce a female if the menstrual blood is excessively cold while colder sperm may produce a male embryo if the menstrual blood is warmer to begin with. Thus while the father's sperm is the causal agent responsible for making the embryo male or female, an adequate account of the process must make some reference to the contribution of the individual mother. For her menstrual blood will have an intrinsic temperature of its own which effects the sperm's ability to concoct it.

§6 Sexual Morphology

According to Aristotle, whether the embryo is male or female depends on the level of natural heat in its heart. And this ultimately depends on whether or not the father's sperm manages to fully concoct the menstrual blood and raise its temperature above the threshold for being male. However, unlike Empedocles, Aristotle denies that the generation of the sexes can be fully explained by reference to hot and cold alone.[28] The problem with this sort of epistemological reduction is that it fails to reveal any necessary connection between having a particular sexual identity and developing a particular sexual morphology. As a result, the crucial difference in sexual morphology is left unexplained:

> Now the opinion that the cause of male and female is hot and cold, or that the difference depends on whether the <seminal> discharge comes from the right side <of the father> or the left side has some degree of truth to it (τινὰ λόγον). For hotter seed (σπέρμα) is seed that has been concocted and the fact that it has been concocted means that it

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[28] The same holds for the Anaxagorean account of sex in which the difference between males and females is due to the causal history of the seed (males develop from seeds that come from the father's right testicle, females from those that come from his left testicle). In this way (at least according to Aristotle) Anaxagoras believed that the generation of the sexes can be fully explained by reference to right and left alone.

> has been fused together and compacted. And the more compact the seed is, the more potent (γονιμώτερον) it is. Nevertheless, to state the matter this way is attempting to grasp (ἅπτεσθαι) the cause from too far away. And we must come as close as we possibly can with the primary causes (δεῖ δ' ὅτι μάλιστα προσάγειν ἐκ τῶν ἐνδεχομένων ἐγγὺς τῶν πρώτων αἰτίων). (*GA* 4.1, 765a34-b6)

Aristotle's point here is that it is one thing to say that the cause of the difference between male and female embryos is the relative temperature of the seed (Empedocles) or the side of the father from which it came (Anaxagoras) but quite another to then try to explain why males develop one set of parts while females develop a completely different set with reference to these causes alone. What is the connection between 'hot' and developing male parts and 'cold' and developing female parts? Likewise, what is the connection between 'right' and developing male parts and 'left' and developing female parts? It is this explanatory gap that Aristotle thinks Empedocles and Anaxagoras cannot bridge. By reducing the generation of the sexes to hot/cold or right/left they "attempt to grasp the cause [sc. of the difference in sexual morphology] from too far away".

Although Aristotle himself thinks the cause of the difference in sexual morphology can ultimately be traced back to the relative temperature of the embryo and thus to the level of concoction effected by the father's sperm,[29] he is able to bridge the explanatory gap by appealing to teleology. The strength of natural heat in an animal's heart determines the kind of spermatic residue it produces. And this in turn *hypothetically necessitates* certain structural differences in the parts which are present for the sake of receiving that residue:[30]

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[29] Note however that the cause cannot be traced back any further than this. For the ability to bring the temperature of the menstrual blood above the threshold for being male is not an intrinsic property of the sperm but depends in part on the initial temperature of the menstrual blood itself.

[30] Aristotle isolates the parts whose function is to receive the spermatic residue as the characteristic difference in male and female sexual morphology. Therefore it is this difference that an account of the generation of males and females (anatomically defined) needs to explain.

Nature assigns to each of the residues the part capable of receiving it (τὸ δεκτικὸν μόριον). Now σπέρμα is a residue, but in the hotter of the blooded animals, i.e. the males, this is manageable in size and amount; for this reason in males the parts which receive this residue are small passages (πόροι). In females, however, on account of their inability to effect concoction, this residue is a considerable volume of bloodlike substance (for it has not been reduced to its final state, ἀκατέργαστον). Thus, here too there must of necessity be some part fitted to receive it, different from the part in the male, and of a considerable size. That is why the oviducts have this nature – and that is the part wherein the female differs from the male. (766b18-26)

This passage nicely weaves together teleology and chemistry into a paradigmatic example of hypothetical necessity. The teleological principle is expressed in the first line of the passage. For each residue produced in an organism its genetic nature constructs parts which are adapted to receive those residues.[31] It follows that every animal that is capable of producing σπέρμα will have parts whose function is to receive it. These are the seminal channels and oviducts (or their analogues). The structural differences between these two functionally identical parts is referred back to the quantitative difference in the corresponding spermatic residues produced by males and females. And this in turn can be traced back to the relative strength of each sex's principle of natural heat and ultimately to the level of concoction effected by the father's sperm.

§7 The four causes of sex

Of course a complete Aristotelian account of the generation of males and females (*qua* male and female) would require a four-fold explanation. Although this is not explicit in *GA* 4.1, I think we can offer one based on what has been said here.

The functional and anatomical accounts of male and female (sexual identity and sexual morphology) reflect the formal and material causes of sex, respectively.

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[31] This is grounded in the more basic principle that an organism's genetic nature does nothing in vain but always what is best with respect to the possible ways of being that kind of organism (*IA* 2, 704b10-17). For an excellent discussion of the epistemological significance of this principle see Lennox 2001b, 205-223.

The form in this case is the ability to produce sperm. It is the presence and absence of this ability (in the heart) that makes one animal male and another female.[32] The principle of natural heat in the creature's heart is the physiological basis of its sexual identity. Males are animals whose natural heat lies above a certain threshold (the level necessary for producing sperm) while females are those whose natural heat lies somewhere below that threshold. The corresponding sexual morphologies, on the other hand, are the material causes of males and females: they are the parts out of which males and females are composed.[33]

The efficient cause of an animal's sex will be the causal mechanism responsible for producing the properties in question. What this is, however, depends on what we mean by "male" and "female". The efficient cause of the offspring's *sexual identity* is the father's sperm, or rather the heat which is present in it. This is the agent which is causally responsible for making the embryo male or female (functionally defined), which it does by concocting the matter thereby raising its level of natural heat. The efficient cause of the development of the offspring's sexual morphology, on the other hand, is its genetic nature.[34]

The final cause of sexual morphology is fairly straightforward. As we have seen the structural differences between the male's seminal channels and the female's oviducts (the parts wherein they differ *qua* male and female) is explained teleologically by referring the cause back to the kind of spermatic residue that animals of those sexes produce. This is not circular, however, if the property in virtue of which an animal is primarily male or female is distinct from its sexual morphology. For Aristotle, the sex of the offspring is ultimately a function of the relative strength on the principle of natural heat in its heart. For this determines whether it will be capable or incapable of producing sperm (and thus whether it is male or female). The sexual identity of the embryo *in turn* hypothetically necessitates the physical

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[32] "Formal cause" is only being used loosely here, since properly speaking there is no essence of male and female (since these are not genuine substances).

[33] Compare the use of material cause at *GA* 1.1. 715a9-11.

[34] The mechanism underlying the inheritance of sexual morphology is set out in *GA* 4.3 in terms of spermatic "movements" which are said to be present in the genetic material of all sexually reproducing animals (767b35-768a2, 768a11-14). See chapter five below.

dimensions of the parts which come to be for the sake of receiving the spermatic material produced by those kinds of animals.

The question about the final cause of an organism's sexual identity is more complicated. We can give a teleological explanation for why animals are differentiated into males and females at the level of species. In both *GA* 2.1 and 4.3 Aristotle argues that males and females exist for the sake of reproduction. On the other hand, we cannot give a teleological explanation for why any *particular* embryo becomes one sex *rather than* the other.[35] For the final cause of sex determination is simply to make the embryo one sex *or* the other, not one sex *as opposed to* the other. To close this chapter I shall offer a defence of this claim by considering the widespread view that Aristotle thinks reproduction is aimed at generating a perfect replica of the sire.

§8 Was Aristotle's biology misogynistic?

According to Morsink, Aristotle "clearly viewed" an instance where the father reproduces a son that looks like himself in every respect as the ideal case.[36] Likewise, Furth argues that for Aristotle the process of development is naturally directed towards a male resembling the father.[37] For Sober, "reproduction that is completely free of interference would result in an offspring which exactly resembles the father" and that any resemblance to the mother is "a departure from the natural state" produced by "interfering forces (βίαιον) deflecting reproduction from its natural pattern".[38] On Balme's interpretation a "correct reproduction" is one in which the offspring is a clone of the father while everything else is just a "distortion" of this likeness.[39] More recently Katayama has suggested that for Aristotle males of the species have "the complete form" and so "are substances most of all" whereas

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[35] As we have just seen, however, we *can* give a teleological explanation for why any particular embryo develops a particular sexual morphology (but only when its sexual identity is taken as given).

[36] Morsink 1982, 136.

[37] Furth 1988. 128.

[38] Sober 1980. 361-2.

[39] Balme 1987b. 292.

females have "incomplete forms" and "are substances only in a qualified sense".[40] Freudenthal sums up this standard view of Aristotle's biology when he writes:

> The ideal-type case is that in which the male semen informs the female matter into its like: the offspring is then a male closely resembling the male parent. The condition for this to happen is that the semen carry sufficient vital heat as to enable it to master thoroughly the (relatively cold) female matter (cf. *GA* 4.3, 767b21 ff.; 768a22 ff.): the greatest vital heat thus generates in the matter the most perfect form, that of the sire.[41]

For the purposes of evaluating this interpretation, we can separate out two claims being made here concerning Aristotle's biology: (1) Aristotle thinks reproduction is aimed at generating male offspring and that female offspring are a teleological failure; (2) Aristotle thinks resemblance to the father is the ideal pattern of inheritance and that maternal resemblance is just a distortion of this more perfect form caused by interfering forces deflecting reproduction from its natural course.[42] I will examine the second claim when we turn to Aristotle's account of inheritance in the next chapter. As we shall see there is no evidence to support this view. In the remainder of this chapter I shall concentrate on the evidence for the first claim.

One piece of evidence that commentators have often cited in support of the first claim is Aristotle's notorious statement that a female *qua* female is a "πεπηρωμένον" male. I have already touched on this. I argued that the standard translation of πεπηρωμένον, which has Aristotle claiming that females are "deformed" males, is extremely misleading. For it suggests that the female body is in some way malformed, which not what Aristotle means at all. Aristotle's claim that a female is a πεπηρωμένον male is to be taken only in the sense that she lacks a certain capacity, namely, the capacity to fully concoct the residue of nutriment and turn it into sperm. And this is because she has a lower level of natural heat. To be sure, this goes someway towards establishing that Aristotle's biology viewed females (*qua* female) as being somehow inferior to males. However, it is a far cry from

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[40] Katayama 1999, 3.

[41] Freudenthal 1999, 24. See also Gill 1989, 33; Pellegrin 1985, 110.

[42] For the distinction between female births and maternal resemblance see, e.g., 769a3-4.

suggesting that they are mere physical distortions of a more perfect male body type as traditionally understood.

There are two other passages that have been used to support the view that Aristotle's biology takes the goal of reproduction to be a perfect replica of the sire (in both respects): *GA* 767b6-8 and 768a21-2.

GA 768a21-2 is the most widely misinterpreted text. The text reads: "Therefore, the most natural course of events is when [the movements] dominate and are dominated both *qua* male and *qua* father together." This text can only be properly understood within the context of Aristotle's theory of inheritance in *GA* 4.3. Specifically, it requires a proper understanding of the causal mechanism involved and the nature of the spermatic "movements" (κινήσεις). I will have much more to say about both of these in the coming chapters. All we need to know here is that the movement corresponding to "male" (ἄρρεν) is the genetic factor that transmits the parts of Socrates' sexual morphology while the movement corresponding to "father" (πατήρ) transmits those features that make him a unique individual (cf. 768a29: "the movement coming from Socrates").

Commentators have traditionally read this text as suggesting that the most ideal outcome is when a male is produced resembling his father in every respect.[43] However, this is not what the text says at all. Suppose that by "the most natural" Aristotle means the most ideal. In that case Aristotle would be saying that the most ideal scenario is not only when the sire's movements dominate (κρατεῖν) but also when they *are* dominated (κρατεῖσθαι). In other words, the most ideal outcome would not only be a son who looks like his father but also a daughter who looks like her mother. For the latter is what results when the movements "male" and "father" are both dominated.[44] Thus, at best, *GA* 768a21-2 says that ideally we want sex and resemblance to match up, sons looking like their fathers and daughters looking like their mothers.

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[43] See esp. Morsink, Balme, and Freudenthal. (The reference in Morsink to *GA* 769a22 is presumably a misprint.)

[44] This follows from the principle of "displacement" (ἔκστασις), which is one of the three "general suppositions" (καθόλου ὑποθέσεις) that make up Aristotle's theory of inheritance (see chapter six below).

But this is not Aristotle's point here. By saying this is "the most natural" course of events Aristotle means that the phenomenon is something that happens for the most part ("natural" in the sense of a statistically frequent occurrence). As we shall see, the general point of this passage is that the movements for sex and resemblance are linked in such a way that the phenotypic characters associated with those movements are usually inherited together (ἅμα). And this provides the causal mechanism behind one of the phenomena Aristotle's theory of inheritance is meant to explain, namely, why sons tend to resemble their fathers and daughters their mothers (767b3-4). Aristotle simply uses the movements of the sire here to illustrate the point.

GA 767b6-8 is more tricky. Aristotle says that when the offspring comes to be female (θῆλυ) and not male (ἄρρεν) nature "has in a sense departed (παρεκβέβηκε) from the γένος". Now whatever Aristotle means here, it is important to recognise that the scope of his remark extends only to the offspring's sex and not its resemblance to the mother. One reason for suspecting this is that throughout *GA* 4.3 Aristotle consistently distinguishes "female" (θῆλυ) from "mother" (μήτηρ); the former is never used for maternal resemblances. For Aristotle's point applies as much to daughters who resemble their father as to those who look like their mother (but *not* to sons who look like their mother). Thus, contrary to the standard interpretation, this text is not claiming that in a correct reproduction the offspring perfectly resembles the father. At best it can be read as saying that reproduction aims at a generating males as opposed to females *whichever* parent the offspring happens to look like. However, I think we can offer an interpretation of this text which does not even suggest this much. This interpretation is consistent with what I have claimed above, namely that the process of sex determination does not have a final cause.

It is not entirely clear what παρεκβέβηκε ἐκ τοῦ γένους is supposed to mean. Most commentators translate this as saying that in making the offspring female nature has in a sense "departed from the type". "Departed" is probably an appropriate translation of παρεκβέβηκε. But γένος has to be interpreted very carefully here. It clearly has no strict taxonomical significance: it does not pick out a natural kind with species (it is not the technical sense of γένος which is related to εἶδος). In fact, Aristotle's denial that males and females are proper substances (Z5, 1030b21-8) or that maleness and femaleness belong to an animal in virtue of its οὐσία (I9, 1058b21-4) tells against reading γένος in any strong metaphysical sense at all. If this is right,

then Aristotle is not suggesting that males are the prototypical specimen of the kind so that in producing a female nature has somehow departed from this masculine ideal (e.g. that women are somehow less human than men or mares less horse than stallions).

I want to suggest that in this context a γένος is "a continuous generation of things of the same form" (*Metaphysics* Δ28, 1024a29-30).[45] The point, then, is that whenever the *male* sperm makes a *female* embryo there is a departure from a continuous generation of things of the same form, namely males producing males. The reason why this is only "in a sense" (τρόπον τινά) a departure is that technically male *F*s and female *F*s are the same in form. For example, it is not an instance of generating something of a different species. Aristotle explicitly denies that male *F*s and female *F*s constitute different species of *F* on the grounds that sex is not a difference that is included in the account of an *F* (*Metaphysics* I9).[46] Nor are we talking about the generation of things of a different form where "form" means soul. For Aristotle insists that males and females are identical in soul (*GA* 2.5, 741a6-7). A male generating a female is a departure from a continuous generation of things of the same form only in a very loose sense.

It is significant that Aristotle does not include maternal resemblance among the "departures" in *GA* 4.3 but only monsters and female births. There is still much more that needs to be said before we can appreciate why. Briefly stated, maternal resemblance is ultimately traced to a corresponding "movement" coming from the mother herself (see, e.g., 768a19: ἡ τῆς γεννώσης <κίνησις>). As such, we should not expect Aristotle to say that an offspring that looks like its mother and not its father is a departure from the γένος. For it *is* an instance of like begets like (the mother generates a likeness of herself). It would only be a departure of the relevant sort if the father was not only responsible for making the offspring female but also for the fact that it looked like its mother. This will be taken up in the next chapter. The point here

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[45] Pelligrin (1985, 111) also takes this reading of γένος but then falls back on the traditional interpretation of the passage, taking the point to be that anything that does not perfectly resemble the father has "strayed from the genetic type". What I offer here is a completely novel way of reading the text.

[46] See Deslauriers 1998.

is that when "γένος" is defined in terms of a continuous generation of things of the same form, then maternal resemblance is not a "departure from the γένος". For there is only a departure when cause and effect are different in form (as when the male sperm produces a female embryo).

But does Aristotle think sex determination is aimed at producing males *as opposed to* females? There is a sense in which Aristotle thinks female births result from the failure of the mechanism that makes the embryo male. However, the idea that this is a "failure" of some kind must be read into the text. Aristotle's Greek only says females result when the father's sperm "is not able to concoct" (μηδέ δύνηται πέψαι, 766a18-19) the menstrual blood and endow it with the level of heat that makes it male. And when this happens the offspring is *ipso facto* female. There is no suggestion that this is a failure to achieve some natural goal.

Aristotle's remarks at 767b6-8 do not suggested this either. On my reading, to depart from the "γένος" is to depart from a continuous generation of things of the same form, not from some ideal standard or type. Since the male sperm is the agent responsible for determining the embryo's sex, the "γένος" will be a continuous generation of males; female births count as a departure from *this*. If the sex of the embryo was determined by the level of concoction effected by the female's contribution instead, then the γένος would be a continuous generation of females. In that case male births would be a departure (it would be an instance of female producing male). The point here is that there is nothing overtly normative about the idea of "departing from a γένος" when γένος is taken in this way.

Another reason for thinking that males are not a teleological goal of reproduction is that Aristotle goes on to say that females are generated *both* because sometimes the sperm does not fully concoct the menstrual blood *and* because they are necessary for the sake of preserving the species (767b8-11).[47] The fact that the existence of females can be given a teleological explanation is inconsistent with the idea that reproduction aims at generating males as opposed to females. For in that case. female births would only be subject to the first kind of explanation: females

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[47] Aristotle contrasts the sense in which females are necessary with the way monsters (i.e. birth defects) are necessary: the latter are necessary κατὰ συμβεβηκός (767b13-15).

exist *only* because sometimes the father's sperm does not fully concoct the menstrual blood.

If the goal of sex determination was to make the embryo male, that is to say, if the process occurred *for the sake of* producing males, then the fact that females are generated would be merely accidental and not for the sake of anything. In that case the only thing preventing female births from being a chance outcome would be the sheer regularity with which they are produced.[48] Like males, females are a good result insofar as they are necessary for reproduction. And (on this reading) they are the result of a process which is among those that occur for the sake of something. However, in this case the result is accidental and not the end for the sake of which the process took place. If this were Aristotle's view, then *GA* 767b8-11 would imply that females are present in the species for the sake of something even though no particular offspring comes to be female for the sake of anything but is the accidental result of a process that is aimed at making males.

We can eliminate the tension here by simply denying that the process of sex determination is among those ontogenetic events that has a final cause. If offspring do not come to be male for the sake of something – if reproduction does not *aim at* producing males – then female births will not count as something that occurs accidentally and not for the sake of anything. On this reading, while human beings are divided into males and females for the sake of something, no *particular* human being comes to be one sex rather than the other for the sake of anything. The reason why one offspring comes to be male and another female is simply the fact that in the one case the concoction of the matter was brought to completion while in the other it was incomplete.[49]

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[48] With the following see *Physics* 2.5, 196b19-25: "Hence it is clear that even among the things which are outside (παρά) what is necessary and what is for the most part, there are some in connexion with which the phrase 'for the sake of something' is applicable. (Things that are for the sake of something include whatever may be done as a result of thought or of nature.) Things of this kind, then, when they come to pass accidentally are said to be by chance." (Hardie & Gaye transl. in Barnes 1995)

[49] Compare *Metaphysics* I9, 1058b21-5: "And male and female are indeed modifications peculiar to animal, not however in virtue of its οὐσία but in the matter,

i.e. the body. *This is why the same embryo becomes female or male, by being acted on in a certain way.*"

Chapter Four

The Problem of Maternal Inheritance

The second issue that needs to be addressed before moving on to Aristotle's account of the mechanisms of inheritance is the nature of the mother's contribution to the process. In this chapter I will examine the controversy surrounding the mother's contribution that stems from Aristotle's remarks on maternal inheritance in *Generation of Animals* 4.3.

§1 The charge of inconsistency

According to the theory set out in *GA* 4.3 Socrates' ability to generate a new individual resembling himself is explained by the fact that his sperm contains a set of "κινήσεις" corresponding to each of his parts (767b35-768a2, 768a11-14, 768b1-5).[1] According to the standard reading of the theory, these κινήσεις are the actual informing movements of Socrates' sperm as it fashions the material supplied by the female into an offspring resembling himself in every respect. According to Furth, for example, the father's sperm "is *active* and formative in character, being pre-programmed with a variety of highly intricate 'motions', which 'shape' and 'set' the catamenia in stages as development advances".[2] Likewise, Cooper identifies the father's sperm as "the causal agent active in generation" which possesses "specific movements (κινήσεις) that are such as to shape the material that the female provides in her womb into a member of the same species".[3]

This interpretation usually goes hand and hand with the analogy of sculpting. The father is compared to the sculptor who imposes a certain form on the bronze through the motions of his tools while the mother's contribution is compared to the bronze which is entirely passive in the reception of that form. By analogy, the father is seen as making the only genetically significant contribution to the process of reproduction just as the sculptor (not the bronze) determines the eventual shape and

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[1] I explore the peculiar nature of these spermatic κινήσεις in the next chapter. Much of the argument in this chapter is dialectic, and so for the most part I shall adopt the standard reading (introduced just below). However, part of my solution to the problem raised here involves rejecting that reading.

[2] Furth 1988, 118 (emphasis Furth).

[3] Cooper 1988, 15.

form of his statue. Furth criticises Aristotle's account of reproduction on both of these points:

> ...much of this account is factually incorrect: it is a mistake to suppose that only the male parent makes a genetically significant contribution to the specific form of the offspring... and Aristotle's idea of the causal influence that is exercised by this genetic contribution, literally "shaping" and "forming" the matter, is by present-day lights quite crude and childlike compared to the actual mechanisms involved, which are more complicated and more indirect as between the nature of the genetic material itself and the form manifested in the eventual offspring.[4]

Yet, as several commentators have recognised, this account is at odds with the theory of inheritance set out in *GA* 4.3. There Aristotle appears to introduce movements coming from the mother which are supposed to account for resemblances to her side of the family.[5] Apparently Aristotle's idea is that, like the father, the mother contributes a set of movements associated with her own features as well as those of her various ancestors. This is most explicit in the following passage where Aristotle introduces the causal mechanism behind the phenomenon of atavism:

> [Resemblance to ancestors occurs when] the formative movements (αἱ κινήσεις αἱ δημιουργοῦσαι) relapse into the ones which stand closest

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[4] Furth 1988, 119. What Furth refers to as "the form manifested in the eventual offspring" is precisely what I mean by "phenotypic nature"; what I call the "genetic nature" is the productive source of that form.

[5] Most commentators tend to assume that these "movements" are in the mother's menstrual blood to begin with (this will have to remain obscure for the time being). One problem for this view is that Aristotle said back at 766b12-14 that one difference between male and female σπέρμα is that the former contains motions while the latter contains "matter only" (ὕλην μόνον). However, this is the only text of its kind and looks to be corrupt. Even if it is genuine, we could easily accommodate it by taking the mother's movements to be present in the nutritive blood that passes into the embryo via the umbilical cord rather than in her menstrual blood. I shall not insist on this much detail here.

to them. For example, if the movement of the father (τοῦ γεννῶντος) relapses, it passes into that of his father (the least difference) and in the second instance into that of his grandfather. Indeed in this way too, on the female side just as on the male side:[6] the movement of the mother (τῆς γεννώσης) passes into that of her mother, and if not into that one, then into that of her grandmother. And in the same way for the more distant ancestors. (768a15-21)

Aristotle starts this text by giving a general explanation for atavism. Atavism occurs when "the formative movements relapse into the ones which stand closest to them". Paternal-line atavism is then offered as an example (οἷον) of this general phenomenon. The crucial bit of text for our purposes is the next line. Aristotle says that maternal-line atavism occurs *in the same way* as paternal-line atavism. The latter occurs when the movement of the father "relapses" into that of his father (and so on). Likewise on the maternal line, atavism occurs when the movement of the mother passes into that of her mother (and so on).

There are several technical concepts being deployed in this account that we can largely ignore for the time being. For example, Aristotle speaks of an effect called "relapse" (λύσις).[7] Although I shall have more to say about this when we turn to the details of Aristotle's theory of inheritance, what relapsing is supposed to do is (at least in the abstract) sufficiently clear from this passage to allow us to proceed without that analysis. We can get a sense of what Aristotle has in mind in this passage by considering the example of the woman from Elis from Book 1 (722a8-11).

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[6] I follow Cooper's suggestion that instead of excising καὶ ἐπὶ τῶν ἀρρένων with Lulofs or καὶ ἐπὶ τῶν ἀρρένων καὶ ἐπὶ τῶν θηλειῶν with other editors we should simply change the second καὶ on a18 to ὥσπερ (Cooper 1988, 40 *n.* 15). However, the general point is unchanged whether we accept this or not. For the idea that things occur in the same way on the female side is clearly implied by the next sentence.

[7] I follow Peck in translating λύσις as "relapse". Although this is not one of the meanings listed in Liddell and Scott, "relapse" most effectively captures the idea behind Aristotle's highly-specialised use of λύσις here. It gives the sense of shifting backwards down the blood-line (reverting to some past form), which is precisely the image Aristotle intends to convey.

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The story runs as follows: The woman from Elis, who was pale skinned, had a daughter with a man from Ethiopia, who was dark skinned. The daughter (F_1) was pale skinned, but her son (F_2) was dark skinned (the assumption being that the boy's father was also pale skinned). What needs to be explained is the F_2 generation, specifically, how two pale-skinned parents manage to produce a dark-skinned offspring. Aristotle's explanation is supplied by our text. The daughter of the woman from Elis (the mother of F_2) contributes to the act of reproduction two movements for skin colour, one corresponding to her own pale skin and another corresponding to the dark skin of her father (a property not displayed in her own phenotype). As we shall see, Aristotle's theory of inheritance allowed him to infer on the basis of the F_2 generation that the mother's pale-skin movement had "relapsed" into the dark-skin movement of her own father (the man from Ethiopia), which resulted in the offspring's coming to have dark skin like his maternal grandfather.

This is only a brief sketch of what is a very complicated story (one that is not "crude and childlike" as Furth suggests). We will have a chance to explore Aristotle's theory of inheritance in greater detail in the coming chapters. What is important here is that, as the above passage makes clear, maternal movements occupy the central explanatory role in Aristotle's account of resemblances to the mother's side of the family. The most natural reading of 768a15-21 is to take the movements contributed by the mother to be functionally equivalent to those of her male counter-part in the process of inheritance.[8] This is the position I shall defend in what follows. The advantage of this interpretation is that if we assume the movements from both parents are functionally equivalent, Aristotle has a straightforward story to tell for how maternal-line atavism works. Resemblance to the mother's ancestors occurs when her movements relapse, just as resemblance to the father's ancestors occurs when his do.

Not surprisingly, many commentators have come to see the introduction of maternal movements in *GA* 4.3 as inconsistent with the hylomorphic theory that dominates the earlier books. The charge of inconsistency is seen as arising from three premises. According to Aristotle's theory in the *GA*:

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[8] By saying the maternal movements are "functionally equivalent" (or "functionally identical") to the paternal movements I mean that the mother supplies her own set of spermatic movements which have the same hereditary function as the father's movements (whatever that function turns out to be).

(1) The father alone supplies the form manifested in the eventual offspring, while the mother supplies the matter which receives that form.

(2) The way the father makes his formal contribution is through the movements of his sperm which determine the offspring's form by directly fashioning the matter into that new individual.

(3) The mother contributes a set of movements which are functionally equivalent to their paternal counter-parts.

The first two premises of this triad are supposed to yield the matter-form theory which dominates the early books of the *GA*. According to Cooper, for example, that theory says that only the father, working through the formative movements of his sperm, is in any way at all capable of fashioning the materials supplied by the female into a new animal.[9] Thus by introducing maternal movements into the theory which perform the same function as their paternal counter-parts, *GA* 4.3 appears to suggest that the female's matter is not entirely passive after all but is fully capable of supplying its own formative movements by means of which it fashions *itself* into an offspring with a determinate shape and form. The problem is how to resolve this apparent inconsistency.

It is important to understand that the controversy surrounding *GA* 4.3 is not about whether or not Aristotle thinks the mother supplies "movements" to the process of inheritance; this much is explicit in the text. What is controversial is the role that such movements play in Aristotle's theory. The main project of this chapter is to defend premise (3), which is the most natural reading of the text. For example, *GA* 768a15-21 seems to clearly identify paternal movements *and* maternal movements as being demiurgic in nature (αἱ κινήσεις αἱ δημιουργοῦσαι).

On my reading, the mother is directly responsible for all of those aspects of the offspring's form that make it look like the individuals on her side of the family. And the way she does this is by supplying a set of spermatic movements which occupy the same causal role in the process of inheritance as those supplied by the father (whatever that causal role turns out to be). I shall argue that, when properly understood, *GA* 4.3 provides an intelligible account of maternal inheritance that fits perfectly well not only with what Aristotle says in the rest of that chapter but also with what he says in the *GA* as a whole. The apparent inconsistency arises, not from

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[9] See Cooper 1988, 19; cf. 26.

1. Motions of Socrates' sperm in fashioning the parts of the offspring out of menstrual blood.
2. Changes of the menstrual blood initiated by active potentials carried in Socrates' sperm.
3. Changes of the menstrual blood carried directly into the female inside Socrates' sperm (as in a vessel) initiated by potentials in Socrates' body.

Reading 1 is inconsistent with one of the central tenets of the *GA*, namely, the offspring is responsible for the construction of its own body. The central problem with reading 2 is that the κινήσεις in question are supposed to be present in the father's sperm while the δυνάμεις from which they are drawn are located in his own body. Nor does it seem reasonable to suggest that the father's sperm carries actual changes into the female (reading 3) without being the subject of those changes (something Aristotle categorically denies). It is fairly certain that whatever the κινήσεις in Socrates' sperm turn out to be, they are not motions or changes in the ordinary Aristotelian sense.

I want to suggest a fourth reading of the text:

4. The spermatic κινήσεις are separate entities carried inside Socrates' sperm.[31]

On this interpretation, the spermatic κινήσεις are not ordinary changes (they are not changes *of* anything) but the vehicles through which an organism's form is physically transmitted to its offspring in the act of reproduction.[32] For lack of a better translation I shall simply use "movement" (but not "motion") to refer to these entities. However, it should be stressed here that the "movements" in Socrates' sperm are not the eventual

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[31] A process of change will not count as an "entity" in the sense in which I am using the term (see, e.g., *Metaphysics* Z1). I suspect Aristotle uses "κίνησις" merely as a placeholder for these physical entities in the way "gene" functions in Mendelian genetics.

[32] Gotthelf suggests something akin to this (1987, 216 *n.* 20).

motions and changes that transform the menstrual blood into the parts corresponding to those "movements" (they are not preset changes).[33]

§5 "Movements" as vehicles in *Generation of Animals* 5

In using the word "κίνησις" or "movement" to refer to a physical vehicle for conveying biological form Aristotle has clearly extended its meaning well beyond the ordinary sense of motion or change. (This is unlike "δύναμις" which retains its more familiar Aristotelian meaning of an active potential.) However, this specialised use of the word κίνησις is not confined to the discussion of inheritance in *GA* 4.3. We also find it being used in a similar way in the account of sense-perception in *GA* 5.[34] There Aristotle deploys the concept of a κίνησις which is not an ordinary process of change (it is not a motion or change *of* something) but a vehicle for conveying an object's sensible form from the object to the perceiver.

For example, at 780a27-31 Aristotle says the thickness of the membrane around the eye-jelly can affect the direction of the κίνησις "coming into the eye from without" (θύραθεν) and whether or not it "passes straight through <the membrane>" (εὐθυπορεῖν). Again, at 780b34 Aristotle refers to a κινήσις "coming from distant objects" (πόρρωθεν) and "arriving at" (ἀφικνεῖσθαι) the perceiver's sense organs. The use of directional terms which ascribe locomotion to a κίνησις suggests that the concept is not being used in any ordinary sense: they are not the motion *of* something travelling but things which are themselves in motion. This provides strong evidence that Aristotle is

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[33] This idea will become clearer momentarily. Witt also suggests that the spermatic "movements" are information-bearing vehicles (1989b, 56 *n.* 26), though she does not expand on this. For the idea of a κίνησις bearing informational content see *De Mem.* (e.g. 452b23-4: "the κίνησις of the fact" and "the κίνησις of the time").

[34] I suspect that this use of κίνησις is also at work in *De anima* and *De sensu*. It is certainly found in other parts of the *Parva Naturalia* (esp. *De mem.*, *On Dreams*, and *On Prophecy in Sleep*).

not thinking of these κινήσεις as ordinary changes but vehicles that physically transmit the sensible properties of an object.

The sensory κινήσεις in *GA* 5 are not only subjects of locomotion. They are also subjects of other sorts of physical changes such as being broken up into pieces. At 780b13-781a12 Aristotle introduces a mechanism whose function is to collect the sensory κινήσεις coming from distant objects and funnel them into the perceiver's eyes. He tells us that the concavity of an animal's brow literally shapes a portion of air between its eyes and the perceived object into a kind of "tube" (αὐλός). The further this tube extends, the more accurately the object is seen:

> Things at a distance, then, would be seen best if there were, so to speak, a continuous tube extending straight from the eyes to the object seen, for then the movements coming from the object would not be dissipated; but, if that isn't possible, still the further the tube extends the more accurately distant objects must be seen. (781a8-12)

Aristotle's idea is this. The sensory κίνησις coming from a distant object will begin to "dissipate" or "break up" (διελύετο) almost immediately. How accurately that object is seen depends on the concentration of the signal (the κίνησις) when it reaches the perceiver's eyes. The more of the κίνησις that reaches the organ, the more clearly that object will be seen. This is where the perceptual tube comes in (the portion of shaped-air extending from the eye). The tube functions as a mechanism for collecting the κινήσεις coming from objects and passing them on to the organ where they produce sensation. And only those κινήσεις that enter the visual tube will reach the eye (cf. 780b18-21).[35] In this way the ability of an animal to see objects at a distance is a function of the length of its visual tube which is in turn determined by the depth and shape of its ocular concavity. Thus, Aristotle says, animals with sunken eyes placed in a hollowed recess are able to see

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[35] At 780b21-2 Aristotle remarks that this is why people in pits and wells can sometimes see the stars (a satirical reference to Thales' reputation for falling in wells perhaps).

things at a distance "because the κίνησις does not get scattered (σκεδαννυμένη; cf. 781b11: διασπῶνται) but goes straight to the mark" (780b35-781a2).[36]

The fact that the sensory κινήσεις are themselves subjects of verbs of change (εὐθυπορεῖν, ἀφικνεῖσθαι, διελύετο, σκεδαννυμένη, διασπῶνται) endows them with a special ontological status not enjoyed by ordinary motions and changes. Ordinary motions and changes cannot be subjects of change.[37] By using the word "κίνησις" in this way Aristotle has clearly extended its meaning well beyond its ordinary sense. In this context a "κίνησις" is a vehicle that carries sensory information about the object from which it came.

There is a nontrivial similarity between Aristotle's genetic use of κίνησις in *GA* 4.3 and the use of κίνησις in *GA* 5.1 as a vehicle for transmitting the sensible properties of an object to the perceiver. While at first glance the two may appear to be quite

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[36] Aristotle's perceptual "tubes" are not simply confined to vision. In *GA* 5.2 he discusses how the same mechanism accounts for the ability to smell and hear distant objects (781b7-16).

[37] *Physics* 5.2 argues that there cannot be change of (ordinary) change. At 225b20-1 Aristotle explicitly states that change cannot be a subject (ὑποκείμενον). (See also *Metaphysics* 1028a20-31.) Someone might object here that ordinary changes can be the subject of verbs of (say) locomotion in the *accidental* sense, that is, when it is the change *of* something which is itself in locomotion. For example, the decaying of the ship's hull moves through the water insofar as the ship is itself moving through it (cf. *De anima* 1.3). In this case the change or κίνησις would be in motion in the accidental sense (only in the sense that *the thing of which it is a change* is in motion). However, this does not seem to be what Aristotle has in mind here at all. He is clearly thinking of these sensory κινήσεις as the things which are *themselves* in motion: not κατὰ συμβεβηκός but καθ' αὑτό. This is most explicit in 780b35-781a2 when he says "the κίνησις does not get scattered but goes straight to the mark". In this sentence "κίνησις" is the καθ' αὑτό subject of the motion: *it* is the thing which gets scattered and goes straight to the mark (or in this case does not get scattered and go straight to the mark).

different events, from one perspective inheritance and perception are instances of the same general phenomenon. They both involve the transmission of the form *without* the matter.

It is well-known that Aristotle characterises perception in the *De anima* as an event involving the transmission of an object's sensible form without its matter (*DA* 2.12). In *Generation of Animals* 5 we are given the mechanism that underlies this event. There we are told that the formal properties of an object (e.g. its colour) are conveyed from the object to the perceiver by means of "movements". Likewise, one of the central features of Aristotle's theory of reproduction is the idea that the father transmits his form to the offspring *without* transmitting any of his matter. And just as in the case of perception, we find Aristotle appealing to "movements" in Socrates' sperm that transmit that form.

Before moving on I want to make an important point concerning the relation between the account of inherited resemblances in *GA* 4.3 and the account of sex determination in *GA* 4.1-2. Although the account of inherited resemblances is quite obviously an extension of the account of sex determination, the causal mechanisms responsible for the two phenomena are quite different. I do not think this is sufficiently appreciated by commentators. As we have seen, an embryo's sex is determined by the level of concoction effected by the sperm during conception. If the sperm is able to fully concoct the menstrual fluid, then the resulting embryo is male. If it only manages to partially concoct it, the embryo will be female. However seminal concoction simply raises the temperature of the matter. Clearly making the offspring look like specific individuals requires much more than this. For while the difference between male and female (functionally defined) is reducible to a difference in temperature (males are hotter than females), differences in, say, facial features are not. This is the reason we find Aristotle introducing the concept of a spermatic "κίνησις" in *GA* 4.3. I am arguing that these κινήσεις are specialised vehicles of inheritance that transmit those highly-specific phenotypic resemblances from one generation to another.

§6 What happens at the receiving end?

Up to this point the discussion has focused exclusively on the transmission end of inheritance. According to the interpretation developed here, an organism's form is transmitted to its offspring by means of "movements" in its seed derived from the "potentials" of its genetic nature. Each one of these potentials is the productive source of a corresponding phenotypic character. The final question to ask is what happens at the receiving end of this transmission. Although Aristotle never actually addresses this question directly, I think we can speculate as to a possible answer.

In order to bridge the gap between Aristotle's account of natural generation and his analysis of the mechanisms of inheritance in *GA* 4.3 we must assume that the reception of the spermatic movements derived from potentials in the parent's body, on the one hand, and the subsequent development of the offspring's body, on the other, are interposed by the formation of a new set of potentials: those that make up the offspring's own genetic nature. For the only way that the process of development will count as *natural* is if all of the changes that make up that process originate directly in a set of potentials in the embryo itself.

Assuming Menexenos is a naturally generated organism, the construction of his body must have been preceded by the formation of his genetic nature, which functions as a source of change in himself *qua* himself. It follows from this that the movements transmitted inside Socrates' sperm cannot be those that make up the process of Menexenos' development (reading 3). First, if the movements imported into the menstrual blood by Socrates' sperm immediately set to work building it into the parts of Menexenos' body, then there would have been no time for the formation of his genetic nature.[38] Second, those spermatic movements are derived from the potentials of Socrates'

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[38] This cannot be avoided simply by saying that some of the changes Socrates' sperm "imports" into the matter are charged with the responsibility of forming Menexenos' genetic nature. For we have just finished saying that in order for Menexenos' generation to be "natural" the entire process must be derived from his nature.

genetic nature, which is a principle of change in another. In that case it is not clear how Aristotle could distinguish Menexenos from a mere artefact.[39]

Morsink's reading (reading 2) would avoid both of these problems. According to Morsink the potentials of Socrates' genetic nature (or copies of them) are carried directly into the embryo inside his sperm. When these potentials are activated they cause the matter to develop into an organism resembling Socrates in every respect. After all they are (copies of) potentials of *Socrates'* genetic nature. However, while these potentials would count as sources of change in Menexenos himself *qua* himself, Aristotle is explicit that what is carried into the female inside Socrates' sperm are not the potentials of his nature but "movements" derived from those potentials.

The alternative (arising out of reading 4) is that the function of the spermatic "movements" is to directly reproduce the active potentials from which they were drawn. On this reading Menexenos will resemble Socrates to the extent that the potentials reproduced by the "movements" in Socrates' sperm are copies of those in Socrates' own genetic nature. For each of the latter is a distinct potential for the formation of a different part of *Socrates'* body.

§7 The transmission of biological form: a summary

In the text with which we began Aristotle set out the basic causal mechanism behind the transmission of biological form. According to that text, Socrates' sperm contains a set of κινήσεις derived from corresponding δυνάμεις in himself. I have argued that these δυνάμεις are the components of Socrates' genetic nature, each of which is a distinct potential for the formation of a given phenotypic character (including potentials for the formation of characters which are not part of his observable form). I have also argued that the κινήσεις which are present in Socrates' sperm are not actual (or even potential) processes of change but the vehicles through which his form is transmitted to

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[39] This point extends to those developmental changes whose causal history can be traced to spermatic κινήσεις derived from potentials of the mother's genetic nature. For at best her genetic nature counts as a principle of change in itself *qua* other (depending on the metaphysics behind the mother-embryo relation).

his offspring in the act of reproduction. Finally, I have argued that in order to bridge the gap between Aristotle's transmission genetics and his account of natural generation we must assume that the reception of spermatic movements from the parent and the subsequent transformation of the embryo into its adult form are interposed by the formation of a new set of potentials in the offspring itself. These new potentials will be the components of its own genetic nature, which provide a source of change in the thing itself *qua* itself (thereby satisfying the condition for *natural* generation). If this is right, then the function of the spermatic movements which are carried in Socrates' sperm is not to produce the parts of Menexenos' body directly but rather to reproduce the potentials of his own genetic nature which are the productive sources of those parts.[40] In this way organisms reproduce their phenotypic natures *indirectly* by directly reproducing their genetic natures.

§8 An evolution of species?

One interesting implication of this is that it seems to leave room for genetic mutations and thus the possibility of an evolution of species. In *GA* 4.3 Aristotle suggests that monstrosities can result when the κινήσεις become "confused together" (συγχέονται).[41] Now Aristotle could just be referring to the motions and changes that make up the process of development – the motions initiated by the new potentials of the offspring's genetic nature.[42] In that case the deformed phenotype that results will not be heritable (it will not be included among those properties that belong to that individual

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[40] Recall the difference between this interpretation and formal preformationism. On the latter reading the δυνάμεις that pre-exist in the embryo are the offspring's potential parts. These potentialities are exhausted or used up as they "flower into actuality". On my reading the δυνάμεις are potentials *for the formation* of different parts whose activation initiates a series of changes that terminate in those parts. These δυνάμεις are not exhausted in the course of development but are preserved in the adult organism as active potentials of its genetic nature.

[41] *GA* 768b10 (cf. 769b9-10).

[42] cf. 772b13-26.

"καθὸ γεννητικόν"). For only the active potentials or δυνάμεις of a creature's genetic nature are directly reproduced in the act of reproduction. However, 768b10-12 appears to be talking about the spermatic κινήσεις themselves (the things transmitted in the parents' seeds). In that case those confused movements will produce mutated potentials in the offspring's genetic nature. And those mutations *will be* heritable. For in that case there will be a movement in the offspring's own seed derived from that mutated potential.

Of course, even if this is right, Aristotle either does not recognise it or does not appreciate the implication. For while his account of the mechanisms of inheritance might leave room for a theory of natural selection, this is not something Aristotle entertains.

However, the current suggestion *is* compatible with Aristotle's belief in the fixity of species. According to Lennox, for example, the view Aristotle defends in the *Generation of Animals* is not that species are eternal but that, through the act of reproduction, the *individual* becomes "eternal in form" (the only sort of immortality available to it).[43] On this interpretation, an eternal "species" is simply a continuous reproduction of individuals which are one in form, where being "one in form" means sharing a particular sort of account in common:

> Among accounts which make clear what a thing is [essence-revealing accounts], there is one which relative to the kind being defined is not further divisible and which is common to many things. Those things which share such an account are one in form.[44]

However, no account is indivisible in itself (1016a33-5). A more detailed account of a thing's phenotypic nature is always available which will reveal further features of that particular individual, albeit ones which are not essential to its ability to survive and flourish within its particular environment. Two or more individuals are thus "one in form" if they share an account which specifies their essence but which, were it more precise, would not reveal any *further* features that are essential to its survival.[45]

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[43] This is the main line of argument presented in Lennox 2001b, 131-59 (cf. 128).

[44] Lennox 2001b, 174.

[45] Lennox 2001b, 181 *n.* 35.

Lennox's account of the nature of biological kinds is much too complicated for me to summarise here. The relevant idea is that species-level features such as "nose", "eyes", and "leg" do not pick out actual features of any particular individual but represent what Lennox calls "features with range", "*possible* ways in which human noses, eyes and legs may be realized".[46] On this reading, Socrates' snub nose, blue eyes, and short legs and Callias' bulbous nose, brown eyes and long legs are two concrete realisations of the same generic human features. The key here is that the eternal form – the form which is continuously reproduced from one individual to the next – will display a certain amount of phenotypic plasticity, a range of possible ways in which the essential structures of the kind may be concretely realised in those different individuals.[47] If a mutation occurs outside of this allowable range, then the offspring will no longer be suitably adapted to its environment and thus will perish. Of course Aristotle never fully articulates this idea. However, my point is simply that biological forms can be eternal insofar as they are continuously reproduced from one generation to the next whilst admitting of a certain amount of variability (produced through mutation) within limits set by the creature's particular environment.

The implication here is that species are fixed, not because individuals possess some sort of innate capacity to maintain the species-form against all odds; rather, the fixity of the species is parasitic on the fixity of the environment.[48] On my interpretation Aristotle's account allows for an evolution of species, then, insofar as individuals would eventually be forced to adapt to a changing environment. For as the environment changes, the allowable range of possible ways of realising the species-form changes.[49] Of course there is good reason to suspect that Aristotle thinks the motions of the heavens, which determine the nature of the sublunary environment, are eternal and unchanging.

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[46] Lennox 2001b, 175, 178.

[47] See Lennox 2001b, 178: "Yet at each level there will be an organization among the allowable ranges for each feature of each differentia which is essential to an animal's life, particularly its mode of feeding, cooling itself, and rearing its young."

[48] cf. Charles 1991, 123 *n.* 24-5.

[49] This is also suggested by Lennox 2001b, 178.

Thus an evolution of species is ruled out on cosmological (though not biological) grounds. So it is Aristotle's cosmology, not his biology, that is incompatible with an evolutionary world view.

Chapter Six

Aristotle's Theory of Inheritance

§1 The three suppositions

Now that the mechanisms are in place, let us turn to the theory of inheritance proper. It consists of three "general suppositions" (καθόλου ὑποθέσεις),[1] formulated succinctly at *GA* 768b5-10:

> We must grasp the general suppositions, not only the one stated, (1) among the movements present in the parents' seeds some are present in potentiality while others are present in activity, but also two others: (2) being dominated causes displacement into the opposite (κρατούμενον μὲν ἐξίσταται εἰς τὸ ἀντικείμενον), while (3) relapsing causes a change into the movement which stands next to it <on the blood-line> (λυόμενον δὲ εἰς τὴν ἐχομένην κίνησιν). If it relapses a little, it passes into the movement which stands closer; if it relapses a lot, it passes into the one farther away.

Supposition one concerns the existence of movements in the seeds of all sexually reproducing animals, some of which are "in activity" while others are "in potentiality". The other two supply the principles or 'laws' that govern the interactions between the maternal and paternal movements.[2] The outcome of those interactions determines the pattern of inheritance for the particular offspring.

Having an account of the general contents of the parent's genetic material will make it easier to set out Aristotle's theory of inheritance. *GA* 768a11-14 is an important text in this respect:

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[1] Lennox has suggested to me that the use of ὑποθέσις here probably reflects its technical meaning from the *Analytics* (cf. *An. Po.* 72a15ff.). A "θέσις" (or "posit") is an immediate, indemonstrable first principle the grasp of which is not necessary for acquiring knowledge. A "ὑποθέσεις" is a posit which assumes one or the other part of a proposition, viz. that something does or does not exist. I shall not explore the implications of this here.

[2] I shall call these latter two ὑποθέσεις the principle of displacement (ἔκστασις) and the principle of relapse (λύσις), respectively.

> Some of the movements are present in <the father's sperm>[3] in activity while others are in potentiality: in activity, those of the father and the universals (e.g. Human and Animal); in potentiality, those of the ancestors.[4]

Here Aristotle divides the paternal movements into three general groups: those of the father (τοῦ γεννῶντος); those of the universal (τοῦ καθόλου); and those of the ancestors (τῶν προγόνων). Those of the first two groups are said to be "in activity" while those of the third group are "in potentiality". I shall return to this distinction later.

The movements "of the father" include two sets of movements, one for the sexual morphology proper to a male and another for those features of Socrates' phenotype that make him a unique individual. Both of these movements are derived from potentials of Socrates' genetic nature which correspond to those parts of his phenotype (see, e.g., 768a28-9: ἡ ἀπό τοῦ ἄρρενος κίνησις and ἡ ἀπό τοῦ Σωκράτους κίνησις).

In order to explain why some offspring resemble the father while others resemble the mother with respect to different parts (phenomenon 2b) Aristotle postulates movements in the parents' seeds corresponding to each of their several parts (τῶν μορίων, 768b1-5).[5] Each part-movement is itself a discrete unit of inheritance that can undergo displacement and relapse independently of the other movements in the set. This raises several difficult part-whole puzzles that would take us too far outside of the immediate project. Thus, to avoid unnecessary complications I shall simply talk about the movement of "Socrates" (the movement for the whole) as being made up of the movements for the parts of Socrates. On this reading,

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[3] The subject of ἔνεισιν is left unexpressed here; however, it is fairly certain that Aristotle is talking about movements present in the father's genetic material (or σπέρμα). As I go on to say, Aristotle clearly wants us to generalise this to the genetic material of both parents.

[4] Reading δυνάμει δὲ αἱ τῶν προγόνων for δυνάμει δὲ αἱ τοῦ θήλεος καὶ τῶν προγόνων. I argued for this emendation in chapter four.

[5] "Part" should be understood in the broad sense of phenotypic character, including such features as eye colour and skin colour.

resemblance to Socrates as a whole occurs when all of the several part-movements are inherited together (though individually).[6]

The two movements corresponding to the universals Human and Animal do not play a central role in Aristotle's account of inheritance in *Generation of Animals* 4.3. This is not to say they do not play a central role in reproduction. Rather, *GA* 4.3 is concerned with the eight phenomena set out at the beginning of that chapter, which primarily have to do with the inheritance of individual differences below the level of species.[7] The movements of the universals enter into the explanation of phenomena 7 and 8, which fall outside the immediate scope of the theory of inheritance itself.[8] These two phenomena have to do with the loss of family resemblance owing to the malfunctioning of the mechanisms involved, and so are both teratological in nature. I shall postpone the discussion of these until the end of the chapter. Here we can simply note that the movement in Socrates' sperm corresponding to "Animal" transmits the εἶδος of the animal (*qua* animal) in the strict sense. More specifically, it reproduces a potential (or set of potentials) in the offspring's genetic nature that controls the

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[6] The same applies for the other movements in Socrates' sperm (e.g. the movement "male" is made up of movements for the parts of a male). The question about how the movement of the whole is related to the movements of the different parts is not essential to Aristotle's theory of inheritance *per se*. What we would ultimately have to answer is whether or not the movement of the whole is reducible to the several movements of the parts and, if so, whether this threatens the unity of the phenotypic nature as a whole. I do not think so, though I shall not defend that here.

[7] Eventually I shall argue that insofar as reproduction itself is concerned the movements of the individual actually play a minor, secondary role. They are responsible for the 'details' of an organism's phenotype. (For a contrasting view see Balme 1987b.) However, they take the lead role in the inheritance of family resemblances, which is the primary target of *GA* 4.3.

[8] Phenomenon 7: offspring who fail to resemble either its parents or its ancestors may still look like a human being at any rate. Phenomenon 8: in the extreme cases the offspring's observable form (τὴν ἰδέαν) may fail to bear any likeness of a human being at which point it is a monstrosity (τέρας).

development of its sensory system, which is the property in virtue of which it is an animal.[9]

Finally, by postulating a set of movements in the parent's seed that convey resemblances to other members of its family (the movements of the third group) Aristotle was able to account for the fact that offspring who do not resemble their parents tend to resemble their ancestors more than any chance individual of the same species (phenomenon 4). On the other hand, the fact that these movements are only "in potentiality" while those corresponding to the parent's own phenotype are "in activity" is supposed to explain why offspring tend to resemble their parents more than the ancestors (phenomenon 3). I will have more to say about this later. For it is not exactly clear what it means to say that some of the movements in the parent's seed are δυνάμει while others are ἐνεργείᾳ. However this distinction is cashed out, the way it figures into Aristotle's theory of inheritance is clear. The ancestor movements change from being δυνάμει to being ἐνεργείᾳ whenever the parental movements undergo "relapse".

There is one final point to make concerning 768a11-14. It would be a mistake to conclude from the fact that Aristotle only enumerates the contents of the father's genetic material in that text that the point is limited to his contribution. Even Cooper concedes that the general suppositions of Aristotle's theory apply to maternal movements as well: "Once movements in the female fluid are introduced into Aristotle's account, at 768a18-21, they obviously fall within the scope of the general principles about actual and potential movements first set out for the male fluid alone at 767b35-7 and 768a11-14, and he simply takes note of this fact at 768a4 and 6."[10] It is likely that 768a11-14 simply uses the father to illustrate a more general point about the contents of an organism's genetic material but which implicitly extends to the mother as well.

And we do find roughly the same movements coming from the mother elsewhere in the text. For example, we have seen at 768a19-21 Aristotle mentions both the movement of the mother (τῆς γεννώσης: compare a16, τοῦ γεννῶντος)

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[9] cf. 736b1-5, translated in chapter two above. It follows from Aristotle's reproductive hylomorphism that this movement will only be present in the father's sperm.

[10] Cooper 1988, 40 *n.* 14.

and the movements of her various ancestors (τῆς μητρός, τῆς τήθης: compare a17-18, τοῦ πατρός, τοῦ πάππου). Presumably the movement of the mother (like the movement of the father) includes two sets of movements, one for the sexual morphology proper to a female and another for those features of her phenotype that make her a unique individual.[11] Moreover, her movements will also be further analysable into the movements of her parts in accordance with 768b1-5. Finally, it is implied by 768b13-15 that the mother's spermatic movements include the universal "Human".[12]

Now I have argued that the most natural way to read the text is to take the mother's spermatic movements to be functionally equivalent to their paternal counter-parts. Thus the maternal movements will likewise function as vehicles for transmitting the heritable properties of the mother's body including (but not limited to) those that make her a unique individual. And like the movements coming from the father, the mother's movements will be derived from corresponding δυνάμεις in her own genetic nature. Each δύναμις in her nature is a distinct potential for the formation of a different phenotypic character, both those that are displayed in her own phenotype as well as ones corresponding to features of her ancestors.

§2 Supposition two and three: "displacement" and "relapse"

The real meat of Aristotle's theory of inheritance is expressed by suppositions two and three. Taking a movement in Socrates' sperm as a reference point, there are three things that can happen: that movement can dominate (κρατεῖν); it can be

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[11] For convenience I shall use "the movement coming from female" and "the movement coming from Xanthippe" as the maternal counter-parts for "the movement coming from male" and "the movement coming from Socrates" (cf. 768a28-9). Aristotle does not mention the mother by name.

[12] The other universal movement "Animal" will only be present in the father's sperm in accordance with Aristotle's reproductive hylomorphism. However, we have seen that Aristotle thinks the mother provides the offspring's nutritive soul, which is to say that the genetic factor responsible for the organisation of its nutritive system can be traced to a corresponding spermatic movement coming from the mother. If this is right, then although Aristotle does not explicitly mention it, Xanthippe's contribution should also include the universal movement "Plant".

dominated (κρατεῖσθαι); or it can undergo relapse (λύσις). According to supposition two, being dominated causes displacement into the opposite, while relapsing causes a change into the movement which stands next to it (supposition three).

We are already familiar with the principle of relapse. If the movement corresponding to Socrates' nose relapses, the potential movement in his sperm corresponding to his father's nose is activated (becomes ἐνεργείᾳ). In this case Menexenos inherits his grandfather's nose. Socrates' nose-movement may relapse back two generations, in which case Menexenos will inherit his great grandfather's nose (and so forth).

The principle of displacement (ἔκστασις) is somewhat more complicated. We know that being dominated causes displacement and that this is a change "into the opposite". This gives us a general idea of how the principle of displacement affects the outcome of inheritance: if displacement occurs with respect to a property on the father's side, then the offspring will come to display the maternal version of the trait in which displacement occurred. However, the two principles of Aristotle's theory are supposed to govern the behaviour of the causal mechanism that underlies the phenomena. And how displacement works at this level is extremely vague. Specifically, it is not clear what exactly changes to the opposite.

The text itself seems to be inconsistent on this. On the one hand, 768a2-5 tells us that that which is *not* dominated (μὴ κρατούμενον) changes into the opposite:

> Everything, when it gets displaced, does not change into any chance thing but into its own opposite. Therefore, in the case of generation, that which is not dominated must of necessity be displaced and become the opposite with respect to that potential (δύναμις) wherein the generating and moving cause did not dominate.[13]

The ensuing discussion makes it clear that what Aristotle is referring to here is the embryo (or the matter).[14] And this is simply a logical point. The idea is that whenever the offspring does not resemble the father, it does not come to resemble any random

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[13] Compare 766a14-16 and 768b25-7.

[14] It makes no difference whether we take the thing that "changes over" here to be the embryo or the material supplied by the female. For the fertilised menstrual blood *is* the embryo.

individual but must of necessity resemble someone on the mother's side of the family (since "mother" is in a sense the opposite of "father", 768a5-9). And yet, on the other hand, when we turn to the official formulation of the principle of displacement at 768b7-8 that which *is* dominated (κρατούμενον) is said to change into the opposite.

Of course these two texts are only inconsistent if we assume that they are both about the embryo changing over. In that case 768a2-5 says the embryo changes into the opposite when it *is not* dominated (presumably by the sperm) while 768b7-8 says that it changes into the opposite when it *is* dominated. The problem can be resolved simply by taking the principle of displacement at 768b7-8, which Aristotle includes as one of the three general suppositions of the theory of inheritance, to refer to something else that changes into its opposite. The best candidate for this is the κίνησις (the hereditary unit) which is dominated by the corresponding κίνησις from the opposite parent. On this reading both suppositions two and three will refer to changes between movements: ἔκστασις causes inheritance to change from the movements of one parent to those of the other (a change between movements on opposite blood-lines); λύσις causes inheritance to change from the movements of the parent to those of the ancestor (a change between movements on the same blood-line).

The suggestion that the principle of displacement (like the principle of relapse) refers to a change between the movements coming from the parents can be supported by supposing that Aristotle took over the concept of κρατεῖν (at least in one of its uses: see below) from Democritus. And in Democritus' theory κρατεῖν, or "dominance", expresses a relation between functionally equivalent genetic contributions from each parent, which he took to be preformed parts:

> Democritus of Abdera holds that the difference between male and female is produced in the womb, indeed, but he denies that it is because of heat and cold that one becomes male and another female [as Empedocles held]. This, he claims, is determined by whichever of the two parents' σπέρμα (the σπέρμα which is drawn from the part wherein male and female differ from one another) is dominant over the other. (*GA* 4.1, 764a6-11)

In general, to hold that the superiority of the <σπέρμα which is drawn from> one part is dominant <over the σπέρμα which is drawn from

> the other> and that this dominance is what makes the embryo female is certainly better than saying that heat alone is the cause of this without stopping to think about it. (*GA* 4.1, 764b20-4)

These texts come in the midst of Aristotle's discussion of the causes of sex determination. And *Generation of Animals* 4.1 is a classic Aristotelian opening chapter where the theories of his predecessors are examined and evaluated. The purpose of the exercise is not only to highlight the problems with their accounts but, more importantly, to determine what progress has been made in the investigation of the subject in question and how we might build on that progress. In both of the above texts the transition from Empedocles to Democritus signals what Aristotle sees as progress. Although Aristotle found much of Democritus' theory untenable (specifically its preformationist assumptions), he preserved what he took to be Democritus' contribution to the subject: the concept of "dominance". Thus, we should expect to find a similar use of the concept in Aristotle's theory which expresses a relation between the genetic contributions of each parent, which for Aristotle are the spermatic "movements".

If I am right, then supposition two can be read as supplying the causal mechanism behind the phenomenon described at 768a2-5. When the movement of the father is dominated (alternatively, when the mother's movement dominates), inheritance automatically switches over to the opposite movement coming from the mother. It will be the dominance of *this* movement that ultimately explains why the embryo develops the opposite maternal trait.

In this way suppositions two and three both refer to changes between movements. The principle of displacement (supposition two) describes a change between movements on opposite blood-lines while the principle of relapse (supposition three) describes a change between movements lying on the same blood-line. Putting all of this together, if Socrates' nose-movement dominates, Menexenos will come to have the same nose as his father. However, if this movement is dominated, then it gets displaced which causes inheritance to switch over to Xanthippe's nose-movement (a change between movements on opposite blood-lines). In this case Menexenos' nose will resemble his mother's not his father's. However, if Xanthippe's movement *relapses*, it passes into the movement of her mother (a change between movements on the same blood-line). When that happens Menexenos will come to have the same nose as his maternal grandmother.

It is not obvious from the text how we get resemblance to Socrates' grandmother or Xanthippe's grandfather. All we are given is the mechanism for resemblance to males on the paternal-line (the father's father, grandfather, great-grandfather, etc.) and females on the maternal line (the mother's mother, grandmother, great-grandmother, etc.). One possibility is suggested by 768a31-2. There Aristotle seems to say that resemblance to Socrates' father occurs when the movements coming from "male" and "Socrates" relapse while the former "stands fast" (μείνῃ). Perhaps the suggestion here is that "standing fast" keeps the process of inheritance on the male line while *not* standing fast causes it to switch tracks from the movements of Socrates' male ancestors to those of his female ancestors. And likewise on Xanthippe's side of the family.[15]

§3 Mastery versus dominance: two senses of κρατεῖν

The foregoing makes it clear that the concept of κρατεῖν is used in two different ways in *GA* 4. In some cases (e.g. 766a14-16, 768a2-5, 768b25-7) κρατεῖν is used to describe a sort of chemical reaction produced by concoction.[16] For convenience I shall translate κρατεῖν as "master" when used in this physical sense. Here we are talking about the father's sperm "mastering", i.e. fully concocting, the materials supplied by the female (or the embryo). The connection between "mastering" and "concocting" is brought out clearly in *Meteorologica* 4. For example, at 379b33 a thing is said to be properly concocted whenever the matter is mastered by the heating agent (compare 768b25-7). In other cases (e.g. 768a21-2, 768a28-b1, 768b7-8) κρατεῖν is used to express a relation between spermatic movements (the vehicles of inheritance). When used in this hereditary sense I shall translate κρατεῖν as "dominate". According to supposition two, one movement's "being dominated" causes the process of inheritance to change over to the opposite movement (e.g. from

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[15] Even if this turns out to be correct, it should be stressed that Aristotle's theory does not include a καθόλου ὑποθέσεις that describes this event. Thus he would need to introduce another principle into the theory.

[16] Since the account of sex determination in *GA* 4.1-2 does not make use of the specialised concept of spermatic "movements". we can be sure that κρατεῖν is being used exclusively in this physical sense there.

the movements of the father to the movements of the mother). Which sense of these two senses of κρατεῖν is being used will ultimately depend on the context.

How do these two ideas fit together? What is the relation between the sperm's "mastering" (i.e. concocting) the menstrual fluid and one movement's "dominating" over another? Do they describing two different events in the process of inheritance? I think we can offer an answer by turning to 768b15ff.

According to the classic account of theory reduction in modern philosophy of science, the first step in incorporating one theory into another is to supply appropriate bridge laws.[17] This involves translating the concepts of the one theory into the vocabulary of the other theory. For example, the reduction of classical (Mendelian) genetics to molecular genetics would begin by providing bridge laws that specify which molecular structures correspond to "genes" (a concept from classical genetics) and give an account of the "dominance" relation at the molecular level. Now Aristotle never specifies which physical structures correspond to the κινήσεις and δυνάμεις, which are the basic units of inheritance postulated by his genetics. However, at 768b15ff. he does attempt to provide some sort of bridge laws for translating the two principles that govern the interaction between κινήσεις (the principles of relapse and displacement) into a chemical vocabulary. This suggests that Aristotelian genetics can, at least in principle, be reduced to Aristotelian chemistry via these bridge laws.[18]

Now whether or not Aristotle's genetics can in fact be reduced to his chemistry is irrelevant here. What is important is that the attempt to provide bridge laws gives us a clue as to how "mastery" and "dominance" are related. When Aristotle talks about the father's sperm "mastering" the menstrual fluid, and when he

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[17] The following comes from Sterelny and Griffiths 1999, 137. Sterelny and Griffith provide a good summary of the account of theory reduction proposed by Nagel 1961.

[18] Morsink (1982, 168-9) argues that Aristotle's theory lacks appropriate "bridge principles". However, he is misusing this term. What Morsink refers to as "bridge principles" are the necessary principles for "bridging the gap" between the genotype level and the phenotype level. In other words, he claims that Aristotle does not provide a sufficient account of how the δυνάμεις of the embryo's genetic nature produce the phenotypic characters we see. But that is not what philosophers of science mean by "bridge principles" or "bridge laws".

talks about one movement "dominating" over another, he is not describing two different events in the process of inheritance. Rather, talk of seminal concoction and mastery, on the one hand, and talk of spermatic movements dominating and being dominated, on the other, describe the same event (displacement) at two different levels. One is a description of the event at the chemical level, the other a description of it at the abstract theoretical level.[19]

This is consistent with the account of displacement at 768b25-7. Aristotle must be describing the phenomenon at the chemical level here. For it is associated with "οὐ κρατεῖται", whereas in the second supposition of Aristotle's theory (which describes events at the abstract genetic level) displacement is associated with "κρατούμενον". These two accounts can be made consistent simply by taking "οὐ κρατεῖται" at 768b25-7 to mean "is not mastered" (an event at the chemical level) and "κρατούμενον" at 768b7-8 to mean "is dominated" (an event at the genetic level). Thus, when giving an account of displacement at the chemical level we talk about the sperm failing to concoct or "master" the material supplied by the female owing to a deficiency in its concocting heat (768b25-7), whereas at the more abstract genetic level we would talk about the father's spermatic movements "being dominated" (768b7-8).

The picture that emerges thus looks like this. If the movement in the father's sperm corresponding to his nose dominates over the opposite movement coming from the mother, then the offspring will come to have the same nose as its father. However, if the paternal movement is dominated, then inheritance switches over to the opposite movement coming from the mother according to the principle of displacement. In this case the offspring inherits its mother's nose. I want to suggest that this dominance relation is determined at the chemical level by whether or not the father's sperm manages to fully concoct or "master" the menstrual fluid. If the sperm "masters" the matter, then his movement dominates. However, if the menstrual fluid is not mastered by it (if the sperm fails to fully concoct it), then his movement is dominated.

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[19] The difference I am after here is analogous to molecular genetics versus Mendelian genetics.

§4 Simultaneous displacement

I have already touched on Aristotle's account of phenomenon 5 in chapter four (why males tend to resemble their fathers and females their mothers). At 768a21-8 Aristotle says that "the most natural" course of events is when the movements corresponding to sex and resemblance dominate and are dominated together (ἅμα):

> Therefore, the most natural course of events is when <the movement> dominates and is dominated both *qua* male and *qua* father together (for the difference is slight so that it is not difficult for both <properties> to occur together <in one individual>; for Socrates is a particular sort of male). This is why males tend to resemble their fathers and females their mothers: displacement occurs into both opposites *together*, and "female" is the opposite of "male" and "mother" of "father" (displacement being a change into opposites).

Now if by saying that this is the "most natural" Aristotle means it is the most ideal scenario (as most commentators read the text), then his point is that ideally we want sex and resemblance to match up, sons looking like their fathers and daughters looking like their mothers. But obviously this is not Aristotle's point. What Aristotle provides here is the causal mechanism which explains the fact that offspring tend to resemble the same sex parent (son/father, daughter/mother). By calling this the "most natural" he clearly means it is the usual outcome ("nature" as what happens for the most part).

The idea here is that the movements corresponding to sex and resemblance are linked in such a way that the properties associated with those movements tend to be inherited together as a set (the fate of the one normally determines the fate of the other). We can call this the principle of simultaneous displacement. Simultaneous displacement is not afforded the status of a καθόλου ὑποθέσεις in the official theory of inheritance. However, it clearly has the status of a theoretical principle that governs the behaviour of the mechanism. The reason why this is not included in the καθόλου ὑποθέσεις of Aristotle's theory is probably because he thinks it is deducible from those principles. More than likely Aristotle wants to cash this out in terms of some sort of physical bond between the entities corresponding to the κινήσεις, so that

simultaneous displacement may just be a special case of the principle of displacement together with this bond.[20]

The fact that the movements for sex and resemblance are themselves discrete units of inheritance that can dominate and be dominated independently of one another explains why offspring sometimes resemble the parent of the opposite sex (son/mother, daughter/father).[21] This supplies the explanation for phenomenon 6, as set out in the following passage:

> But if the movement coming from "male" is dominated while the one coming from "Socrates" does not dominate, or the latter dominates but the former does not, in that case both a male resembling its mother and a female resembling its father are generated [respectively]. But if the movements relapse, and the movement stands fast *qua* male while the movement coming from "Socrates" relapses into that of his father, the result is that the offspring will be a male that resembles its grandfather (or some other ancestor according to the same account). However, if it is dominated *qua* male, then the offspring will be female and usually resemble its mother. But if this movement also relapses, then resemblance will be to the mother's mother (or some other ancestor according to the same account). (768a28-b1)

This passage is extremely rich. For it gives us a relatively complete picture of the causal mechanisms behind the phenomena and the principles that govern their behaviour. It is interesting to note how the explanation proceeds. By applying the principles of the theory Aristotle is able to go from a son who resembles his father all the way to a daughter who resembles her maternal ancestors.

The text runs through the following scenarios (again taking the movements in Socrates' sperm as a starting point):

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[20] Something like the principle of simultaneous displacement (cashed out in terms of a physical bond between movements) may lie behind Aristotle's account of resemblance to the whole. On this model the movements for the parts, although they remain (functionally and physically) discrete units of inheritance, are linked in such a way that they tend to be inherited together as a single unit.

[21] See 769a3-4, b5-6.

(1) If the movement coming from "male" dominates while the movement coming from "Socrates" is dominated, the offspring will be male and look like Xanthippe.

(2) If the reverse happens, the offspring will be female resembling Socrates.

(3) If "male" stands fast and "Socrates" relapses into the movement of Socrates' father, the offspring will be a male resembling its paternal grandfather.

(4) However, if "male" is dominated, the offspring will be female and usually resemble its mother.[22]

(5) But if "this" movement relapses, then the offspring will resemble its maternal grandmother.

The first three scenarios are relatively straightforward. However, (4) and (5) require a bit more work. The problem is identifying "this" movement in (5). Just looking at the Greek, αὕτη λυθῇ ἡ κίνησις (768a35-6) would seem to refer back to the κίνησις in Socrates' sperm corresponding to "male" (the implied subject of κρατηθέντος ᾗ ἄρρεν at 768a34). However, Aristotle has just told us at 768a19-21 that resemblance to the mother's mother occurs when her own movement (ἡ τῆς γεννώσης <κίνησις>) undergoes relapse. So we should expect "this" movement at 768a35 to refer to the movement of the mother and not to any of Socrates' movements – certainly not the movement coming from "male" (which transmits the parts proper to males).

This reading is consistent with what has just been said in 768a21-8 about simultaneous displacement. In (4) Aristotle says that if "male" is dominated, the offspring will be a female and usually resemble its mother. We can account for this by recalling the principle of simultaneous displacement, which says that the movements for sex and resemblance – in this case "male" and "Socrates" – are linked in such a way that they tend to dominate and be dominated *together*. Thus it is implied in (4) that when "male" is dominated "Socrates" will usually be dominated along with it. But how do we get an offspring that resembles its mother from this? For this we need to recall the second supposition of Aristotle's theory, that being dominated causes

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[22] This suggests that perhaps "standing fast" is not a special principle after all but is merely another way of saying the movement dominates and does not get displaced into its opposite.

displacement into the opposite. I have argued that this supposition refers to a change between opposite movements. Thus, when the movement "male" is dominated the movement "Socrates" is also dominated which causes *both movements* to be displaced into their opposites together. So (4) is actually describing a change in *two* movements, one of which is only implicit in the text. There is a change from "male" to "female" *and* a change from "Socrates" to "Xanthippe". (5) can then be understood as saying that if *this* movement, namely the movement coming from "Xanthippe", relapses, their daughter will resemble her maternal grandmother. And this is precisely what we have already been told at 768a19-21 (maternal-line atavism occurs when the mother's movement undergoes relapse).

§5 Supposition one: actual versus potential movements

I now want to look closer at the first supposition of Aristotle's theory. According to this supposition, some of the movements are present in the parent's genetic material "in activity" (those of the parent and the universals) while others are only "in potentiality" (those of the ancestors).[23] I shall ignore the universals here and concentrate on the active parental movements, on the one hand, and the potential ancestor movements, on the other.

By postulating a set of movements in an organism's seed corresponding to its ancestors Aristotle was able to account for the fact that offspring who do not resemble their parents nevertheless resemble one of their ancestors rather than any chance individual (phenomenon 4). However, the fact that the ancestor movements are only "in potentiality" while those of the parent are "in activity" is supposed to explain why offspring tend to resemble their parents *more* than their ancestors (phenomenon 3). While this may seem straightforward on the face of it, supposition one is actually quite puzzling. For one thing it places constraints on how we understand the idea that there are "movements" present in Socrates' sperm. For we have to understand this in such a way that it makes sense for some of those movements to be "δυνάμει" and others "ἐνεργείᾳ". I think a lot of commentators fail to consider this.

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[23] I shall talk about the movements being present "in activity" and "in actuality" interchangeably (though "in activity" is slightly better suited for the reading I shall eventually propose).

For example, according to Furth, Socrates' sperm is "pre-programmed with a variety of highly intricate 'motions' which 'shape' and 'set' the catamenia in stages as development advances".[24] On this reading, the movements that shape the embryo are "present in" Socrates' sperm (while in transit) only in the sense of being programmed into it. Let us grant for the sake of argument that Aristotle thinks the father's sperm literally constructs the parts of the offspring out of menstrual blood (something I have already rejected). In order to be consistent, the sperm will have to be pre-programmed with movements that not only impose on the offspring features that make it look like Socrates but also those that make it look like the various ancestors. It is not clear how Furth intends to map the actual/potential distinction onto this. The distinction cannot be between actual movements programmed into the sperm and potential movements programmed into the sperm. For any movement which is programmed into the sperm is a potential movement of the sperm almost by definition. It makes even less sense to draw the distinction between movements which are *actually* programmed into the sperm and those which are only *potentially* programmed into it.

On a weaker reading of δυνάμει, the ancestor movements will be present in the parent's seed potentially only in the sense that I am potentially (though not actually) in Manchester. Here the distinction is between movements that are actually present in the sperm and those which are potentially (but not actually) present. There are different ways that one could cash this out depending on what one takes the "movements" in Socrates' sperm to be.

Again suppose we take the κινήσεις in Socrates' sperm to be literal movements *of* his sperm as it fashions the parts of the offspring out of menstrual blood. The movements which are present "in actuality" are, straightforwardly, the actual movements of his sperm as it is actually attempting to fashion the parts of the offspring into parts like his own. On the other hand, Socrates' sperm has ancestor movements "in potentiality" only in the weaker sense that it has the potential to execute movements that will impose resemblances to his ancestors.[25] An analogy might help. The actual movements in (of) the sperm are analogous to the actual movements of the sculptor as he is currently attempting to form the bronze into a

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[24] Furth 1988, 118.

[25] This is Cooper's reading. See esp. 1988, 32 which makes use of the following analogy (discussed in chapter four above).

statue of Hermes. However, in addition to those movements he is actually making, the sculptor can potentially make other movements, say, those that would shape the matter into a statue of Zeus. It is in this latter sense that the ancestor movements are (on the current reading) in Socrates' sperm "in potentiality", namely as the potential of his sperm to execute movements that will form the matter into a likeness of his ancestors.

The problem with this reading of the actual/potential distinction is that it leaves the sperm's potential to generate resemblances to remote ancestors unexplained. It is obvious that the sperm has this potentiality, since offspring do resemble their remote ancestors. What needs to be explained is how the sperm is able to do this. In virtue of what does the sperm have the potential to execute movements which cause the offspring to look like those other individuals? Simply drawing a distinction between the movements the sperm is actually (currently) making and those that it has the potential to make does nothing to explain this phenomenon. To say that the ancestor movements, which are said to be present in Socrates' sperm "in potentiality", are just those movements it has the potential to make simply repeats the fact to be explained.

What we are attempting to do here is make sense of the idea that some of the sperm's movements are "δυνάμει" while others are "ἐνεργείᾳ". On the reading I am defending, the κινήσεις in question are separate entities (vehicles of inheritance) carried inside Socrates' sperm. For Aristotle, it is the possession of these κινήσεις that gives Socrates' sperm the capacity to generate formal resemblances. A weaker reading of δυνάμει thus entails that Socrates' sperm *actually* contains movements that transmit resemblances to his own phenotype and *potentially* (but not actually) contains movements that transmit resemblances to his ancestors. However, in this case it is hard to imagine Aristotle having any story to tell for how those ancestor movements come to be present in Socrates' sperm. As we have seen, the ancestor movements change from δυνάμει to ἐνεργείᾳ when the sperm is inside the female doing its thing: they become ἐνεργείᾳ when Socrates' own movements relapse. On the weaker reading Socrates' sperm thus comes to acquire a brand new set of movements that it only potentially had before just as the city of Manchester would acquire a brand new resident if I were to go there. But how could movements

corresponding to features of Socrates' relatives come to be present in his sperm when it is inside the female?

Whatever Aristotle means by saying among the movements present in the parents' seeds some are "in potentiality" while others are "in activity", it seems fairly certain that both sets of movements *really are* present in the robust sense. On my reading these movements are the vehicles through which formal resemblances are physically transmitted to the offspring in the act of reproduction. And it is in virtue of *actually* possessing those movements (some of which are nevertheless "in potentiality") that Socrates' sperm is able to generate just those resemblances in his offspring (in whatever way sperm generates resemblances).[26]

Although Cooper takes the κινήσεις in the sperm to be literal informing movements *of* the sperm (which I have rejected), he does offer a way to make sense of the idea that the ancestor κινήσεις really are present in Socrates' sperm in the robust sense whilst preserving the idea that they are nevertheless "in potentiality". In one place Cooper characterises the potential ancestor κινήσεις in Socrates' sperm as "underlying movements that become active when... the normally active ones give way".[27] This suggests that the ancestor movements are present in some sort of de-activated state. I think something like this is what Aristotle has in mind. On this reading there will be a κίνησις in Socrates' sperm corresponding to his father's nose which is present in a de-activated state (δυνάμει). It gets activated (becomes ἐνεργείᾳ) only in those cases where the κίνησις corresponding to Socrates' own nose undergoes relapse.

Whether or not this is the proper way to understand supposition one, any interpretation of Aristotle's theory must allow that there really are movements in Socrates' sperm corresponding to the features of his ancestors. For he not only needs

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[26] I shall speak of the spermatic movements generating features only in the loose sense. It makes no difference whether we speak in terms of the κινήσεις producing the features or whether we speak of them producing δυνάμεις in Menexenos' genetic nature. For a teleological account of the κινήσεις and the δυνάμεις will make reference to the same phenotypic characters (although properly speaking the latter are the productive sources of those characters).

[27] Cooper 1988, 23.

to explain why Socrates' sperm doesn't actually have the ability to generate features that make the offspring look like Coriscus (a non-familial relation), but also why it doesn't even *potentially* have that ability. The fact that Socrates' sperm really does possess ancestor movements (they refer to actual entities inside Socrates' sperm) grounds its potential to generate the features of those individuals who are, after all, just as removed from the current act of reproduction as any chance individual.

§6 The facts explained

It will be useful to summarise the account of inheritance in *GA* 4.3 by listing which of the eight phenomena we now have explanations for.

Phenomenon 1. The reason offspring tend to resemble their parents more than other members of the same species is that there are κινήσεις present in each parent's genetic material that transmit the features that make them unique individuals.

Phenomenon 2. The reason why some offspring resemble the father while others resemble the mother with respect to different parts (phenomenon 2b) is that there are κινήσεις present in each parent's genetic material corresponding to those parts, each of which is itself a discrete unit of inheritance that can dominate and be dominated independently of the others. Resemblance to the parent as a whole (phenomenon 2a) occurs when all of those κινήσεις dominate together.[28]

Phenomenon 4. The reason why offspring who do not resemble their parents nevertheless resemble their ancestors rather than any chance individual is that there are also κινήσεις present in each parent's genetic material corresponding to the features of those ancestors.

Phenomenon 3. The reason offspring tend to resemble their parents *more* than their ancestors is that the parental κινήσεις are present in activity while the ancestor κινήσεις are only in potentiality (they are present in a deactivated state).

Phenomenon 5. The reason males usually resemble their fathers and females their mothers is that the κινήσεις for sex and resemblance are linked in such a way that the properties carried by those κινήσεις tend to be inherited together (simultaneous displacement).

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[28] Both 2a and 2b will apply to resemblance to ancestors as well.

Phenomenon 6. The reason why females sometimes resemble their fathers and males their mothers is that the κινήσεις for sex and resemblance are themselves discrete units of inheritance that can dominate and be dominated independently of one another.

The two remaining phenomena—cases where the offspring fails to resemble the members of its family but nevertheless resembles a member of its own species (phenomenon 7) and cases where the offspring is so deformed that even this species resemblance is lost (phenomenon 8)—fall outside the immediate scope of the theory of inheritance. For they both have to do with the loss of familial resemblance owing to the malfunctioning of the mechanisms involved and so are teratological in nature. I shall attempt to give a brief sketch of this below. However, first let me summarise the interpretation developed over the last few chapters and draw out some of the more immediate implications.

§7 The transmission of biological form: some concluding remarks

In chapter four I defended the view that Aristotle's theory of inheritance postulates κινήσεις or "movements" coming from both parents which are functionally equivalent to one another: they are both vehicles of inheritance. It follows from this that Menexenos will receive *two* sets of movements for each part of his phenotype (including potential ancestor movements), one from Socrates and one from Xanthippe.[29] In chapter five I argued that in order to bridge the gap between Aristotle's transmission genetics and his account of natural generation we must assume that the reception of spermatic movements from the parent and the subsequent transformation of the embryo into its adult form are interposed by the formation of new potentials (like those from which the movements were drawn) which together make up the offspring's own genetic nature. This new generative principle will be the source of growth and development in the offspring itself *qua* itself.

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[29] This does not apply to all parts of the phenotype but only those in which the offspring can resemble one member of its family *more* than another (those for which the offspring is, as we would say, heterozygous). For example, it follows from Aristotle's reproductive hylomorphism that an offspring will receive only one movement for the parts of its sensory system (the movement "Animal", which comes from the father).

It follows that for each part of the offspring's phenotypic nature its genetic nature will contain *two* potentials (or two versions of the same generic potential), one from each parent's spermatic movement. Since these will be potentials for the formation of contrary properties (e.g. snub nose versus straight nose). only one of them can be expressed in the offspring's phenotype at any given time.[30] What I want to suggest here is that which version of a given potential gets activated at the appropriate stage of the embryo's development, and thus which version is expressed in its phenotype, is determined by whichever parent's movement corresponding to that potential was dominant over the other according to the principles of displacement and relapse.

This interpretation of the events in *GA* 4.3 can be supported by appealing once again the case of the woman from Elis. Recall the example. The woman from Elis, who is pale-skinned, has a pale-skinned daughter with a dark-skinned man from Ethiopia. Their daughter (Hypatia) then has a dark-skinned child with another pale-skinned man. According to Aristotle's theory of inheritance, we first explain why Hypatia has pale skin rather than dark skin by pointing to the dominance of the pale-skin movement coming from her mother over the dark-skin movement coming from her father. The explanation for why her own son has dark skin is two-fold. First, the paternal pale-skin movement coming from Hypatia's husband is dominated, which causes inheritance to switch over to Hypatia's own pale-skin movement according to the principle of displacement. This movement then relapses into her father's dark-skin movement, which was present in her seed in a state of potentiality. The implication of this is that (looking back to the first generation) the defeated dark-skin movement coming from Hypatia's father must have still produced a corresponding potential in

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[30] This actually depends on what level we are talking about. Aristotle defines "contrary" or "opposite" properties as properties that cannot belong to the same subject at the same time (*Metaphysics* Δ10). Snub nose and straight nose are contraries if we are talking about properties at the phenotypic level. For they cannot both be present in Menexenos' phenotypic nature at the same time. His nose must be one shape *or* the other. However, they are not contraries at the genetic level: both properties can belong to the same subject "καθὸ γεννητικόν". In other words, snub nose and straight nose can both be present in Menexenos at the same time as potentials of his genetic nature.

her genetic nature. For each movement in Hypatia's genetic material is said to be derived from corresponding potentials in herself (767b35-768a2). Thus Hypatia's genetic nature must contain *two* potentials for skin colour, one for pale skin (the δύναμις produced by the κίνησις coming from her mother) and one for dark skin (the δύναμις produced by the κίνησις coming from her father). However, since her phenotypic nature cannot display both versions of that trait simultaneously, only one of the potentials will have been activated during her development; the other must be preserved in her genetic nature in a de-activated state.

If this is right, then one spermatic movement dominating over another does not determine which potential corresponding to those movements makes it into the offspring's genetic nature: atavism requires that *both* spermatic movements produce potentials in its nature. What the dominance relation must determine is which of those two potentials gets activated at the appropriate stage of development and thus which version of the trait is expressed in the offspring's phenotypic nature.[31]

§8 The inheritance of the species-form

To close this chapter I want to say a word about the last two phenomena, both of which concern the loss of family resemblance. In some cases Aristotle says that the offspring who fails to resemble a member of its own family will still be recognisable as a member of its species (phenomenon 7). However, in the more extreme cases the offspring's observable form will not bear any species-likeness at all at which point it is a "monster" (phenomenon 8). I already touched on this latter phenomenon in the last chapter. Here I want to focus on the former, which concerns the inheritance of the species-form.

Although it is not explicit from the text, phenomena 7 and 8 appear to share a common cause: the "confusion" of spermatic κινήσεις. Aristotle says that sometimes the κινήσεις become so confused together that familial resemblance is lost

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[31] Above I argued that dominance itself is determined at the chemical level by whether or not the father's sperm manages to fully concoct or "master" the menstrual blood (cf. 767b15-20). If the sperm fully concocts the matter, then his movement dominates. If it fails to fully concoct it, then it is dominated in which case inheritance switches over the movement coming from the female according to the principle of displacement.

completely. In the less severe cases the offspring will still resemble a member of its own species (768b10-12). This is phenomenon 7: "Some offspring resemble none of their family, although they resemble some human being at least" (767b4-5; cf. 769b8-9). Aristotle does not mean here that Socrates and Xanthippe have a child that resembles Callias. For that would still be a case of family resemblance; Callias would be the father in this case.[32] Rather, Aristotle is describing a situation where two individuals have a child together who resembles a human being though not any *particular* human being. I suspect that what Aristotle has in mind are children with Down's syndrome. These offspring do not resemble any members of their own family yet all look like a human being (indeed the same human being). However, they do not look like any specific human being: they all share a sort of generic or common human form.

The explanation for this is set out in the passage just after Aristotle has presented the three general suppositions of his theory of inheritance:

> In the end the movements become so confused together that there is no resemblance to family or kindred at all, but what remains is what is common only, namely the human character. The reason is that this accompanies all the particulars (πᾶσιν ἀκολουθεῖ τοῦτο τοῖς καθ' ἕκαστον): for Human is universal, while Socrates (the father) and the mother (whoever she may be) are particulars. (768b10-15)

Further on we are told that in the more extreme cases even this species-likeness is lost so that the only thing remaining is what is common to all animals (769b11-16). In these extreme cases, although the offspring is still a sentient being, its observable form (τὴν ἰδεαν, 767b5) is badly deformed to the point where it is no longer recognisable as a member of its own species. At this point it has become a "monster" (τέρας).

Although I shall focus exclusively on phenomenon 7 here, which concerns the inheritance of the species-form, much of what I have to say will also apply to phenomenon 8 (assuming the two phenomena share a common cause).

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[32] It is possible, I suppose, that phenomenon 7 is just Aristotle mistaking cases of adultery for some strange phenomenon where two people have a child that happens to look like some other person. However, that is unlikely.

What needs to be explained here is why, when the movements coming from the parents and ancestors get "confused together", the offspring still develops recognisably human features. I think there are two possible answers to this question depending on how one reads the statement that the species movements "accompany" those of the individual.[33] For this is supposed to account for the fact that when familial resemblance is lost the offspring still resembles a member of its species.

On one interpretation the human features are produced by the movements of the individual themselves.[34] On this reading there is no independent set of movements in Socrates' sperm that transmit the species-form; rather, there are only those movements that transmit Socrates' distinctive form.[35] The idea behind this reading would be that Socrates' human features merely supervene on those that make him a unique individual so that the human form is reproduced simply as a consequence of reproducing Socrates' own particular version of that form (which is qualitatively different from other versions). For example, Menexenos comes to have a human nose insofar he comes to have Socrates' distinctive snub-nose. It would follow from this that only the distinctive forms of individuals would be directly reproduced in the act of reproduction.

The metaphysical underpinnings for such a view could be supplied by Lennox's account of the relation between kinds (γένη) and forms of kinds (εἴδη) (traditionally, "genus" and "species"). Again, the relevant idea is that species-level

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[33] By the movements "of the individual" I mean, for example, "the movement coming from Socrates" (768a28-9). The idea, then, is that the movements in Socrates' sperm corresponding to the species "accompany" those that correspond to the features that make Socrates a unique individual. The same applies for each individual represented in the act of reproduction, for example, the movements coming from Socrates' father are also accompanied by a set of species movements.

[34] Again I speak of the spermatic movements "producing" features only in the loose sense. As I have said, it makes no difference whether we speak of the movements in the parent's seed or the potentials produced by those movements (the δυνάμεις that make up the offspring's genetic nature). For a teleological account of both will make reference to the same phenotypic characters (though properly speaking the latter are the productive sources of those characters in the offspring).

[35] Something like this is held by Coles 1995, 76-81.

features such as "nose", "eyes", and "leg" do not pick out actual features of any individual but simply represent what Lennox calls "features with range", "*possible* ways in which human noses, eyes and legs may be realized".[36] Thus Socrates' snub nose, blue eyes, and short legs, and Xanthippe's straight nose, green eyes and long legs are two concrete realisations of the same generic human features.

This first reading of 768b10-15 faces two problems. First, when enumerating the contents of Socrates' sperm Aristotle explicitly identifies a second set of active movements corresponding to the species-form (768a13). Second, we are told that both the kind (τὸ γένος) and the particular (τὸ καθ' ἕκαστον) are at work in the act of reproduction (767b30-5).[37] So not only does Aristotle posit an independent set of movements corresponding to the kind Human, he assigns them an active role in generation, even if those corresponding to "what is peculiar and individual" exert the stronger influence (b29-30).

On the alternative reading of 768b10-15 (the reading I shall adopt) Aristotle thinks the offspring's human features are the product of a distinct set of movements corresponding to the species form. Here the movement in Socrates' sperm corresponding to "Human" is not reducible to the movement corresponding to "Socrates"; it is a separate movement that merely accompanies it.[38]

There are two ways to cash this second reading out. The first is to take the human movements as a redundant set that normally have no effect but function as a sort of back-up that produce default human features whenever the movements of the individual fail. However, what is more likely is that the movements of the individual (the parental and ancestral movements) are simply responsible for the details of the offspring's form, the colour of its eyes, the shape of its nose, and so forth (cf. 743b20-5). The accompanying species movements, on the other hand, would be responsible for the basic organisation of the body, the production of its species-specific tissues and organs, and any other features that are characteristic of that particular kind of

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[36] Lennox 2001b, 178

[37] The contrast with τὸ καθ' ἕκαστον suggests that τὸ γένος has taxonomical reference to the kind Human here.

[38] This reading is also held by Balme 1987b, 294-3.

animal.[39] On this reading, when the movements of the individual become "confused" the characteristics corresponding to those movements will be distorted and any resemblance lost. However, if the species movements remain unaffected, they will ensure that the offspring is still at least recognisable as a member of its kind.[40]

Although the species movements have a role to play in the generation of offspring that look like their parents (at least insofar as they resemble them in species), Aristotle suggests that the movements corresponding to what is distinctive and particular always exerts the stronger influence (ἀεὶ δ' ἰσχύει πρὸς τὴν γένεσιν μᾶλλον τὸ ἴδιον καὶ τὸ καθ' ἕκαστον). The reason, Aristotle says, is that this is the οὐσία (767b35). Some have concluded from this that the *Generation of Animals* advances a radically new theory of substance in which individual-forms (as opposed to species-forms) are primary.[41] Of course in both the *Metaphysics* and the *Categories* Aristotle is quite forthcoming in suggesting that particulars (καθ' ἕκαστα) like Socrates and Callias are ontologically prior to universals like Human and Animal. However, the reference to τὸ ἴδιον appears to suggest something more than this.

One way to respond to this is to argue that Aristotle is not making any claims about what the real entities are: he is not talking about the οὐσία which is the primary subject of *Metaphysics* Z. Rather, by saying what is distinctive (τὸ ἴδιον) about a particular individual is the οὐσία he is simply making a statement about the proper object of the science of inheritance.[42] When studying inheritance the geneticist will

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[39] This differs from Balme's view, which takes the movements of the individual to be primary throughout.

[40] If these κινήσεις also become "confused", then only the accompanying animal movements will do their job. In this case the species likeness is lost so that the only thing remaining is what is common to all animals (769b11-16). Although this offspring will still be a sentient being, its observable form will be badly deformed and will no longer resemble *the same kind* of animal as its generating parents (phenomenon 8).

[41] Individual-forms are discussed in chapter seven.

[42] That Aristotle thinks we can have scientific knowledge of genetic variation within a species is clear from the fact that it can be described in terms of καθόλου ὑποθέσεις. See note 1 above.

take as her object the form that displays variation (the individual-form) not the form that includes only what is common to all members of the same kind (the species-form). Simply put, *from the perspective of genetics* it is the unique individual that is the real thing (the οὐσία). I shall have more to say about this in my final chapter.

Chapter Seven

Particular Forms and Teleological Explanation

To end this study I want to briefly consider two issues related to the transmission of biological forms. The first is the on-going debate concerning whether or not Aristotle believed in so-called particular forms. The second has to do with the nature of teleological explanation. The relevance of these two issues will become clear as we proceed.

§1 Did Aristotle believe in particular forms?

I speak of "particular" forms rather loosely here because the literature is quite muddled on this. For different people tend to mean different things by "particular" forms.[1] However, first let me say a word about the opponents of particular forms.[2] They argue that there is only one form for each species and that each particular member of the species has qualitatively *and* numerically the same form. Some in this camp argue that the species-form is a universal insofar as it belongs to many individuals at the same time.[3] Others deny this on the grounds that a species-form is predicated of matter which, prior to that form's being predicated of it, is not a countable thing (it is not an individual 'this'). And since it is predicated of *no* individual, it follows that it is not predicated of *many* individuals.[4]

According to Gill, a "particular" form is a form which is proper to a single composite alone.[5] Whiting characterises this position by the commitment to the view

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[1] Unless otherwise stated, the current discussion will take place at the level of phenotypic natures (taken in the broad sense). Although there may be interesting new variations on the issue that arise when we distinguish between phenotypic natures and genetic natures, I shall not explore them here.

[2] The following comes from Whiting 1990, 35-34.

[3] Aristotle definition of a universal is that whose nature it is to be predicated of a number of different individuals. A particular (καθ' ἕκαστον) is that whose nature is not to be predicated of a number of different individuals, i.e. a non-repeatable instance (*De interp.* 7).

[4] Code 1976; Woods 1967.

[5] Gill 1989. 31-33. (Gill does not endorse particular forms.)

that there are a plurality of numerically distinct forms for each species.[6] Put simply, the idea is that Socrates and Callias each have their own personal forms which are numerically distinct from one another. On this reading, Socrates' form and Callias' form are two *particular instances* of a form. This is the view held by Frede and Patzig.[7]

However, sometimes what commentators mean when they ask whether Aristotle believes in "particular" forms is whether he thinks (biological) forms include features below the level of species. For example, does Socrates' form include only those features which he shares with other human beings or does it also include features that make him a unique individual, such as his particular nose shape and eye colour? David Balme argues that Aristotle believes in particular forms in this sense.[8]

§2 Individual and particular forms

These two versions of particular forms are very often confused with one another; however, they are distinct positions.[9] For convenience I shall refer to Balme's version as "individual-forms" and reserve "particular" forms for the Frede-Patzig thesis. Individual-forms are forms which include properties below the level of species, while particular forms are numerically distinct, non-repeatable instances of a form. The reason these two theses must be kept distinct is that those who accept particular forms can deny individual-forms. For example, one could argue that Socrates and Callias have numerically distinct forms which are nevertheless qualitatively identical. On this reading Socrates has his own human form while Callias has his own human form (they are two non-repeatable instances of a generic human form).[10]

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[6] Whiting 1990, 34. (Whiting endorses particular forms.)

[7] Frede and Patzig 1988; Frede 1985. For other references see Whiting 1990.

[8] Balme 1987b. For other references see Whiting 1990.

[9] For a good discussion of this see Sharples 1985, 119.

[10] This is how Frede-Patzig takes it. Cf. Cooper 1988, 36: "...some have thought from reading just the *Metaphysics* that an Aristotelian form is a non-repeatable instance of some general specific type, differing from other instances not internally (by reference to the λόγος of its being) but only by the accidental historical facts about the individual object whose form it is by which we mark that individual off from others of

The difference between particular forms and individual-forms ultimately comes down to whether we are talking about the form itself or its content. Thus we have two separate questions:

(1) Are forms universals or particulars?

(2) Are the contents of forms species- or individual-specific?

I shall assume without argument that each organism's form is a particular.[11] The universal species-form is simply an abstraction from these. Thus particular forms are ontologically prior to species-forms, although species-forms are prior both in account and in knowledge. As I see it (2) is by far the more interesting question. The only way to cash this out, I think, is in terms of reproduction. If Socrates' form is whatever it is about him that gets itself reproduced, then (ontologically speaking) his form will include all of those features that belong to him insofar as he is capable of reproduction (καθὸ γεννητικόν). And according to the *GA* at least, this includes those features that make him a unique individual.

A commitment to the reality of individual-forms raises an important epistemological issue. In the *Metaphysics* Aristotle argues that only what is universal counts as a proper object of definition and scientific knowledge.

Now I have argued that Socrates' individual-form includes features which are not common to all human beings. However, it is still knowable insofar as it is the

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the same species." Gill (1989, 33) argues that one can accept individual-forms without having to accept particular forms. For example, one could argue there is a single form that is passed from Sophronicus to Socrates to Menexenos through reproduction. This form would be universal insofar as it is predicated of a number of things *and* individual-specific insofar as it includes features not found in every human being (e.g. it includes a distinctive family nose). However, this kind of family-form would be universal only in the trivial sense of belonging to more than one individual. It is not universal in the sense that each member of the same species has qualitatively *and* numerically the same form. Moreover, a form that only belongs in common to every member of a single family could not do the work required of universals in Aristotle's biology.

[11] Aristotle's position in *Metaphysics* Λ3 at least seems to favour particular forms. There we are told that the principles of particulars are themselves particulars *not* universals (1071a17-24).

object of a universal account. By universal account I mean one that does not pick out Socrates' form uniquely (it is not an account of his form *per se*) but applies universally to all individuals of the same kind. Such an account would abstract away from the peculiarity of Socrates' form – it would exclude those features that make him a unique individual – so that the content of that account is universal. On this reading, Socrates and Callias are one in form in virtue of sharing an account in common, not in virtue of sharing the form specified by that account (which is an abstraction from the forms of individuals).[12]

However, we can still give a more detailed account of Socrates' form that would reveal features peculiar to him and which mark him off as a unique individual. Something like this is suggested by Cooper:

> The *GA* makes it clear that… each form has in principle a full λόγος of its being as the form that it is that includes the specification of all those distinctive characteristics of structure and organization for which in the individual whose form it is it is directly responsible. …Thus Aristotelian forms are individual in that each form contains within itself the basis for its differentiation from (as well as, of course, its affiliation with) other forms of the same specific type.[13]

So a definitional account of Socrates' form would include only information about him that is also contained in a definitional account of Callias' form. This is the account that reveals his essence. However, a more precise account of his form is available which would reveal further facts about Socrates that distinguish him from Callias as a unique individual. This is not incompatible with the *Metaphysics*, since this will not be a *definitional* account of Socrates' substantial being.

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[12] A similar interpretation of "being one in form" is defended by Lennox 2001b, 174.

[13] Cooper 1988, 37. I have changed "Aristotelian forms are *particular*" to "Aristotelian forms are *individual*" to reflect the distinction made above. What I am calling "particular" forms (Frede-Patzig) do not require a form to contain within itself the basis for its differentiation from other forms of the same specific type. "Particular" forms are only required to be *numerically* distinct from one another.

§3 Individual-forms and teleological explanations

One might object here that there is a tension between Aristotle's theory of inheritance, on the one hand, and his view that form includes only what is common to all members of the species, on the other, which I have glossed over.[14] For example, at the outset of *GA* 5 we are told that a definitional account of an animal's substantial being (τὸν λόγον τὸν τῆς οὐσίας) excludes such individual differences as eye colour in humans (778a29-35). These features do not come to be for the sake of anything but only from necessity, and their causes must be traced back to "the matter and the moving principle" (a35-b1).

I am not disputing that the species-form is the proper object of definition and that this includes only what is common to all members of the species. On my reading the species-form is an abstraction from the particular forms of individual members of that species and is prior both in account and in knowledge. Rather, I am disputing the standard reading of Aristotle according to which everything below the level of species is merely a by-product of the species-form being realised in different quantities of matter. This faulty view is even endorsed by Balme. Balme held that individual differences such as eye colour are material accidents "that arise necessarily from the matter".[15] Such features (according to Balme) are not part of the form taken by itself but "are due to the matter in the composite form-in-matter". On this reading we get individual differences when the species-form is realised in different parcels of matter.[16]

The tension that commentators have generally found between Aristotle's views in the biology and his views in the *Metaphysics* is due in large part to a false dichotomy. Traditionally commentators have divided the properties of organisms into two exhaustive categories: those which are included in its essence, and those which are accidental and due to the matter (so-called material accidents). Now according to *GA* 5.1, biological essences include two types of properties (παθήματα): those

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[14] See Sharples 1985.

[15] Balme 1987b, 294.

[16] Cooper makes the generalisation that all of those features of the offspring discussed in *GA* 5 are "determined by accidental features of the matter that the mother happens to provide for its formation on the occasion of the conception" (1988, 36).

which are the common products of animal natures (τῆς φύσεως ἔργα κοινῆ) and those which are distinctive of each particular kind of animal (ἴδια τοῦ γένους ἑκάστου).[17] Hearts (and their analogues) are among the common products of animal genetic natures while hands are among the distinctive products of human genetic natures. Aristotle tells us that any property which is not common in either of these two ways is excluded from a definitional account of an animal's substantial being.[18] If we accept the standard dichotomy, then all common properties are essential and due to the form while all individual differences are accidental and due to the matter.

Now at 778a35-b1 Aristotle says that the cause of individual differences must be referred back to the matter and the moving principle alone (τὴν ὕλην καὶ τὴν κινήσασαν ἀρχήν). However, I disagree with Balme in taking this to mean that all the properties in question are material accidents (that they are due to "the matter and the movements of matter" and "arise necessarily from the matter").[19] *GA* 5.1 is about explanation. Aristotle's point is that the individual differences in question are only subject to explanations in terms of material and efficient causes while common traits that come to be for the sake of something are subject to explanations in terms of all four causes (including "the matter and the moving principle"). I want to suggest that for some (though not all) individual differences the moving principle is the creature's genetic nature. This introduces a further classification outside the standard dichotomy. For example, *GA* 5.1 excludes eye colour from a definitional account of a human's substantial being on the grounds that it is not something that is common to all

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[17] 778a29-32.

[18] The account in question is relative to that particular kind of animal. Thus, we are talking about the definition of a thing *qua* horse or *qua* human (not *qua* animal).

[19] It is true that Aristotle says these individual differences come to be "from necessity". However, in the biological works every part of the organism is generated "from necessity"; the difference is that its functional structures are generated *both* from necessity *and* for the sake of something (see 743a36-b5, translated above). These types of explanations are prevalent throughout the *PA*. For a good example in the context of development see Aristotle's account of the formation of extraembryonic membranes around the embryo at 739b28-33.

humans.[20] However, it does not follow that eye colour is therefore a material accident. For Aristotle goes on to tell us that the colour of an individual's eyes is due to the activity of its genetic nature (780b6-12, translated below).

So there are some intraspecific differences which are directly programmed into a creature's genetic nature and thus are not material accidents. The standard dichotomy, which divides the properties of organisms into those which are included in the essence and those which are accidental and due to its matter, cannot accommodate this.[21]

One of the important lessons from *GA* 4.3 is that a fair amount of phenotypic variation within a species is part of its heritable form. Moreover, this variation can even be described as "essential". Of course nothing is "essential" and "accidental" (or "inessential") to an organism *simpliciter* but always relative to this or that description. While having a particular eye colour and being someone's next-door neighbour are both accidental to Socrates insofar as he is a human being, the former is essential to him insofar as he is capable of generation: it belongs to him "καθὸ γεννητικόν". What this means is that Socrates' eye colour is included in the form that is directly transmitted to his offspring in the act of reproduction.

Where Balme went wrong in arguing for this was classifying inherited likenesses, such as eye colour in human beings, as material accidents.[22] Thus what many commentators were objecting to was not the idea that Socrates' form might include such properties as his eye colour and nose shape *per se* but that it should

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[20] Note however that eye colour *is* included in a definitional account of, say, a cow. For having black eyes is distinctive (ἴδιον) of that kind of animal (778a33-4).

[21] Sharples (1985) makes a distinction between "form" and "formal". The suggestion is that individual differences such as eye colour in humans are not part of the "form" but are nevertheless "formal" properties (rather than material accidents). But Aristotle does not make that distinction. Instead we find Aristotle using the concept of "form" (εἶδος) in different ways. When "form" is taken in the narrow sense of intellectual (or even sensory) soul, then Socrates' eye colour is not included in his form. But when "form" is taken in a broader sense (as it generally is in the biology), then it is considered part of his form.

[22] Coles makes the same mistake (see 1995, 76-81).

include material accidents.[23] I agree that form (in any sense of εἶδος) cannot include material accidents. I simply deny that inherited likenesses such as eye colour and nose shape *are* material accidents insofar as they are directly programmed into an individual's genetic nature.

Although biological form in the strict and narrow sense is simply the set of functions characteristic of the organism in question (its "soul"), I have emphasised that in the biology Aristotle typically employs a much broader sense of form as "the differentiae in the matter" (*PA* 643a24). This concept of biological form includes, in addition to functions like swimming and flight, functional structures such as webbed-feet and wings. The current point is that this form will not only include those features of an organism that it shares with other individuals of the same kind but also certain heritable differences that fall below the level of species. This is consistent with Aristotle's position in *GA* 5.1. For what he tells us there is that these heritable differences will not be included in a *definitional* account of the substantial being. The definable part of an animal is the part of its phenotype that includes those features which are the common products of all animal natures as well as those which are distinctive of that particular kind of animal (i.e. the form reached by abstracting away from the properties which are unique to particular individuals).

However, Aristotle's point in *GA* 5.1 is ultimately about explanation not definition. Definitions are only one of the four causes in a proper explanatory account of biological phenomena. What needs to be explained is why a given trait comes to be present in the offspring's phenotypic nature. Those common properties which come to be for the sake of something are subject to explanations in terms of all four causes. For example, a complete explanation for why an animal develops eyes will make reference to (1) the account of its being (the definition), which tells us what the developing thing is, (2) the function of eyes in the adult organism, (3) the matter out of which those parts are formed, and (3) the activation of the corresponding potential of its genetic nature (the moving principle). However, a complete explanation is not always available. In some cases we cannot explain why a particular individual has a certain trait by pointing to the kind of thing it is (the account of its being) nor by pointing to any functional value (it may not exist for the sake of anything). In these

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[23] This is not universally true, however, since some commentators objected to the idea that form (on any reading of εἶδος) should include features below the level of species.

cases the explanation will only make reference to material and efficient causes ("the matter and the moving principle"). For example, we explain why Socrates' eyes are blue in part by the volume of fluid material in the eye and in part by the activity of his genetic nature:

> Therefore, those eyes which contain a large amount of fluid are dark, because large volumes of fluid are not transparent; those which contain a small amount are blue... Eyes intermediate between these two extremes differ only by the more and the less. (*GA* 5.1, 779b28-34, translated after Peck)
>
> Greyness [in hair colour] is a certain kind of weakness of the fluid in the brain, namely a lack of concoction. So is blueness of the eyes, since unduly thin fluid and unduly thick fluid are the equivalent of a small amount and large amount of fluid, respectively. For this reason, when the nature <of the animal> is not able to make both eyes correspond exactly by concocting the fluid in both eyes or not concocting them in both but rather concocts it in one and not in the other, the result is that odd-coloured eyes are produced. (780b6-12, translated after Peck)

The colour of an animal's eyes is determined by the amount of fluid in them, which is determined by the amount of concoction that fluid undergoes. And the level of concoction that the fluid in each eye undergoes is *in turn* controlled by its genetic nature.

It is important to recognise why explanations in terms of material causes alone are not sufficient in this case. When attempting to understand why Socrates' eyes are blue it is not enough to know the amount of fluid contained in them. For the amount of fluid in each eye is itself a function of the level of concoction the fluid undergoes during the process of the eyes' formation. Thus we could further inquire as to why the fluid in Socrates' eyes underwent *precisely that* amount of concoction (and indeed the same amount in each) rather than some other amount. Here we would make reference to the primary moving cause, namely, the genetic nature. And so a complete explanation for why Socrates' eyes are blue (rather than, say, green) would not only refer to certain properties of what the eyes are made out of (such as the quantity of fluid in them) but also to the activation of a corresponding potential in his genetic

nature whose function is to regulate the level of concoction in each eye. It will be this potential that ultimately explains why Socrates' eyes are blue.

Finally some differences between individual members of a population can only be explained by reference to the matter. These features are not directly programmed into the individual's genetic nature. Some may be due to the material nature of the organism alone, which makes it vulnerable to certain kinds of affections. For example, grey hair is said to result from insufficient concoction of the hair owing to a weakening source of natural heat (*GA* 5.4). Other peculiar features may simply be the consequence of an accident that occurred during the process of its development. However, Aristotle also allows for various material features which are not accidental in this way but are simply due to environmental causes (785b12-15) or the quality of the food the animal eats (786a34-b5).

What we are talking about here are ultimately 'differentiae'. And whether or not the differences in question are included in the definition of the thing (and thus whether or not their development is subject to explanation in terms of formal causes) ultimately comes down to a question about natural kinds. For example, beaks are a common product of bird natures, while long, skinny beaks are distinctive of curlews. Curlews constitute a natural kind (they are a species of bird). As such, we can explain why this particular bird develops a long, skinny beak by referring that trait to a universal account of its substantial being (though insofar as it is a curlew *not* insofar as it is a bird). On the other hand, while the genetic nature of every normal human being includes a potential for the formation of eyes of a certain shape and structure, they do not all include a potential for blue eye colouring. As such, we cannot explain why one human develops blue eyes (rather than, say, green eyes) by referring the colour to an account of its substantial being either *qua* human or *qua* animal.

But suppose blue-eyed humans were a distinct species of human. In that case having blue eyes would be included in a definitional account of my form. And we could explain why I developed blue eyes rather than green eyes in part by referring to the kind of human being I am (a blue-eyed human) just as we explain why one bird develops a certain beak shape in part by referring to the kind of bird it is.

However Aristotle denies that blue-eyed humans actually constitute a new species of human being. For genuine speciation is dependent on functional

difference.[24] If the division of humans into blue-eyed humans and green-eyed humans were due to functional-fine tuning to a specific environment (as differences in beak shape are in birds), then these two sub-groups of human would constitute natural kinds.[25] As it is, differences in eye colour are not something that exist in humans for the sake of anything. In this case the fact that I have blue eyes rather than green eyes is explained strictly in terms of efficient (and material) causality and ultimately by the facts surrounding inheritance. In other words, the only reason I have blue eyes is that my genetic nature contains a specific potential for that eye colour. And this is in turn explained by the dominance (κρατεῖν) of the spermatic movement coming from my father over the corresponding movement coming from my mother.

Where there is a functional value on a particular trait, the presence of the corresponding potential in the creature's genetic nature is subject to teleological explanation in terms of the good. This is what ultimately grounds teleological explanations of the parts of organisms. For example, we can explain why a duck's genetic nature contains a potential for the formation of webbed-feet by pointing to the fact that it produces an effect on a duck's phenotype which increases its ability to survive and flourish in its particular environment. The same is not true for a person's eye colour. The presence of a potential for blue eye colour in the genetic natures of some human beings cannot be explained teleologically by reference to any functional value of that trait (since it has no functional value). In other words, individual human genetic natures do not contain potentials for blue eye colour or green eye colour *because* those potentials generate something that contributes positively to the individual's ability to survive and flourish. The reason why the genetic nature of any particular human being contains a potential for one eye colour as opposed to another is explained solely by the general suppositions of Aristotle's theory of inheritance.[26]

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[24] I have been greatly influenced here by Lennox's exceptional study of this issue in Lennox 2001b, 160-81.

[25] Sex differentiation provides an especially difficult speciation problem for precisely this reason. For Aristotle's explanation of why male *F*s and female *F*s do not constitute two species of *F* see *Metaphysics* I9.

[26] The presence of a potential for webbed-feet, on the other hand, need not be explained by inheritance. Since all ducks have webbed-feet, we do not need to have recourse to the general suppositions of Aristotle's theory of inheritance to explain

§4 The nature of final causality

The idea that the species-specific potentials of an organism's genetic nature (unlike the individual-specific potentials) are subject to teleological explanations can be contrasted with Allan Gotthelf's account of final causation.[27]

According to Gotthelf, some part (trait, characteristic, etc.) *X* is present in an organism for the sake of something only if the changes that produced *X* occurred for the sake of that end, that is, only if *X* is the natural goal of the process leading up to it. And a process *P* is for the sake of its end *X* only if *P* is the actualisation of a potential which is irreducibly *for* that outcome.[28] Since the actualisation of a potential for form provides the teleological grounds for the presence of the parts of organisms, Gotthelf argues that the presence of that potential itself must be explanatorily basic. Otherwise "whatever explains the presence of such a potential will be more basic, and will be in fact what grounds teleological explanation".[29] This is where my account improves on Gotthelf's analysis.[30] I am suggesting that we *can* explain why a human being's

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why any particular duck comes to have webbed-feet rather than feet of some other kind.

[27] The following is taken primarily from Gotthelf 1987. See also Gotthelf 1997 (esp. 74-5) and 1989b.

[28] I have condensed a lot of argument here. According to Gotthelf the actualisation of a potential for form is irreducible (or irreducibly *for* its outcome) just in case it is not merely the sum of actualisations of material or element potentials the account of which makes no (necessary) reference to the form of the thing produced. As I go on to say, Gotthelf thinks that Aristotelian teleological explanations are grounded in the activity of these special kinds of efficient cause and, in particular, in their irreducibilty to element-potentials.

[29] Gotthelf 1987, 232.

[30] Charles (1991, 106) criticises the reduction of all (indeed any) forms of teleological explanation to the operation of a special kind of efficient cause. Sorabji (1980, 171ff.) also charges that Gotthelf's thesis gets things the wrong way round and that. especially in the biological works, Aristotle insists that 'being for the sake of' is prior to 'coming to be for the sake of', not vice versa (cf. Charles 1991, 106 *n.* 4). (For Gotthelf's response to Sorabji see the postscript to Gotthelf 1987.) My account goes some way towards reconciling Gotthelf's interpretation with these two criticisms.

genetic nature contains a potential for eyes in teleological terms by referring to the contribution that having eyes makes to a human being's ability to survive and flourish in its particular environment. On this reading, it will be the contribution to the organism's overall good (understood as biological flourishing), not the activity of a special kind of efficient cause, that ultimately grounds teleological explanations for parts.[31]

A caveat is necessary here. According to Gotthelf, the presence of a potential for form is epistemologically basic in the sense that it cannot be further explained *teleologically* by reference to some other end.[32] For Gotthelf would agree that we can explain the presence of that potential by reference to the corresponding spermatic movement coming from the parent. However, this would not be a teleological explanation. Rather, the inheritance of a spermatic movement will count as the efficient cause of the corresponding potential. That is not to say a teleological explanation for the presence of that potential would be incompatible with an explanation in terms of spermatic movements. For Aristotle insists that, wherever possible, explanations should include *four* causes.

My interpretation is intended to build on Gotthelf's reading while avoiding one of its critical weaknesses. By taking the actualisation of a potential for form as basic (teleologically speaking), Gotthelf's account cannot differentiate between those heritable properties of an organism's form which are present for the sake of something and those which are not. Gotthelf holds that some part (trait, characteristic, etc.) *X* is present in an organism for the sake of doing φ if and only if (a) *X* does φ and (b) the presence of *X* can be traced to an irreducible potential for *X* in the organism's genetic nature.[33] As we have seen, Aristotle thinks the colour of Socrates' eyes is not a material accident but (to use Gotthelf's terminology) due to the actualisation of a

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[31] This is consistent with the view I argued for earlier concerning the priority of the phenotypic nature over the genetic nature (the genetic nature is present *for the sake of* the phenotypic nature rather than vice versa).

[32] Gotthelf 1987, 232-3.

[33] Gotthelf 1987. 238. I have (superficially) adjusted Gotthelf's analysis here to make it more compatible with my own analysis. Gotthelf's condition (b) actually says that *X* must come to be for the sake of doing φ, which he cashes out in terms of the actualisation of an irreducible potential for *X*.

corresponding potential in his genetic nature which is irreducibly *for* that specific colour.[34] According to Gotthelf's account, this means that Socrates' eyes are blue for the sake of something (indeed, for the sake of whatever effects it happens to produce), which is something Aristotle denies.

Gotthelf might object to this by denying that Socrates' genetic nature contains a potential for eye colour. However, the current point applies generally to all those individual differences for which there are "movements" in Socrates' sperm, *whatever* those particular traits turn out to be. For each of those spermatic movements will have been derived from a corresponding potential in Socrates' genetic nature (which I take to be the same potentials that Gotthelf has in mind). This alone should be enough to guarantee my argument. For the individual phenotypic differences that the mechanism of inheritance in *GA* 4.3 is primarily meant to explain will be among some of those very same properties that *GA* 5.1 tells us do not come to be for the sake of anything. So there will be properties of an organism which are the direct result of the activation of a corresponding potential (thus satisfying Gotthelf's conditions (a) and (b)) but which are not present in that organism for the sake of anything. I have simply chosen to focus on eye colour since there is explicit textual evidence that this feature is among those directly produced by the activity of an animal's genetic nature.

I agree with Gotthelf that we can identify which parts of an organism are natural goals of its development and which are not by pointing to corresponding potentials in its genetic nature.[35] And I also agree that being the goal of the process leading up to it is a necessary condition for a part's being present in the organism for

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[34] It should be stressed that this is not the fulfilment of the matter's potential to be an eye of a certain colour (compare the potential of wood to be a ship). Even less is it meant to refer to a process where some kind of latent or not-yet-actualised form "flowers into actuality". Rather, we are talking about the activation of a δύναμις which initiates a series of changes in the matter that terminates in eyes of a certain colour. This δύναμις is an active potential that is preserved in the adult as a component of its genetic nature.

[35] Moreover, I agree that identifying which parts are the objects of irreducible potentials for form allows us to identify which parts are developmental goals without reference to the good (see Gotthelf 1997).

the sake of something.[36] However, this cannot be a sufficient condition. For we have seen that some properties of an organism can be traced to a corresponding potential in its genetic nature but which are not present in the phenotype for the sake of anything (they do not serve any biological function). My interpretation avoids this problem. On my reading, some part *X* is present in an organism for the sake of doing φ if and only if (1) the presence of *X* can be traced to the activity of a corresponding potential in its genetic nature,[37] (2) doing φ makes a positive contribution to the organism's ability to survive and flourish in its particular environment (its good), and (3) that contribution *explains* the presence of the corresponding potential in the organism's genetic nature.[38] According to this analysis, even if having blue eyes produced some effect φ, that trait will not be present for the sake of doing φ, since it fails conditions (2) and (3).[39]

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[36] For a convincing argument in favour of this see Gotthelf 1987, 238-9 (esp. the example of Empedocles).

[37] Following Gotthelf I take (1) (Gotthelf's (b)) to be equivalent to saying *X* is the goal of the process leading up to it (that the coming-to-be of *X* occurred for the sake of that end). I have left out of my analysis Gotthelf's condition (a) that *X* actually do φ, which seems to be rather superfluous. For if *X* did not do φ, we wouldn't be asking whether *X* was present in the organism for the sake of doing φ.

[38] This third condition is emphasised by Lennox 1992 (esp. 327). Lennox sees Aristotle as offering an account of teleological explanations for the parts of organisms "that sound remarkably like modern 'adaptional explanations'".

[39] Although Aristotle clearly wants to say that the contribution that some part makes to an organism's ability to survive and flourish explains why the genetic nature of that particular kind of animal contains a δύναμις for that part, he does not have a story to tell for how this might be cashed out. In what way does that contribution actually explain the presence of that δύναμις? This is a very complicated issue which I shall pass over here. In one sense no story will be forthcoming, since Aristotle thinks there have always been animal's with those kinds of parts and so the question of how a δύναμις for those parts came to be present in the species simply will not arise for him. However, condition (3) could easily be cashed out in terms of natural selection. If a part makes a positive contribution to an organism's ability to survive and flourish,

This reading is compatible with Gotthelf's account insofar as one can explain why human beings have eyes (in part) by referring the process of their development to the activation of a corresponding potential in its genetic nature. Where my account of teleological explanation differs is in the role it assigns to the good (biological flourishing). While condition (1) ensures that the part in question is the goal of its development, condition (3) ensures that the fact of the goal's goodness will be causally relevant to the explanation.[40] It is this added dimension that ultimately allows Aristotle to say meaningfully that *the reason* an organism has eyes is that eyes are useful for seeing and that they exist in part *because* they are good for the organism.

This brings us back to the paradox of teleology with which we began. The problem, recall, was how to understand Aristotle's claim that an organism's "nature" is both the source *and* the end of its development. This seemed to imply a sort of finalism in which the form at the end of development acts as an efficient cause guiding the process so that it terminates in that end. I have argued that the key to resolving this seemingly paradoxical statement is to recognise the distinction Aristotle makes between an organism's phenotypic nature (nature ὡς τὸ τέλος) and its genetic nature (nature ὡς ἡ κινοῦσα). The phenotypic nature is the form towards which the process of development is directed while the genetic nature is the efficient cause that directs the process towards that goal. There is no finalism here, since these two natures pick out two numerically distinct "parts" of the organism. However, we can now see that there is in fact a very robust sense in which the goal of development (nature ὡς τὸ τέλος) is responsible for the process leading up to it, namely, insofar as it explains the presence of the source of that process (nature ὡς ἡ κινοῦσα).[41] In

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then it will increase the likelihood of its corresponding δύναμις being passed on in the act of reproduction.

[40] See Lennox 1992, 326-7.

[41] More specifically, it is that goal's goodness (e.g. the contribution that having webbed-feet makes to a duck's ability to survive and flourish) that is causally relevant to the explanation. The idea of the goal's goodness being causally relevant and the idea of its being responsible for the process leading up to it are two essential features of Aristotle's natural teleology emphasised by Lennox (1992, 326-7 and 2001b, 230, respectively).

this way the organism's phenotypic nature can be said to be the cause of its own existence.

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Aristotle's part to save that theory from flying in the face of the observed facts.[11] In the end, however, that theory "inevitably crashes".[12]

Like Furth, Morsink accepts that *GA* 4.3 introduces maternal movements which are capable of imposing on the offspring resemblances to the mother's side of the family.[13] However, he denies that this "overthrows" the matter-form hypothesis of the earlier books. Rather, Morsink argues that the introduction of maternal movements is "an important qualification" of that earlier theory, an "admission" that the mother does indeed "put her stamp on the offspring" in many cases.[14] However, like any theory, he claims that Aristotle's matter-form theory is only meant to apply to the normal cases of development where everything goes according to plan. According to Morsink this is when the father's formative movements successfully "master" the matter supplied by the female. When this happens the offspring will resemble its father in every respect. In this *ideal* scenario, Morsink argues, the father alone supplies the offspring's form (a perfect reproduction of his own) while the mother supplies only matter. However, sometimes the paternal movements fail. In these deviant cases a second set of movements coming from the mother will take over and impose on the offspring resemblances to her side of the family. So maternal movements are only brought in later to explain what happens when the process *deviates* from the ideal scenario.[15]

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[11] Furth 1988, 141 (cf. Morsink 1982, 171).

[12] Furth 1988, 132 *n.* 22; cf. 133. Furth also refers to *GA* 4.3 as a "rout", a "retreat", and an "embarrassing *denouement*".

[13] Morsink 1982, 138.

[14] Morsink 1982, 138. A similar response might be to take Aristotle's "admission" that the mother does indeed "put her stamp on the offspring" as a concession to the *endoxa*. On this reading, it is the *endoxa* that is inconsistent with Aristotle's official theory (represented by premises (1) and (2)). However, Aristotle does not treat maternal inheritance as a commonly held opinion that requires saving but as an empirical regularity that any adequate scientific account of inheritance must explain. (This is true for all eight phenomena that *GA* 4.3 examines.) So we cannot simply explain away the inconsistency as an artefact of Aristotle's methodology.

[15] Morsink 1982, 171.

Morsink's strategy is an interesting approach to the problem. The idea is that although Aristotle's theory should be able to account for abnormal developments, the theory itself is only intended to apply to the normal cases when everything works the way it is supposed to. The crucial step in Morsink's argument is the claim that Aristotle views offspring that look like their mothers as deviations from the ideal paternal form. In this way Morsink attempts to avoid the inconsistency by bringing the phenomenon of maternal inheritance under the scope of teratology (the study of abnormal developments).

This again reflects the common interpretation that Aristotle's biology was chauvinistic. Recall the two parts of that interpretation. First it is claimed that Aristotle thinks reproduction is aimed at generating male offspring and that female births result when nature fails to achieve that goal. Second, it is claimed that Aristotle thinks resemblance to the father is the ideal pattern of inheritance and that maternal resemblance is just a distortion of this more perfect form caused by interfering forces deflecting reproduction from its natural course. I dealt with the first claim in the previous chapter. Here I want to address the second claim. If Aristotle did view resemblance to the mother as a kind of monstrosity (something which is critical to Morsink's strategy), then we should expect the account of maternal inheritance in *GA* 4.3 to exhibit the structure of a teratological explanation. The fact that it does *not* exhibit that structure (or so I shall argue) means that Aristotle did not treat maternal inheritance as a distortion of the paternal form.

A teratological explanation is characterised by two important features. First, it does not introduce any new mechanisms into the theory whose proper functioning produce the monstrous form; rather, the abnormal result is produced by the same mechanisms which are responsible for producing the normal one. The abnormal result is simply produced by the malfunctioning of those mechanisms (mechanisms that would have produced the intended result had they been functioning properly). Second, although the normal and abnormal outcomes are both *produced by* the same mechanisms, the latter is *explained by* the external factors that caused the malfunctioning in the first place rather than directly by those mechanisms themselves. For Aristotle, these external factors primarily arise from the embryo's material nature (770a4-7, 778a4-9).

According to Morsink, when the mechanism of inheritance is functioning properly (i.e. when the paternal movements successfully master the matter), a replica

of the sire is produced. Now if Aristotle really did consider maternal resemblance to be a deviation from this ideal scenario, then we should expect to find that resemblance to the mother results when this same causal mechanism malfunctions (i.e. when the paternal movements fail to master the matter). Moreover, in this case the external conditions which cause that malfunction should occupy the central explanatory role in the account. For it would be these external conditions, and not the operation of the mechanism *per se*, that would explain why the offspring looks like its mother instead of its father (insofar as maternal resemblance is a deviation from the ideal).

This account of maternal resemblance is an extremely popular interpretation of the *Generation of Animals*. According to Sober, for example, Aristotle's account of maternal inheritance employs what he calls a "natural state" model, which is supposed to be the same model that underwrites Aristotle's teratology:

> According to Aristotle's theory of sexual reproduction, the male semen provides a set of instructions which dictates how the female matter is to be shaped into an organism. Interference may arise when the form fails to completely master the matter. ...Such interferences are anything but rare, according to Aristotle. Mules—sterile hybrids—count as deviations from the natural state (*Generation of Animals*, ii, 8). In fact, the females of a species do too, even though they are necessary for the species to reproduce itself (*Generation of Animals*, ii, 732a [sic]; ii, 3, 737a27; iv, 3, 767b8; iv, 6, 775a15). In fact, reproduction that is completely free of interference would result in an offspring which exactly resembles the father. So failure to exactly resemble the male parent counts as a departure from the natural state. Deviations from type, whether mild or extreme, Aristotle labels "τέρατα"—monsters. They are the result of interfering forces (βίαιον) deflecting reproduction from its natural pattern.[16]

Like Morsink, Sober argues that Aristotle treats maternal inheritance as a deviation from the natural state (a male that resembles its father in every respect) caused by interference with the normal activity of the reproductive mechanisms. Here the external interferences explain the aspects of the offspring's form that make it look like

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[16] Sober 1992. 361-2. Note that the word "βίαιον" (or "τέρατα" for that matter) never occurs in connection with maternal inheritance.

its mother insofar as they are responsible for the malfunctioning that produced those deviant results.

The problem with this interpretation is that when we turn to Aristotle's actual account of maternal resemblance in *GA* 4.3 we find that it does not exhibit the structure of a teratological explanation at all. First, maternal movements are introduced into the theory as an independent source of inheritance whose *proper* functioning is responsible for those features of the offspring's form that make it look like its mother and/or her various ancestors. This is not true for monstrosities. According to Aristotle, genuine monstrosities are not produced by an independent set of movements; there are no "movements of the monster" as it were that take over when those of the generating parent fail. Rather, they are produced by the very same movements that would have produced a likeness of the parent under normal conditions. A monster results when these normal parental movements get distorted so that what they produce is something deformed. Second, as we have already seen, Aristotle thinks the inheritance of maternal traits is explained by movements coming from the mother in the same way that paternal movements explain resemblances to the father's side of the family.

More to the point, the account of maternal inheritance that Morsink himself defends lacks the necessary teratological structure to make his response to the inconsistency charge work. Morsink argues that the normal course of events is when the movements of the father prevail over the matter. The claim being made is that Aristotle's matter-form hypothesis (specifically the idea that the father alone provides the form while the mother provides only matter) is meant to describe this ideal scenario where everything goes according to plan. When things don't go according to plan and the paternal movements fail, Morsink argues that a separate set of movements coming from the mother take over and impose on the offspring formal resemblances to her side of the family. But this is not a teratological explanation. For maternal movements are introduced here as an independent source of inheritance that produce (and explain) the outcome when the paternal movements fail. This is not consistent with a view of maternal inheritances as deviations from some ideal (i.e. monstrosities).

It seems clear to me that if one accepts the terms of the inconsistency charge set out above. then one is forced to accept Furth's conclusion. At best Aristotle's

theory of reproduction in the *Generation of Animals* is internally inconsistent and at worst it all comes crashing down in *GA* 4.3 under the weight of empirical evidence.

§3 Cooper's interpretation

The alternative to Furth's conclusion is to reject the terms of the inconsistency charge by denying one or more of its premises. This is Cooper's strategy. Cooper accepts the first two premises; however, in contrast to Furth and Morsink, he denies that the movements contributed by the female are functionally equivalent to their male counter-parts (premise (3)):

> So when Aristotle says the male's fluid fails to master, or is defeated… in its efforts to master these materials, and so the materials are shaped into a female, he does not mean that some independent active, generative activity of the female materials takes over. The movements in the female materials are not a new, second set of movements parallel to the movements in the male's fluid, that directly shape the foetus' bodily parts, as it were by default. Both before and after his discussion in [*GA*] IV of female births and inherited resemblances to ancestors Aristotle repeatedly emphasizes that only the male, through the movements in his semen, is capable in any way at all of fashioning (δημιουργεῖν) the material provided by the female into a new animal….[17]

If one accepts the first two premises of the inconsistency charge, then one of two conclusions follows. If we take the movements coming from the mother to be functionally equivalent to those of the father (premise (3)), then we *must* concede, along with Furth, that the *GA* does not contain an internally coherent theory. However, if we begin from the assumption that the *GA* theory is internally consistent, as Cooper does, then whatever role those maternal movements turn out to play in that theory it *cannot* be the same as the paternal movements. The role of directly shaping the matter into an organism of some determinate form is reserved for the father (premises (1) and (2)).

It is important to see how Cooper's response to the inconsistency charge differs from Morsink's. Recall the three inconsistent premises:

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[17] Cooper 1988, 18-19.

(1) The father alone supplies the form manifested in the eventual offspring, while the mother supplies the matter which receives that form.

(2) The way the father makes his formal contribution is through the movements of his sperm which determine the offspring's form by directly fashioning the matter into that new individual.

(3) The mother contributes a set of movements which are functionally equivalent to their paternal counter-parts.

Both Cooper and Morsink agree that *GA* 4.3 is consistent with the rest of the treatise. However, they pursue different strategies. Morsink accepts all three premises and simply denies that they constitute an inconsistent set. In particular, he argues that (1) and (2) only apply in situations where everything works the way it is supposed to (i.e. when the father's movements are successful), whereas (3) applies in those other cases where the process deviates from this ideal. Cooper attempts to show that *GA* 4.3 is consistent with Aristotle's official theory by denying premise (3): the mother's movements *do not* play the same formative role assigned to the father's movements.[18]

This negative conclusion drives Cooper's positive account of the role played by maternal movements in Aristotle's theory of inheritance. His argument is this: Assume Aristotle is still committed to his hylomorphic theory in *GA* 4.3. In that case, Aristotle must have thought the movements of the father's sperm were somehow responsible for directly imposing on the offspring those features that make it look like individuals on the mother's side of the family. So any contribution the mother's movements might appear to be making to the offspring's form in *GA* 4.3 must be the work of movements in the father's sperm instead. Cooper identifies one text where Aristotle suggests a possible mechanism for this. At 768a14 we appear to be told that the father's sperm contains, in potentiality, movements "of the female" (τοῦ θήλεος).

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[18] Cooper and Morsink superficially disagree over premise (2) insofar as Morsink identifies the paternal movements, not with actual motions of the father's sperm as they mould the parts, but with the motions and changes that make up the development of those parts. However, premise (2) could be rewritten more generally as saying the way the father determines the offspring's form is by supplying κινήσεις which directly fashion the matter into that new individual, whether these are taken to be developmental motions initiated by the sperm (Morsink) or informative motions of the sperm itself (Cooper).

Cooper takes this to be an explicit reference to movements in the father's sperm corresponding to the distinctive characteristics of the mother as well those of her various ancestors.[19] These movements (which Cooper takes the sperm to have independently of the mother) give the father the power to make the offspring look like those individuals. As strange as this may sound, Cooper argues that Aristotle is saying exactly what he *must* say in order to bring the phenomenon of maternal inheritance in line with the theory developed in the earlier books.[20]

Since the primary objective of this chapter is to defend the claim that the "movements" coming from the mother are functionally equivalent to their paternal counter-parts, my main concern will be Cooper's negative thesis (the idea that whatever role maternal movements turn out to play in that theory it cannot be that of directly shaping the offspring into a likeness of the mother). However, it will be instructive to look at Cooper's positive account of the role played by those maternal movements.

§3.1 Cooper's positive account of maternal inheritance

The success of Cooper's positive thesis ultimately comes down to his ability to show that the father is directly responsible for the parts of the offspring's form that make it look like individuals on the mother's side of the family while at the same time showing how maternal movements are central to this process. For Aristotle obviously thinks those movements have some important role to play in the theory. Moreover, Cooper's ability to show that the father is directly responsible for maternal resemblances crucially depends on his reading of 768a14 (the father's sperm contains movements corresponding to the distinctive features of the mother and her ancestors). I do not think he succeeds on either front.

Let us grant for the moment that 768a14 does identify a set of movements in Socrates' sperm corresponding to the distinctive features of Xanthippe's form as well as those of her various ancestors.[21] Cooper takes these (potential) female movements

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[19] Cooper 1988, 21-2.

[20] Cooper 1988, 30.

[21] Xanthippe was Socrates' wife (Menexenos was one of their three sons). Aristotle never actually mentions the mother by name (see 768b14-15: "...the particular mother, whoever she may be").

in Socrates' sperm to be distinct from the (actual) maternal movements coming from Xanthippe herself (those mentioned at 768a19-21). Thus, on Cooper's reading there will be not one but *two* sets of movements for every maternal trait: one set in Xanthippe's menstrual fluid and a second, parallel set in Socrates' sperm. According to Cooper, the latter alone are directly responsible for those features of the offspring's form that make it look like individuals on Xanthippe's side of the family.

So where do the movements coming from Xanthippe come in? The first thing to mention is that Cooper does not think her movements have any role to play in explaining how the offspring comes to resemble herself. According to Cooper, it is only when Aristotle comes to explain resemblance to her ancestors that he "opens up the theoretical space into which movements in the female's matter might be placed".[22] As such, we can divide Cooper's positive account into two parts: how resemblances to the mother are produced; how resemblances to her ancestors are produced. I shall begin with the former.

§3.1.1 Resemblance to the mother

Cooper attempts to reduce the tension between Aristotle's hylomorphic analysis of reproduction and the appearance of maternal movements in *GA* 4.3 by denying that these movements play any role (formative or otherwise) in explaining resemblance to the mother herself. According to Cooper, Aristotle explains this solely in terms of movements in the father's sperm. He points to the following passage as evidence for this reading:

> So that if it [sc. the motion of the sire] masters it [sc. the matter], it will make a male and not a female, and like the father but not the mother. But if it fails, then it makes a defect (ἔλλειψις) with respect to whichever potential (δύναμις) it fails to gain the mastery. (767b20-3)

Aristotle goes on to associate the "potentials" in question with different characteristics of the generator's body (e.g. those that make it a particular individual). The precise relation between a δύναμις and the corresponding phenotypic trait is not important at this point. For now it is enough to know that Aristotle envisions some kind of correspondence between the success of a "movement" and the inheritance of a given phenotypic trait.

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[22] Cooper 1988, 25.

Whatever else this text says, it at least provides an account of how the offspring comes to resemble its father. Suppose the movement at work here is the one associated with the construction of Socrates' snub nose. If this movement is successful, Menexenos will have a nose shaped like his father's. The question is what happens when this movement fails. According to Cooper this is how resemblances to the mother are produced: "...when the semen *fails* to master the female fluid it is nonetheless the semen that makes the embryo have a 'defect' in precisely the respect that is controlled by the 'capacity' in which it failed to master it – the *semen* fashions the offspring so that it is a female, or resembles its mother".[23] On this reading of 767b20-3, the "defect" left behind in the matter when the sperm's movement fails is the opposite maternal trait (e.g. it makes a nose shaped like the mother's). In this way Aristotle is supposed to have held that the father is directly responsible for making the offspring look like both parents. When the seminal movements succeed they make the offspring look like the father and when they fail they make it look like the mother. The maternal movements mentioned at 768a19-21 (on this reading) do not play any role in this process whatsoever.[24]

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[23] Cooper 1988, 25 (emphasis Cooper).

[24] There is a problem here concerning exactly what Cooper takes the maternal movements to be. Elsewhere Cooper claims that the movements in the mother's fluid are a kind of "programme" (16) that carry "instructions for the formation of her own bodily parts" (27). Yet the current account of maternal resemblance renders those instructions superfluous, since Cooper has just insisted that the mother's movements do not play any role whatsoever in the actual formation of the offspring's parts. Cooper could find a role for these κινήσεις to play by suggesting that the instructions they carry direct the sperm's behaviour as *it* fashions the parts of the embryo, so that the sperm fashions parts like her own. This would allow Cooper to preserve the idea that the mother's movements have no direct *formative* role to play in constructing the offspring (she is not a 'sculptor'), but only at the cost of overturning Aristotle's matter-form hypothesis (as Cooper understands it). For the instructions carried by her κινήσεις will count as a formal cause of maternal inheritance: they determine the particular pattern of inheritance for the offspring insofar as they supply the principle that directs the father's sperm. I will ignore this inconsistency in Cooper's account.

Cooper appeals to the sculpting analogy in order to show how the mother's material can still be said to be a cause of those resemblances produced by the father without making any direct, active contribution to the outcome:

> Consider a sculptor working on some soft stone. It turns out that his skills are not adequate to make this particular piece of stone have exactly the degree of surface finish that the statuary's art demands: he does not possess the lightness of touch necessary to achieve a greater degree of finish without chipping stone. He might of course abandon the effort once the inadequacy of his skills becomes clear to him. But suppose he doesn't. Then whatever features of shape, surface texture etc. the resulting statue has will have been produced by *his* art: his art will have been the originating source, and the only originating source, of these outcomes (assuming nothing pushes his hand or falls on the statue while he is working on it that affects these features). The stone itself contributes only as matter, not as a source of any of the changes it undergoes while these outcomes are being achieved. It is not as if there is a *nisus* in the stone for this kind of surface texture, etc. Yet the principles of the artisan's art, as they actually exist in him in whatever way principles of art do exist actually in the artisan, do not themselves explain these deviant features of the outcome. Still, even these features are not due, even in part, to any accident: the agent is the non-accidental moving cause of them, just as much as he is of the others. He at least settles for these outcomes, even though he does not set out to achieve them or intend them; on the contrary, he is aiming at as perfect a realization of the sculptor's art as he can achieve, not this defective one that he actually achieves.[25]

This same analogy shows up again in Kathleen Cook's treatment of Aristotle:

> I think that all the traits that are inherited from the female on this model are seen by Aristotle from a metaphysical standpoint as the absence, or privation, of the male traits—including not only the trait of being female itself, but also, e.g., the mother's nose shape (cf. 767b22-24, 768a2-15). Now, this may seem easier to make sense of in the case

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[25] Cooper 1988, 32.

of being female... but how are we to make sense of the fact that the shape of my (alas!) snub-nose inherited from my mother is to be described as the absence of the shape of my father's Jimmy Stewart nose? My suggestion is this: that Aristotle thinks that all this is analogous to what we (playing Aristotle) might say in the case of a sculptor who has in mind to form the arms of his statue in a certain way. Insofar as he starts out with a particular shape of arm in his mind but fails to impose it because he, as moving cause, is not able to fully

> or in this way fully prevail over the matter, the product with regard to this feature—the arm—is characterized by the absence of his idea: his idea fails to be imposed, but it does have an arm, and an arm of a certain sort.[26]

The first thing to point out here is that this use of the sculpting analogy is at least not consistent with Cook's interpretation of maternal resemblance.[27] The suggestion is that maternal resemblances are analogous to the deviant features of the statue which result when the sculptor fails to impose his idea on the bronze. On this reading, the parts of the offspring's form that make it look like its mother are the by-products of the sperm's botched attempts to impose the father's likeness on the matter. However, Cook has just finished arguing that the mother supplies her own set of movements that take over whenever the father's movements fail.[28] These two accounts are incompatible. The whole point of the sculpting analogy is to say that maternal resemblances are what are left behind in the matter when the sperm's movements fail

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[26] Cook 1996, 60. Cook has clearly borrowed this analogy from Cooper. However, her interpretation of how maternal inheritance actually works (59) is much closer to Morsink's reading than Cooper's (see below).

[27] Whether or not Cooper's reading is vulnerable to this objection depends on what he takes the potential female movements in Socrates' sperm to be. If they are a separate set of movements over-and-above the movements corresponding to his own features, then he is open to this objection. If, on the other hand, he treats the *actual* movements of the sperm as it fashions the matter into a likeness of Socrates as *potential* female movements (insofar as they have the potential to fail), then he is immune to this first criticism.

[28] Cook 1996, 59.

to produce a likeness of the father and so are reducible to those unsuccessful attempts. So the sculpting analogy only works if one denies that maternal resemblance involves movements over-and-above those responsible for the paternal traits.

More importantly, the sculpting analogy is itself defective.[29] Both Cooper and Cook compare the sperm's making the offspring look like the mother to the sculptor who sets out to form a statue of Hermes but fails to impose that form on the matter because he, as the sole moving cause, is unable to fully prevail over it. But this is not analogous to maternal inheritance at all. The proper analogy would be the case where the sculptor sets out to form a statue of Hermes but what results is a perfectly formed statue of Athena. And no one, including Aristotle, would think that this result is a by-product of the sculptor's abortive efforts to fashion the matter into a statue of Hermes. When the sculptor sets out to form a statue of Hermes and fails, the result is not a perfect likeness of Athena (except by coincidence) but a distorted likeness of Hermes. By analogy, then, if the sperm sets out to impose Socrates' form on the matter and fails, the result will not be a perfect likeness of Xanthippe but a distorted likeness of Socrates. And there is no evidence to suggest that Aristotle thinks the features that make Menexenos look like Xanthippe are reducible to distorted copies of Socrates' features any more than he would characterise a statue of Athena as a malformed statue of Hermes.

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[29] This objection applies to both Cooper and Cook alike. It is important to note that the analogy between sculpting and maternal resemblance presented in these two passages is not *Aristotle's* analogy (neither Cooper nor Cook claim that it is). What Cooper at least has in mind is the vague reference to tools being blunted at 768b15-25. However, that text is simply an attempt to translate the principle of "relapse" – the principle underlying the phenomenon of atavism – into the language of Aristotle's chemistry. And we have already seen that maternal-line atavism involves a set of formative movements coming from the mother herself. So any sculpting analogy suggested by this text would cast the mother's movements in the role of sculptor as well.

I agree that the sculpting analogy set out in the above two quotations effectively captures Aristotle's point at 767b20-3. However I disagree that that text is an account of how resemblances to the mother are produced.[30]

As mentioned, it is at least clear that 767b20-3 provides an account of how resemblances to Socrates are produced. When the movements responsible for the formation of Socrates' features succeed, Menexenos comes to have features just like his father. The question is what happens when Socrates' movements fail. According to Cooper, those botched movements end up producing Xanthippe's features instead, although not intentionally of course but only as a by-product of their failure to make the matter into a likeness of Socrates. But that is not what 767b20-3 actually says. The only thing that text says is that the failed movements produce a "defect" (ἔλλειψις). It is certainly a leap to suggest that this defect left behind in the matter by the sperm's failure to impose Socrates' features on it refers to a perfect likeness of one of Xanthippe's distinctive features. In order to read the text in that way one would have to assume that Aristotle thought Xanthippe's features (and only hers!) are reducible to poorly formed versions of Socrates' features (and only his!).

The central assumption behind Cooper's (and Cook's) interpretation of 767b20-3 is the idea that maternal resemblances were viewed by Aristotle as the absence or privation of paternal traits. While this is certainly true in the case of female births, it does not hold for the distinctive features that make the offspring a spitting image of its mother. For the nature of the properties involved in each case are radically different.[31]

When it comes the generation of the sexes, there are only two possible outcomes: male and female. And these two outcomes are characterised by the presence and absence of a *single* property, namely, the ability to produce sperm.[32] A female (*qua* female) is defined by the *absence* of that ability. As such, it only makes

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[30] For the remainder of the discussion I shall focus strictly on Cooper's reading, though much of what I have to say applies to Cook as well.

[31] In what follows "male" and "female" will be understood in the functional sense (sexual identity).

[32] Moreover, this is reducible to a quantitative difference: hotter embryos are male; colder embryos are female (coldness being a privation of heat). This is also important since concocting the matter simply raises its temperature.

sense to characterise the production of a female embryo in terms of the sperm's failure to make it male. For *not* endowing it with the property that makes it a male *automatically* makes it a female. An analogy with modern biology will help make this point clear.

Aristotle's functional definition of male and female is analogous to the modern genetic account of sex which defines male and female in terms of sex chromosomes. In the case of certain insects such as grasshoppers there is only one sex chromosome: the *X*. Female grasshoppers are *XX* while male grasshoppers are *X0*, where *0* represents the absence or privation of an *X* chromosome.[33] This is analogous to Aristotle's account insofar as the sex of a grasshopper is determined by the presence and absence of a single property. According to modern biology, a male grasshopper is produced whenever the sperm fails to endow the embryo with the second *X* chromosome (the property that makes grasshoppers female). For Aristotle a female is characterised by the absence of the property that makes an animal male (the ability to produce sperm) just as a male grasshopper is characterised by the absence of the property that makes a grasshopper female (the second *X* chromosome).

Things are radically different in the case of inherited resemblances. Those features that make the offspring look like its mother cannot be reduced to privations of the father's features. Unlike the property of being male or female (functionally defined), having a nose shaped like Socrates and having a nose shaped like Xanthippe cannot be understood in terms of the presence and absence of a single nose shape (Socrates' snub nose). Imagine Xanthippe's nose is long and convex while Socrates' nose is short and concave. Xanthippe's nose is quite obviously not the privation of Socrates nose (if anything it is the reverse!). Since the two nose shapes are not related by privation, the failure to impose Socrates' nose shape on the matter does not *ipso facto* make a nose exactly like Xanthippe's.

Eye colour might be taken as an exception to this. For example, in *GA* 5.1 Aristotle tells us that eye colour is due to the relative level of concoction of the fluid in the eye (780b6-12). The more concocted the fluid is, the darker the colour. One might argue that in this case the maternal resemblance can be reduced to a failure of

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[33] Campbell and Reece 2002, 276.

the father's sperm to fully concoct the fluid in the offspring's eyes.[34] However, first, this would only work in cases where the father's eye colour is darker than the mothers' eye colour. And it is not universally true that males have darker eyes than females. (Contrast sex: all females have lower levels of natural heat than all males by definition.) Second, unlike sex, there are more than two types of eye colour in the population. So again failing to make Menexenos' eyes blue like Socrates' does not *ipso facto* make them green like Xanthippe's.

The general point here is that the features that make the offspring look like its mother are not related to those that make it look like its father by privation in the way that the property that makes it female (= the inability to produce sperm) is related to the property that makes it male (= the ability to produce sperm). Unlike the property of being female, maternal resemblances are properties in their own right. And it is the *presence* of those properties that makes the offspring look like its mother. As such, there must be some additional genetic factor that produces maternal traits over-and-above the factor responsible for producing the paternal ones. *This* is why we find Aristotle introducing "movements" coming from the mother herself in *GA* 4.3 (something not found in *GA* 4.1-2).[35]

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[34] The agent in this case is actually the offspring's genetic nature, which regulates the level of concoction in the eye (780b6-12, translated and discussed in chapter seven below). However, for the sake of argument (and convenience) I shall assume that Cooper is right that it is the father's sperm that does the concocting. The point does not turn on this.

[35] This equally applies to the inheritance of sexual morphology. I have argued that Aristotle treats this as a special case of resemblance and so will be governed by the same causal mechanisms responsible for producing familial resemblances, namely the inheritance of spermatic κίνησις. If this is right, then when Aristotle refers to (e.g.) ἡ ἀπό τοῦ ἄρρενος κίνησις (as at 768a28), "τοῦ ἄρρενος" should be understood, not functionally in terms of the ability to concoct the residue of nutritive blood into sperm (sexual identity), but anatomically in terms of the parts proper to animals of that sex (sexual morphology). As we shall see, the κίνησις in question is a vehicle for transmitting the morphological, physiological, and behavioural properties which belong to Socrates *qua* male.

A caveat is necessary here. At *GA* 768a5-9 "female" is said to be the opposite of "male" and "mother" the opposite of "father". However, although Aristotle does think "female" is a privation of "male" (insofar as these are functionally defined), this is not something that follows from their being opposites of one another; being opposites does not entail one term being the privation of the other. In *Metaphysics* Δ10 Aristotle defines opposites as things which cannot be present simultaneously in a single subject. The mother's nose shape and the father's nose shape would be opposites, then, insofar as both shapes cannot be present in the offspring's nose at the same time (it must be one shape *or* the other). However, it does not follow from this that the one shape is *the privation* of the other such that both properties can be reduced to the presence and absence of a *single* nose shape (that of the father). Both nose shapes are properties in their own right.

Let me return now to 767b20-3. The main problem with Cooper's reading of this passage is that he takes it entirely out of context. When read in the context of the surrounding argument, it becomes clear that what the father's failed movements produce is not a perfect likeness of the mother but a distorted likeness of the father (a physical deformity). To appreciate this we need to start back at 767b4.

One of the phenomena that Aristotle thinks an adequate theory of inheritance must explain is the fact that in some cases the offspring may not bear any likeness to its family at all but might still be recognisable as a member of its species.[36] In extreme cases, however, even this species-likeness is lost and the resulting offspring has a "monstrous" bodily form (a deformity). When this happens, Aristotle says, the offspring has "departed from the γένος". On my interpretation, this refers to a departure from a continuous generation of things of the same form (γένος in the sense given at *Metaphysics* 1024a29-30).[37] The first, albeit minor, instance of this occurs when the male sperm makes the embryo female and not male. However, Aristotle says that the production of females is still "necessary", and this in two ways. First, it is necessitated by the fact that sometimes the sperm fails to make the embryo male because it does not properly concoct the menstrual blood. And any embryo that

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[36] I take this up at the end of chapter six.

[37] The current point does not depend on this particular interpretation of "γένος".

is not male is *ipso facto* female. Second, females are necessary for the sake of something, namely, reproduction.

Although most of the attention surrounding this passage has been focused on Aristotle's remarks about female births, the statement that nature has "departed from the γένος" is really meant to apply to the production of physically deformed offspring, those whose observable form (τὴν ἰδέαν) does not even resemble that of its own species. These monstrosities are quite obviously departures from a continuous generation of things of the same form. Again, this occurrence is said to be the product of necessity. However, in this case it is not teleological (they are not necessary for the sake of anything) but merely accidental: they are necessary "κατὰ συμβεβηκός".[38] The discussion that immediately follows this statement (which includes 767b20-3) must be an explanation for this. For the very next sentence begins with an explanatory "γάρ":

> As for monstrosities, they are not necessary with respect to the final cause and the goal; rather, they are necessary with respect to an accident, since the origin <of deformity> at any rate must be assumed to lie in this. For (γάρ) when the spermatic residue in the menstrual fluid is thoroughly concocted, the motion of the male will produce the shape in accordance with himself.[39] (It makes no difference whether

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[38] This idea has fairly important historical significance. Beginning around the 17th century attempts were made to show how monstrosities were not accidents at all but in fact part of God's divine plan (or at least expressions of His omnipotence). For a discussion of these theories of teratology see Monti 2000.

[39] Since I am arguing from within the framework of the received interpretation, I shall assume that ἡ τοῦ ἄρρενος κίνησις ("the motion of the male") refers to the physical motion *of* the father's sperm in fashioning the menstrual blood into a male like himself. Eventually I shall show that the sperm's formative role in reproduction is limited to the organisation of the embryonic heart. On my reading of this text, ἡ τοῦ ἄρρενος κίνησις refers to the process of development initiated by the sperm (in a way to be specified below). Aristotle refers to this as the κίνησις "of the male" either because the causal history of that change can be traced to the father's genetic

> we speak of 'the sperm' or 'the motion which makes each of the [newly constructed] parts grow' or whether we say 'makes them grow' or 'constructs them in the beginning'; for the account of the motion is the same.)[40] So that if it masters it [sc. the matter], it will make a male and not a female, and like the father but not the mother. But if it fails, then it makes a defect with respect to whichever potential it fails to gain the mastery. (767b13-23)

When read in the context of Aristotle's statement about birth defects it becomes immediately clear that (pace Cooper) 767b20-3 is not telling us how maternal resemblances are produced but in what sense such physical deformities are necessary "κατὰ συμβεβηκός".[41]

Aristotle only uses the movements of the father to illustrate the point about birth defects. This is similar to what we find in the account of atavism: paternal-line atavism is only offered as an example (οἷον) of the mechanism. The only difference is that there Aristotle says explicitly that resemblance to the mother's ancestors occurs in the same way as resemblance to the father's ancestors. Resemblance to the mother's ancestors occurs when *her* maternal movements relapse into those of her ancestors, just as resemblance to the father's ancestors occurs when his movements do. Thus it is reasonable to expect that Aristotle's account of resemblance to the mother herself will parallel his account of resemblance to the father at 767b20-3 in this same way. So it is implicit in 767b20-3 that resemblance to the mother occurs

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contribution, or, what is more likely, because a teleological account of that change will make reference to the father's shape and form (see note 40).

[40] Aristotle is *not* saying here that the sperm, the process of growth, and the construction of the offspring are all one and the same thing (which would be absurd since the sperm is not what develops into the offspring). Rather, the idea is that a teleological account of each will make reference to the same form: the form being transmitted by the sperm is the same form as that towards which the processes of growth and development are directed (in this case). As such it makes no difference which of these we refer to insofar as the explanation of why Menexenos resembles Socrates is concerned.

[41] Compare 743a26-30.

when *her* movements succeed just as resemblance to the father is said to occur when his do (and likewise that birth defects occur when her movements fail).

§3.1.2 Resemblance to the mother's ancestors

Maternal-line atavism presents the biggest challenge to Cooper's argument. For he must find a non-demiurgic role for the mother's movements to play in that account. It will be useful to have the relevant text in front of us here:

> [Resemblance to ancestors occurs when] the formative movements relapse into the ones which stand closest to them. For example, if the movement of the father relapses, it passes into that of his father (the least difference) and in the second instance into that of his grandfather. Indeed in this way too, on the female side just as on the male side: the movement of the mother passes into that of her mother, and if not into that one, then into that of her grandmother. And in the same way for the more distant ancestors. (768a15-21)

Here is how Cooper understands the process. It is necessary to quote Cooper in full, for it would be extremely easy to misrepresent his views given the complexity of his account:

> As being the material from which the offspring is constructed the catamenia cannot initiate any of the movements that fashion the offspring, or determine directly the course which any of these movements take. Aristotle points out two ways in which the catamenia can nonetheless affect these processes by affecting the semen itself, which is the source of them. First (see 768b25-7) it can be too cold or too great in amount for the semen to work it up fully according to its natural tendencies (i.e. it can cause the semen to fail to master it). One way this can happen is for the semen to be unable to make the offspring resemble the male whose semen it is, and then, as Aristotle has already explained [at 768a15-21], it [sc. the sperm] makes the material go over to resembling the mother's side of the family. And here the second way Aristotle distinguishes in which the catamenia can affect the semen and its operations comes into play. Since any agent in

acting on materials is itself reciprocally affected by them,[42] the semen can be brought, in working on the catamenia, to be affected by them in such a way that its [the semen's] movements slacken,[43] from being ones that would produce a resemblance to the mother to being ones that produce a resemblance to her mother or another of her ancestors. The catamenia do this when their own movements [those which correspond to features that characterise the mother *qua* individual] slacken into movements of the forebear in question; that alters the character of the catamenia as they reciprocally affect the semen, so that they induce its [the semen's] movements to slacken in just the way required. That is to say that one gets here a combination of both the two processes Aristotle postulates. The semen first fails to master the female fluid, which therefore departs from its nature and is made to resemble not the father (as would be more natural) but the mother. But secondly (and this is where movements in the female fluid enter the theory explicitly) the movements of the female fluid themselves slacken, reciprocally affecting the semen as it acts on it, so that its [the semen's] potentiality to produce in the embryo movements for the mother's ancestors (instead for [sic] the mother herself) comes into play.[44]

Cooper's interpretation dramatically over-complicates what appears to be an otherwise straightforward account of maternal-line atavism by introducing an extra step in the process. Cooper suggests that the process by which the offspring comes to resemble its maternal ancestors actually proceeds in two distinct stages (though Aristotle only mentions one). First the mother's movement relapses (Cooper's "slacken") into the movement of her mother. This then reciprocally affects the father's sperm in such a way that *its* female movements relapse "from being ones that would produce a resemblance to the mother to being ones that produce a resemblance to her mother or another of her ancestors". In this way the movements in the father's

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[42] Cooper is thinking of 768b15-25 here.

[43] This is Cooper's translation of Aristotle's technical term λύσις, which I have translated as "relapse" (following Peck).

[44] Cooper 1988, 26-7.

sperm are supposed to be directly responsible for imposing on the offspring those features that make it look like the ancestors on the mother's side of the family.

The trouble with this reading is that we do not find this second stage anywhere in the text. There is no mention of any further process where the relapsing maternal movements *in turn* cause a parallel set of movements in the father's sperm to relapse in tandem. Nor should we expect to find this extra step. For Aristotle prefaces the explanation of maternal-line atavism by emphasising that the process works *in the same way* as paternal-line atavism: it occurs when the mother's movement relapses into those of her ancestors. Aristotle clearly takes this single process of relapse as necessary *and* sufficient for explaining resemblances to the mother's ancestors. And yet on Cooper's reading he has only given us a partial explanation.

Up to this point I have taken Cooper's reading of *GA* 768a14 for granted. According to Cooper Aristotle here identifies a set of movements in Socrates' sperm corresponding to the distinctive features of Xanthippe's form as well as those of her various ancestors. This reading is vital for securing both parts of Cooper's positive thesis. On Aristotle's theory it is in virtue of supplying "movements" that the parent's genetic material is able to transmit resemblances to the offspring. Thus, if the father's sperm is responsible for transmitting *all* formal resemblances (as Cooper claims), then it better come equipped not only with movements for himself and his ancestors but for all the individuals on the mother's side of the family as well. The trouble is that *GA* 768a14 is an extremely weak foundation upon which to rest such a controversial interpretation. As Cooper acknowledges, this is really the only text in the entire treatise to indicate that Aristotle thinks there are movements in the father's sperm capable of transmitting to the offspring bodily resemblances to the mother's side of the family.[45] More importantly, Cooper's positive account ultimately comes down to his assumption that "τοῦ θήλεος" is a reference to the distinctive features of the mother and her various ancestors.

There are several ways to respond to Cooper's reading of 768a14. First of all, the reference to female movements in the father's sperm is an anomaly. For example, there is no mention of any such movements among the potential movements listed at 767b35-768a2. which is the first place we are told about the presence of movements in the σπέρματα of animals. This suggests that τοῦ θήλεος might be an

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[45] Cooper 1988, 27.

interpolation and should be deleted. Deleting τοῦ θήλεος from 768a14 would leave δυνάμει δὲ αἱ τῶν προγόνων, echoing almost exactly the earlier passage at 767b37 (δυνάμει δὲ καὶ [αἱ?] τῶν προγόνων).

However, even if this is not an interpolation, the text still does not say what it must say in order to secure Cooper's positive thesis. Cooper needs τοῦ θήλεος to refer to movements in Socrates' sperm which impose on the offspring features that make it look like Xanthippe and her relatives. However, throughout *GA* 4.3 μήτηρ is used to signal resemblance to the mother whereas θῆλυ is used exclusively in connection with the sex of the animal. This is explicit at *GA* 768a5-9. There Aristotle contrasts "female" (θῆλυ) with "male" (ἄρρεν), on the one hand, and "mother" (μήτηρ) with "Socrates" and "Coriscus", on the other. This contrast makes it clear that the properties corresponding to "female" (θῆλυ) are associated with those sexual characteristics which are common to all females and not with those peculiar features that make the offspring look like specific individuals on the mother's side of the family. This would make the idea of a potential "female" movement in the father's genetic material less strange. For the morphology transmitted by that movement is not distinctive of any particular female in the way that the individual mother's facial features would be. So at best 768a14 says that the father's sperm carries somehow in a state of potentiality a κίνησις that transmits the offspring's female form.

As much as I would like to be able to say that Aristotle brilliantly anticipated the modern genetic account of sex,[46] given the anomalous nature of τοῦ θήλεος at 768a14, it is more likely that this is an interpolation and should be deleted. In what follows I shall take Aristotle to hold that the father supplies the movement corresponding to "male" while the mother supplies the opposite movement

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[46] If the second reading reflected Aristotle's view, it would be a remarkable insight in light of recent discoveries in modern genetics. For we now know that all normally developed males have both an *X* (female) and *Y* (male) chromosome, even though the characteristics carried on the former are not actually displayed in the male's phenotype: they are present only in potentiality. (This is only true for mammals, which are of course Aristotle's model organisms. Moreover, the sex cells of a male only carry one or the other chromosome, so the parallel here would not be exact.)

corresponding to "female".[47] Whether or not this is right, it is at least certain that the movements transmitting the peculiar characteristics of the mother and her ancestors are supplied directly by the mother herself and that these movements occupy the central explanatory role in Aristotle's account of maternal resemblances. And that is sufficient for us to worry about the charge of inconsistency.

§3.2 Cooper's negative account

Let me return to Cooper's negative thesis. Cooper's strategy in avoiding the charge of inconsistency is to remove premise (3): whatever role maternal movements end up playing in Aristotle's theory, they are not functionally equivalent to the father's movements. It is important to appreciate that the force of Cooper's argument does not depend on the success of his positive account of the role that maternal movements actually do play in Aristotle's theory. If one assumes (as Cooper does) that the *GA* contains an internally coherent theory, then the first two premises imply that maternal movements *cannot* be functionally equivalent to their paternal counterparts whatever their role.

Cooper's response to the charge of inconsistency ultimately fails. For I cannot see how one can explain away the unambiguous reference to demiurgic maternal movements in 768a15-21. The text opens with the general statement that atavism occurs when "the formative movements" (αἱ κινήσεις αἱ δημιουργοῦσαι) relapse. What Cooper must argue is that the reference to formative movements is only meant to apply to the movements coming from the father in that text. But this seems unlikely. The reference to formative movements relapsing is clearly meant to cover both the movements supplied by the father (τοῦ γεννῶντος, τοῦ πατρός, τοῦ πάππου) and those supplied by the mother (τῆς γεννώσης, τῆς μητρός, τῆς τήθης). First, paternal-line atavism is only said to be an example (οἷον) of the more general phenomenon of formative movements relapsing. Second, and more importantly, maternal-line atavism is said to work in the same way as paternal-line atavism: "Indeed in this way too, on the female side just as on the male side: the movement of the mother passes into that of her mother, and if not into that one, then into that of her grandmother."

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[47] Here we are talking about the κινήσεις which transmit the sexual morphology common to all males and females, respectively.

§4 A final solution to the charge of inconsistency

There is one other way to resolve the apparent inconsistency that allows us to accept functionally equivalent maternal movements without having to concede Furth's drastic conclusion that their introduction in *GA* 4.3 represents a total collapse of the tidy matter-form theory developed in the earlier books. This solution targets the first two premises of the argument as being the source of the inconsistency. I shall argue that the inconsistency arises from the standard interpretation of Aristotle's 'official' account. In particular, it arises from the way commentators have traditionally understood the nature of the demiurgic "movements" in *GA* 4.3 and, more importantly, Aristotle's hylomorphism itself. I shall begin with the former (premise (2)).

In *GA* 1.21 Aristotle argues that the offspring is formed from the father and the mother in the way that a bed is formed from the carpenter and the wood: the father's contribution is the productive agent (ἡ ποιοῦσα) while the mother's contribution is the thing that gets formed and shaped by that agent (τὸ συνιστάμενον καὶ λαμβάνον τὴν μορφήν).[48] The standard way of reading this is to take Aristotle as saying that the movements of the father's sperm literally construct the offspring's body out of the materials supplied by the female just as the carpenter fashions the wood into a bed. The suggestion that the mother's movements in *GA* 4.3 are functionally equivalent to these thus implies that the matter is not entirely passive after all but is fully capable of fashioning *itself* into an offspring with a determinate shape and form. And that would certainly be a change in policy.

Of course the introduction of functionally equivalent maternal movements in *GA* 4.3 is really only inconsistent with the division of labour set out in *GA* 1.21 if the function of the paternal movements was to literally fashion the parts of the offspring out of menstrual blood. While it is certainly tempting to read the text in this way, this is not Aristotle's settled view. To see why we need to turn to an important argument from *GA* 2.1.

In the closing argument of *GA* 2.1 Aristotle announces that "nothing generates itself but once it has been generated it makes itself grow" (735a12-14: cf. *MA* 700a31-b4). It is supposed to follow from this that an animal's heart must contain the source

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[48] *GA* 729b6-8.

of growth and development of necessity. And the reason is that the heart is differentiated *before* any of the other parts. An important question to ask is at what point in the creature's ontogenetic history does it become responsible for its own growth.

By itself Aristotle's statement that nothing generates itself but once it has been generated makes itself grow is unhelpful. For the distinction between generation and growth is ambiguous here. For example, what I have been calling morphogenesis is the first major stage of embryonic development during which the offspring's primary structures are first differentiated.[49] When used in its technical sense "growth" (αὔξησις) refers to the period immediately following this when the newly formed structures are augmented (a strictly quantitative change).[50] However, quite often Aristotle will use "growth" in the broad sense to cover both morphogenesis and growth-proper (e.g. 740a1). This is how I think it is being used in the present text. Indeed, this is the only reading that makes sense of Aristotle's claim that the heart must contain the principle of growth *because* it is the first part of the offspring to be formed. For at that point the embryo becomes responsible for generating the rest of its body and so must of necessity contain the generative principle inside it.[51]

In contrast to this Cooper argues that the father is directly responsible for the shape and form of the offspring's *entire* body; his sperm is "the instrument he uses to move, fashion and shape the matter so as to have that form".[52] On this reading the offspring grows itself only in the sense of augmenting parts that have already been fashioned by the sperm. However, in that case it would not be necessary for the first

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[49] Morphogenesis and growth-proper (αὔξησις) are distinguished at 776a31-b3. When Aristotle is concerned to distinguish morphogenesis from growth he generally refers to the former as ἐξ ἀρχής συνίστησι (e.g. 740b33) or ἐν τῇ πρώτῃ συστάσει (e.g. 744b28).

[50] Growth-proper (αὔξησις) is further distinguished from the act of nourishing (τρέφειν) in that the former refers to the quantitative increase of structures while the latter refers to their general maintenance in the adult. See *GC* 322a19-27, *GA* 744b33-745a4.

[51] This is confirmed later at 740b25-741a3 (translated in chapter two above).

[52] Cooper 1988, 30; cf. Furth 1988, 118-19.

part to contain the principle of growth, as long as one of the parts fashioned by the sperm contained that principle before the foetus has to begin growing itself.

The fact that Aristotle thinks the heart must contain the principle of growth *because* it is the first part to be formed only makes sense if the idea is that once this part has been formed the embryo immediately takes over the construction of the remaining parts. In that case what Aristotle is saying is that the parent (the external agent) generates the heart while the embryo (which at this point is a one-part organism) builds the rest of its body through the agency of its own genetic nature.[53]

Thus, trivially, I agree with Cooper that the movements coming from the mother are not a second set of movements that directly shape the offspring's bodily parts by default. However, this is not because her movements are not functionally equivalent to those of the father. Rather, it is because Aristotle denies that *either* parent contributes to generation in this way. Since the paternal κινήσεις do not refer to the motions of the sperm as it fashions the materials into a likeness of the father, the suggestion that the maternal κινήσεις are functionally equivalent to them does not imply that the matter is capable of fashioning itself into a likeness of the mother.

I shall investigate the nature of the spermatic κινήσεις in the next chapter. Aristotle most likely refers to these as "formative" or "demiurgic" movements (αἱ κινήσεις αἱ δημιουργοῦσαι) simply because they are in some sense associated with the construction of the offspring's body. Eventually I shall argue that they are only indirectly responsible for this. What the argument in *GA* 2.1 makes perfectly clear, however, is that Aristotle does not subscribe to what Furth calls the "crude and childlike" view according to which the causal influence exercised by the father's (or indeed the mother's) genetic contribution is that of physically shaping the matter into a new individual.

My denial that the father makes his formal contribution by physically shaping the matter into a likeness of himself is not inconsistent with Aristotle's claim in *GA* 1.21 that the offspring is formed from male and female in the sense in which a bed is formed from the carpenter and the wood. For Aristotle's point there is not that the father literally fashions the parts of the offspring out of menstrual blood but that just

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[53] Recall that according to the conditions for potential-being laid down in Θ7, it is at this point that we now have a potential *F*.

as no part of the carpenter's body is used as matter for building the bed, so too no part of the sperm is used as matter for building the offspring.[54]

One might respond to this by saying that even if the maternal movements in *GA* 4.3 do not refer to the movements *of* the menstrual blood as it fashions itself into a likeness of the mother (as traditionally assumed), their introduction in *GA* 4.3 is still inconsistent with Aristotle's reproductive hylomorphism. For according to that analysis (the objection goes) the father alone makes a genetically significant contribution to the offspring's shape and form; the female's contribution is simply the matter which receives that shape and form. The introduction of maternal movements into the theory still implies that Aristotle changed his mind and came to see the mother as making her own formal contribution to the process. For whatever those maternal movements turn out to be, *GA* 4.3 clearly takes them to be *somehow* responsible for the parts of the offspring's form that make it look like the individuals on her side of the family—even if the way they do this is not by literally shaping the matter in the way the sculptor shapes the bronze (since neither parent's "movements" function in that way).

Now it is certainly true that the *GA* advocates a hylomorphic theory of reproduction in which the father provides the form (τὸ εἶδος) and the mother provides the matter (ἡ ὕλη). However, commentators rarely stop to consider exactly what Aristotle means by form here. Form is a notoriously slippery concept in Aristotle. The charge of inconsistency arises from the assumption that Aristotle's reproductive hylomorphism claims that the father is responsible for determining *all* aspects of the offspring's bodily form just as the sculptor (and not the bronze) is responsible for the statue's entire shape. However, a careful reading of the *GA* reveals two versions of the hylomorphic analysis at work, two ways in which the father can

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[54] cf. 730b8ff. In that text Aristotle does compare the movements of the sperm to the movements of the craftsman's tools in building the house. This is consistent with *GA* 2.1 as long as we take those formative movements to be limited to the sperm's behaviour in fashioning (what we would call) the zygote and the embryonic heart. These cannot be the κινήσεις mentioned in *GA* 4.3. though, which are associated with all the parts of the body (τῶν μορίων. 768b1-5). For the sperm does not fashion all of the parts.

be said to provide "form". And neither of these is inconsistent with the introduction of maternal movements.

On the hylomorphic model that dominates Book 1 of the *GA* providing "form" does not involve the formation of the offspring's complex adult structures. Rather, the sperm is said to provide form to the menstrual fluid in virtually the same way (παραπλήσιον) that rennet and fig-juice form curds out of milk (729a9-14, 739b20-7). The heat in the father's sperm acts on the menstrual fluid by drawing together the various bits of spermatic material contained in it and then fuses them together into one solid mass (739b20-7).[55] The product of this event is not a fully formed organism but an amorphous seed, which is the entity implanted in the uterine wall after fertilisation (our zygote).[56] The claim that the male sperm provides form to the menstrual fluid in the way that rennet provides form to milk (forms it into curds) is certainly not inconsistent with the idea that the mother provides, in addition to that material, a set of "movements" which are (somehow) capable of transmitting resemblances to the offspring that eventually develops from that seed.

It is interesting to note here that Aristotle's hylomorphic analysis of conception in *GA* 1.21 has been largely vindicated by modern biology, at least in the abstract. Of course the act of fertilisation is nothing like curdling milk. However, Aristotle was certainly right to insist that the mother *alone* provides the material out of which the offspring's body comes to be (she supplies the material cause). For we now know that it is her ovum that becomes the adult at the end of the process by undergoing a process of cell division and reorganisation. Moreover, he was right to insist that the father's sperm is the efficient cause *and not* a material cause. For we also know that the sperm does not contribute to generation by supplying matter for the process: the new individual does not develop out of the sperm nor is any part of the

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[55] See Peck 1990, lxi-lxii (§54-5), lxii-lxiii (§56).

[56] This is ultimately what Aristotle means at *GA* 1.21, 729b6-8: the idea that the father's contribution is the productive agent while the mother's contribution is "the thing that gets formed and shaped by that agent" (τὸ συνιστάμενον καὶ λαμβάνον τὴν μορφήν) refers to conception. Here we are talking about the sperm's forming the menstrual blood into an undifferentiated κύημα.

sperm used as material for making the offspring.[57] Rather (in one of its roles at least) the sperm functions to catalyse or activate the mother's egg triggering its development: it is the ἀρχή τῆς κινήσεως.[58]

The second formulation of Aristotle's matter-form hypothesis comes in *GA* 2.4. This is the more important model. Here the "form" the father is said to provide is the offspring's soul (738b25-6). In this context "form" is being used in the very narrow sense of εἶδος.[59] Now the maternal movements in *GA* 4.3 are supposed to explain those features of the offspring's phenotype that make it look like individuals on the mother's side of the family more than those on the father's side. And it is extremely unlikely that any of these phenotypic resemblances count as soul.[60] As such, the introduction of maternal movements that transmit such resemblances to her

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[57] This is the force of Aristotle's argument in *GA* 1.21 (cf. 730b8ff.) that the sperm contributes to generation in the way the carpenter contributes to the production of the bed (the bed is not built out of the carpenter as out of matter).

[58] Even according to modern biology, although the father supplies genetic *material* to the process (DNA), this does not function in reproduction as a *material cause*. The offspring's body is not made out of the father's (or mother's) DNA in the way a bed is made out of wood or a statue out of bronze. Although Aristotle never backs away from his insistence that the father does not supply the material cause, he is willing to relax the claim that the sperm alone supplies the ἀρχὴ τῆς κινήσεως. This is because he found empirical evidence of parthenogenesis, cases in which females are able to fertilise their own eggs (see esp. *GA* 2.5). Finally, Aristotle thinks both parents make a genetic contribution (the "κινήσεις") over-and-above these two functions.

[59] However, εἶδος does not always mean "soul" in the biological works. The most common use of εἶδος in the biology is the sense in which it means "the differentiae in the matter" (648a24). This is a much richer conception of εἶδος and is meant to include not only functions (e.g. the capacity to swim) but functional structures (e.g. webbed-feet). I have been using "form" throughout in this richer sense.

[60] For one thing a creature's "soul" is the set of functions that belong to its body. And *GA* 5.1 tells us that none of those features in which the members of a species differ are *functional* differences (778a31ff.). (Yet, neither are they so-called material accidents: see chapter seven below.)

side of the family is not inconsistent with the idea that the father alone provides the offspring's "form" (taken in the narrow sense of soul).

More interestingly, however, when we turn to *GA* 2.5 we discover that this body/soul hylomorphism does not even apply to the offspring's entire soul. In the final analysis, what the male alone is said to provide is simply the offspring's *sensory* soul. This is what Aristotle ultimately means when he says that the father's exclusive contribution to the generation of an animal is the "form". For the sensory soul is the form of an animal in the most strict sense: it is the property that makes that creature an animal (its essence). More importantly, Aristotle also reveals in that chapter that the mother's contribution is not confined to providing the offspring's body; she also provides a portion of its soul. In some species the female will often produce embryos which are capable of minimal growth without being fertilised by the male. Aristotle thinks this shows that the nutritive soul comes from the mother (741a16ff.).

§5 The mother's contribution to inheritance

In addition to providing the material out of which the new organism comes to be (*GA* 1.21), it turns out the mother also provides a set of spermatic movements which are somehow responsible for the offspring's nutritive soul (*GA* 2.5) as well as those aspects of its phenotypic nature that make it look like individuals on her side of the family (*GA* 4.3). What the father *alone* provides is the offspring's sensory soul, which is the form of an animal *qua* animal.

Although I shall continue to refer primarily to the movements in the father's sperm in the discussion that follows, most of what I have to say equally applies to the movements supplied by the mother. The reason for speaking in terms of the paternal movements is this. I suspect that Aristotle uses the father as his stock example of how the mechanisms of inheritance work for the very same reason he employs the standard analogies of sculpting and house building throughout the *GA*. It is simply easier to keep the different contributions to the process straight because in these cases agent and patient are physically distinct.[61] The conceptual snags that arise when talking about maternal inheritance are analogous to those presented by the doctor healing herself. In both cases things become much less easy to distinguish since agent and patient are numerically one and the same individual. In the case of maternal

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[61] cf. Balme 1972. 95.

inheritance, we would have to distinguish between the changes *of* Xanthippe's menstrual blood as it is developing into the offspring and the spermatic κινήσεις *in* her menstrual blood (assuming her κινήσεις are supplied through her menstrual blood) which I shall argue are distinct vehicles of inheritance for transmitting resemblances to her side of the family.

Chapter Five

Mechanisms of Inheritance

§1 The facts to be explained

At the outset of *Generation of Animals* 4.3 Aristotle argues that an adequate theory of reproduction must explain (at least) eight different phenomena connected with inheritance:[1]

1. Offspring tend to resemble their parents more than other members of the same species. (767a36-7)
2. Some offspring resemble the father while others resemble the mother, both (a) as a whole and (b) with respect to different parts (e.g. an offspring can have its father's eyes and its mother's nose). (767a37-b1)
3. Offspring tend to resemble their parents more than their ancestors. (767b2)
4. Offspring tend to resemble their ancestors more than any chance individual of the same species. (767b2-3)
5. Usually males resemble their fathers and females their mothers. (767b3-4)
6. Nevertheless, sometimes males resemble their mothers while females resemble their fathers. (769a3-4, b5-6)
7. Offspring who fail to resemble either its parents or its ancestors may still look like a human being at any rate. (767b4-5)
8. In the extreme cases the offspring's observable form (τὴν ἰδέαν) may fail to bear any likeness of a human being at which point it is a monstrosity (τέρας). (767b5)

Aristotle's own account of these phenomena will be explored in detail in the next chapter. In this chapter I want to provide a clearer picture of the causal mechanism behind them. However, the first thing we need to determine is which features of an organism Aristotle thinks are explained by reference to that mechanism.[2]

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[1] These phenomenon do not seem to be taken as mere *endoxa* (as some of the phenomena in *GA* 1.17-18 are) but as empirical regularities.

[2] Here we are talking about explanations in terms of efficient causality. Of course Aristotle thinks that, wherever possible, a given phenomenon should be explained by

The primary application of the mechanism in *GA* 4.3 is to explain the inheritance of features that make the offspring look like certain members of its own family *more* than other individuals of the same species. Thus we can be sure that Aristotle thinks some features below the level of species are included in the form that is transmitted in the act of reproduction. And given that family resemblances are most obvious in the face, it is quite reasonable to expect that Aristotle has such features in mind as nose shape and eye colour.[3] However, Aristotle does not confine the account of inheritance to these individual differences. At *GA* 768a13 the mechanism is extended to include the properties which are common to all humans and animals (the universals). So the causal mechanism at work in *GA* 4.3 actually underwrites the transmission of *all* aspects of biological form (including the species-form).

§2 The basic mechanism

My aim in this chapter is to set out clearly the causal mechanism underlying Aristotle's theory of inheritance in *Generation of Animals* 4.3. My hope is that by grasping the details of this mechanism we will not only be in a better position to understand Aristotle's theory of inheritance itself but also, more generally, how he thinks

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reference to all four causes. For more on this see chapter seven. Whatever else we might say about the spermatic κινήσεις in *GA* 4.3, they are clearly responsible for transmitting *formal* properties; they are not motions and changes arising necessarily from the matter. In other words, the features which are associated with these spermatic κινήσεις are not so-called material accidents.

[3] Skin colour is the phenotypic character in the example of the woman from Elis, which we can also use here. Cooper is certainly wrong to suggest that the differences explained by inheritance are not differences in, say, eye colour and nose shape but in the way "the tissues, organs and limbs essential to a human being… are found constituted and arranged in that particular animal" (1988, 37). Surely when Aristotle says offspring tend to resemble the members of their own family more than other members of the same species he is not referring to the way their basic internal organs are constituted and arranged. For normally members of the same species do not differ in these ways (at least not to the extent that such differences require an elaborate scientific theory to account for them).

biological forms are transmitted from one generation to another in the act of reproduction.

The basic mechanism is introduced to us in the following passage from *GA* 767b35-768a2 (cf. 768a11-14):

> Therefore, there are κινήσεις present in the seeds <of animals> derived from the δυνάμεις of all of these sorts of things [e.g. male, Socrates, Human, 767b24-6; Animal, 768a13], and in potentiality even those of its ancestors, although those of the individual are always closer.

The two central components of the mechanism identified in this text are the "κινήσεις", which are said to be present in the parents' seeds (ὑπάρχουσιν αἱ κινήσεις ἐν τοῖς σπέμασι),[4] and the "δυνάμεις" from which those κινήσεις are drawn (ἀπό τῶν δυνάμεων). (By "all these sorts of things" Aristotle means those phenotypic characters that belong to the organism insofar as it is capable of reproduction (καθὸ γεννητικόν, 767b23-9).) The main interpretive difficulty that arises in connection with *GA* 4.3 is how to understand this mechanism. More specifically, what are the "κινήσεις" and "δυνάμεις" supposed to be?[5]

I begin by entertaining (and subsequently rejecting) two possible interpretations of what Aristotle means by "δύναμις" in this passage. On the first reading δύναμις simply refers to a property which is predicated of Socrates *qua* generator (it is a logical concept). The second reading also identifies a δύναμις with a property that belongs to the generator; however, it takes Aristotle to be identifying actual bodily characteristics rather than mere logical predicates. Against these two readings I take the concept to retain its more familiar sense of active potential or causal power from *Metaphysics* Θ. On the reading I shall defend these δυνάμεις refer to the components of an organism's genetic nature, each of which is an active potential for the formation of a different part of its

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[4] Later ὑπάρχουσιν...ἐν τοῖς σπέρμασι ("present in the seeds") gets shortened to simply ἔνεισιν, as at 768a11-14.

[5] Until this question has been answered for each term I shall continue to employ the Greek as placeholders.

phenotypic nature. In this way each δύναμις is associated with its specific characteristic in the teleological sense: it is a potential *for* that property.[6]

After identifying the nature of the δυνάμεις I turn to the κινήσεις which are said to be derived from those δυνάμεις. Previous attempts to understand Aristotle's use of the concept of a "κίνησις" in connection with inheritance can be roughly divided into three main readings, each of which are rejected here. What is common to each of these is that they all identify the κινήσεις with ordinary motions or changes in some sense. The first reading (which is the standard interpretation from the previous chapter) identifies the κινήσεις with the informative motions *of* Socrates' sperm as it literally shapes the matter into parts of the offspring. On the second reading the κινήσεις in question are not informative motions of the sperm itself but the changes initiated in the menstrual blood by the sperm (those that make up the embryo's development into its adult form). A third reading takes the κινήσεις to be the same motions and changes that make up the process of development; however, it identifies them with things carried into the female inside the sperm. On this reading the father's sperm "imports" changes into the menstrual blood which immediately set to work building that material into a new organism of the same shape and form.

On the reading I shall propose, the κινήσεις are not ordinary motions and changes in any sense but specialised vehicles of inheritance carried inside Socrates' sperm: they are the vehicles through which his heritable form is physically transmitted to the offspring in the act of reproduction. Although I shall argue that in using the word "κίνησις" to refer to a vehicle of inheritance Aristotle extends its meaning well beyond any familiar sense of motion or change, it is not peculiar to the theory of inheritance. We also find the concept being used in this way in the account of sense perception in *GA* 5.

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[6] By saying these are potentials *for* specific characters I mean that their activation during development initiates a change (or set of changes) that terminates in those characters. They are not the potential of matter to *become* those characters.

§3 The "δυνάμεις"

Just prior to 767b35-768a2 Aristotle remarks on his use of δύναμις: "I speak of each 'δύναμις' in the following sense. The generator is not only a male but also a particular sort of male (τοῖον ἄρρεν), for example a Coriscus or a Socrates, and it is not only a Coriscus but also a human being" (767b23-6). While this certainly provides a clue as to the reproductive significance of a δύναμις, Aristotle appears to be offering nothing more than a logical analysis of the concept. If we take "the generator" (τὸ γεννῶν) as the subject, Aristotle's point in this passage is that the predicates "male", "Socrates"[7], and "human being" all belong to the generator insofar as it is capable of reproduction (ὑπάρχει τῷ γεννῶντι καθὸ γεννητικόν) and not accidentally (κατὰ συμβεβηκός). The examples of genetically accidental properties here are being a good scholar and being someone's neighbour (b26-9). Such properties are accidental to Socrates *qua* generator in the sense that they are not part of his heritable form: they are not features which are capable of being passed on in the act of reproduction. What *GA* 767b23-9 makes perfectly clear, however, is that those properties that make Socrates a unique individual (e.g. his distinctive snub nose) *are* part of his heritable form: they are among those formal properties that belong to him "καθὸ γεννητικόν".[8]

But how does this help us understand what a δύναμις is in this context? One of the meanings of "δύναμις" that Peck lists in the introduction to his translation of the *GA*

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[7] "Socrates" stands for the set of characteristics that make Socrates a unique individual, those that would make Menexenos look like him more than other human beings.

[8] We should be careful here not to take the current point too far and say that it is possible to give a *definitional* account of Socrates which includes all of his peculiar features such as his having a snub nose. It may be possible to give a fully detailed account of Socrates all the way down to his unique features. But a proper definition of Socrates will only take into account those features that belong to him *qua* human. I shall return to all of this in the final chapter.

is "distinctive characteristic".[9] This suggests that perhaps Aristotle is simply using δύναμις in a logical sense to refer to properties which are predicated of Socrates *qua* generator. On this first reading, *GA* 767b35-768a2 is simply pointing to the presence of κινήσεις in Socrates' sperm corresponding to those properties without making any claims about the actual presence of δυνάμεις in Socrates himself.

A quick glance at the text shows that Aristotle is quite clearly thinking of things which have some sort of physical (as opposed to logical) significance, things which are actually present in Socrates' body. For the δυνάμεις are supposed to be the sources of the κινήσεις in his sperm: the κινήσεις are "derived from" (ἀπό) those δυνάμεις. Moreover, the current reading takes "male", "Socrates", and "human being" in 767b23-6 to be the δυνάμεις; however, 767b35-768a2 refers to the δυνάμεις *of* these sorts of things. This suggests some sort of ontological distinction between the phenotypic characters and the δυνάμεις *of* those phenotypic characters.

Andrew Coles offers a second interpretation which attempts to preserve the identification of a δύναμις with a property of the generator's body while at the same time respecting its ontological status as the source of a corresponding κίνησις in its seed. According to Coles, by referring to the characteristics of Socrates' body as "δυνάμεις" Aristotle is assigning those bodily characteristics both phenotypic *and* genetic significance:

> …the specific characteristics which make an individual what he is are also responsible for reproducing other specific individuals…. So to describe a characteristic of Socrates as a δύναμις must be to specify its particular

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[9] Peck 1990, li (§26; cf. §27). Peck claims that Aristotle's use of δύναμις in *GA* 4.3 reflects a specialised hereditary concept (liii, (§31)); however, he does not say how we are supposed to understand that specialised use. So it is not clear whether or not Peck thinks this hereditary application of δύναμις can be assimilated to any of the more familiar meanings of the concept he discusses.

> hereditary significance as well as its phenotypic significance in characterising Socrates.[10]

On this reading the same characteristics which are displayed in Socrates' phenotype are also the δυνάμεις from which the κινήσεις in Socrates' sperm are drawn. For example, there is a κίνησις in his sperm corresponding to his snub nose which is drawn directly from his nose itself. In this sense Socrates' snub nose is both an actual part of his body and the source of a change that terminates in that same part in his offspring.

While I agree with Coles that the δυνάμεις in question are the sources of the κινήσεις in Socrates' sperm, they cannot refer to the actual parts of Socrates' body themselves. First, I am not sure that this reading leaves room for the distinction Aristotle makes between a phenotypic character and the δύναμις *of* that phenotypic character. However, even if there is a way to preserve this distinction, Coles' understanding of the concept of δύναμις here crucially depends on his assumption that Aristotle accepted the central tenet of the Hippocratic model of pangenesis, namely, that the capacity of sperm to transmit formal resemblances derives from its pansomatic origin in the parent's body. And this is extremely difficult to accept.

Coles refers to Aristotle's model as "formal pangenesis", as opposed to Hippocratic "material pangenesis". According to Hippocratic material pangenesis, the seed out of which the offspring grows is made of tiny bits of tissue drawn from each part of the parent's body.[11] Coles wants to argue that Aristotle picked up on this idea but held that instead of tiny bits of tissue the parent's genetic material contains formal "κινήσεις", though which also have a pansomatic origin. Coles takes these κινήσεις to be quite literally local motions (not *of* the sperm but (somehow?) *inside* the sperm) that preserve

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[10] Coles 1995, 73.

[11] The underlying assumption behind this theory seems to be the idea that the various tissues drawn from the parent's body have the ability to regenerate themselves (cf. 740b12-18, 741b9-10). On this theory, resemblance in skin colour would be explained by the fact that there are tiny bits of skin tissue in the parent's seed drawn directly from the parts of its body which eventually become the new skin for the offspring.

the shape and form of the parent's body.[12] His idea is this: Socrates' sperm is made from a residue of blood that has (according to Coles) travelled around to every part of his body during the nutritive cycle (viz. the residue left over at the end of that cycle). The κινήσεις which are carried inside his sperm are the very same (local) motions that the blood had undergone as it flowed around the contours of his body during nutrition; those motions are (somehow) preserved in his sperm. Once inside the female, the sperm releases its motions into the menstrual blood which then sketch out the parts of Socrates' body by retracing the path his blood followed as it travelled around his own body.[13] It is in this sense, Coles argues, that the parts of Socrates' body are δυνάμεις or sources of (local) motion: "parts can be sources or originators of movements, it seems, because blood flows around each and every part [sc. during the nutritive cycle]."

There are several reasons why formal pangenesis cannot be sustained as an interpretation of the *GA*. I shall confine myself to three.

First, it is unclear why Aristotle's arguments against pangenesis in *GA* 1.17-18 should not also apply to so-called formal pangenesis. This is especially pressing in cases where Aristotle's attacks are focused, not on the idea that what is drawn from the parts is some *material* component, but rather on the idea that anything at all should be drawn from the parts. One such argument appeals to an experiment with plants (722a11-14). Aristotle says if you pulled off the parts of a plant, pangenesis predicts that those same parts will also be absent from the offspring's phenotype. Since this is not the case, Aristotle concluded that the reproductively significant units (*whatever* those might be) could not possibly be derived from the actual parts of the parent's body. And this applies equally to formal pangenesis. Coles' reading predicts that if we amputated Socrates' legs prior to spermatogenesis, Menexenos would be born without legs. For according to formal pangenesis there will be no κινήσεις in Socrates' sperm corresponding to those amputated parts. For there are no such parts for his blood to flow around during the nutritive cycle.

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[12] This would be an example of the third reading of "κίνησις" discussed (and rejected) below.

[13] Coles 1995, 61ff.

Second, formal pangenesis is inconsistent with the text. For example, *GA* 726b9-15 is categorical that σπέρμα is formed out of an *un*distributed portion of blood: the parts of Socrates' body are nourished by the portion of blood that is distributed to them (τὸ προσελθόν) while his σπέρμα is formed out of that portion which "stays behind" in his heart (τῷ ὑπολειφθέντι) and is *not* distributed. This is a restatement of Aristotle's position, which he had set up in opposition to pangenesis back at *GA* 725a21-7:

> Therefore, we must state the opposite of what our predecessors said [concerning the nature of σπέρμα]. For while they said it is that which comes from the whole body (οἱ μέν γὰρ τὸ ἀπό παντὸς ἀπιόν), we are going to say that σπέρμα is that which naturally goes to the whole body (ἡμεῖς δὲ τὸ πρὸς ἅπαντ' ἰέναι πεφυκὸς σπέρμα ἐροῦμεν). And they said it was a colliquescence, while it is evident that it is more of a residue. For it is more reasonable to suppose that there is a resemblance between the final product that is sent out (τὸ προσιόν ἔσκατον) and the surplus of this product, just as in painting the paint left over (τὸ περιγίνεται) on an artist's pallet often resembles that which he has actually used (τῷ ἀναλωθέντι).

The "οἱ μέν τὸ ἀπό..., ἡμεῖς δὲ τὸ πρὸς..." construction that Aristotle uses in opposing his own view to that of his panspermatic rivals clearly shows that what he is rejecting is the idea that σπέρμα is formed from a residue of nutriment that is derived from the parts of the body (he rejects the pansomatic origin of σπέρμα). This is confirmed by the analogy Aristotle draws between σπέρμα and paint. The portion of blood that gets distributed to the parent's body is analogous to the paint that the artist expends on the painting. The surplus that gets concocted into σπέρμα, however, is analogous to the unused paint left behind on his pallet. And this is exactly what we are told at 726b9-15, namely that σπέρμα is formed out of a portion of blood left behind in the heart (τῷ ὑπολειφθέντι), the bit which *does not* get distributed to the body.

Finally, formal pangenesis (like material pangenesis) will not be able to account for the phenomenon of atavism, which Aristotle thinks any adequate theory of inheritance

must explain. This is the most significant for my purposes here. Consider again the example of the woman from Elis (which Aristotle uses in Book I to undermine pangenesis). The woman from Elis, who was pale skinned, had a daughter with a man from Ethiopia, who was dark skinned. Their daughter (call her Hypatia) was pale skinned, but her son was dark skinned. What needs to be explained is how Hypatia is able to generate a dark-skinned offspring. Aristotle's theory explains this by pointing to a κίνησις in Hypatia's seed derived from a corresponding δύναμις in herself (in accordance with 767b35-768a2). Obviously the δύναμις which is the source of that dark-skinned κίνησις does not refer to an actual characteristic of Hypatia's body (even less could it refer to the actual characteristic of her father's body!).

Any one of these three arguments would be sufficient to show that Aristotle rejects the idea that the reproductively significant units in an organism's genetic material, which for Aristotle are the κινήσεις, are derived from the parts of its body. Accordingly, the corresponding δυνάμεις from which the spermatic κινήσεις are derived cannot be those parts themselves.

Morsink offers a third possibility for understanding what the δυνάμεις in our text might be. According to Morsink a "δύναμις" is not an actual phenotypic character but the causal power behind that character (presumably the power to produce that part of the organism).[14] Though I think Morsink goes too far in calling these δυνάμεις "the most basic components of an organism",[15] this interpretation at least takes us in the right direction. For it recognises an ontological distinction between an organism's bodily characteristics and the δυνάμεις *of* those characteristics. This distinction is critical for accommodating Aristotle's rejection of the panspermatic thesis that the units of inheritance are drawn directly from the parts of the body themselves. For example, since the δυνάμεις in Socrates are not the actual parts of his body, there is nothing preventing

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[14] Morsink 1982, 134. Morsink compares the phenotypic characters of an organism to symptoms of underlying causes and argues that what we find here is one of the earliest recognitions of the difference between phenotype and genotype.

[15] Morsink 1982, 134-5. I return to this below.

Aristotle from postulating a set of δυνάμεις corresponding to the parts of his ancestors. Moreover, Aristotle's account is not vulnerable to the objections raised by his plant experiments. For the κινήσεις in an organism's genetic material are derived from the δυνάμεις of its parts which are ontologically distinct from the actual parts themselves. As such, removing the latter will not have an effect on the outcome of reproduction.[16]

The reading I shall defend here can be seen as building on Morsink's insight. Following Morsink, I shall take "the δυνάμεις of all these sorts of things" to refer to the productive sources of an organism's formal characteristics, not only those that make up its own observable form, but also those that correspond to various properties of its ancestors (which are not displayed in its observable form). I want to argue that these δυνάμεις are in fact components of the organism's genetic nature, each of which is a separate potential for the formation of a specific part of its phenotypic nature.

There are two problems with Morsink's reading that my interpretation seeks to avoid. First, Morsink takes the δυνάμεις in question to be the reproductively significant units which are carried inside Socrates' sperm.[17] However, 767b35-768a2 is quite explicit that what is transmitted in Socrates' sperm are not the δυνάμεις but κινήσεις derived from those δυνάμεις. So the δυνάμεις in question must refer to entities located in Socrates' body (which are nevertheless distinct from the bodily characteristics for which they are δυνάμεις). Second, it is entirely unclear what Morsink means by calling the δυνάμεις the "most basic" components of an organism. One way we might cash this out is in terms of teleological priority. On this reading *x* is a more basic component of an organism than *y* if *y* is present for the sake of *x*. Given the general priority of the

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[16] Although Morsink argues that by associating the characteristics of Socrates' body with δυνάμεις Aristotle has extended the concept of δύναμις well beyond its ordinary use, he essentially takes these to be active potentials or causal powers. And this is one of the familiar senses of δύναμις from Θ (assuming that by saying a δύναμις is the "power behind" a given phenotypic trait Morsink means, as I do, the productive source of that trait).

[17] Morsink 1982, 135.

phenotypic nature over the genetic nature, the δυνάμεις will not be "more basic" than the phenotypic characters for which they are δυνάμεις in this teleological sense. For the former are present in the organism's genetic nature *for the sake of* generating those characters. Morsink's reading, on the other hand, suggests that the phenotypic characters themselves are instruments of the δυνάμεις and are only present in an organism because they are necessary for propagating those more basic entities.[18]

It is important to note also how my interpretation differs from formal preformationism. On the latter reading the δυνάμεις that pre-exist in the embryo will be the offspring's potential parts. These potentialities are exhausted or used up as they develop into actual parts. However, the κινήσεις which are present in the adult organism's seed are supposed to be derived from those same potentials (ἀπό τῶν δυνάμεων). On my reading the potentials which pre-exist in the embryo are not used up in the course of development but preserved in the adult organism as the components of its genetic nature.[19]

The δυνάμεις that comprise an organism's genetic nature will play two distinct roles in Aristotle's ontogeny. In the first place, each δύναμις serves a developmental function in the embryo as the primary source of a change that terminates in some part of its phenotypic nature.[20] However, we also know that there are κινήσεις in the seed of the adult organism which are derived from these δυνάμεις. Thus in addition to their

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[18] This is the view of the relation between phenotype and genotype advocated by Dawkins (see chapter two, note 64). Gotthelf argues for the view that the phenotypic characters are only present in an organism because they are the products of entities (the δυνάμεις) whose own existence is taken as *epistemologically* basic (1987, 232-3). I shall return to this in chapter seven (see §4).

[19] Compare Furth 1988, 119.

[20] See note 6 above. This does not mean that each potential in the creature's genetic nature actually *does* generate a part. Some of them (namely those corresponding to ancestor traits) will not be activated during development and thus will not be expressed in the offspring's phenotype.

developmental function, each δύναμις of the adult's genetic nature plays a major role in reproducing its phenotypic nature in another organism. I shall develop this interpretation further once we have a clearer picture of the nature of Aristotle's spermatic κινήσεις.

§4 The "κινήσεις"

Having determined that "the δυνάμεις of all these sorts of things" are the active potentials that make up an organism's genetic nature, the next thing to determine is the nature of the spermatic "κινήσεις" which are said to be derived from those potentials.

The most common interpretation of *GA* 4.3 takes the κινήσεις in Socrates' sperm to be the motions *of* his sperm as it fashions the parts of the offspring's body out of menstrual blood.[21] Although it is extremely tempting to read the text in this way (especially given the fact that Aristotle refers to them as αἱ κινήσεις αἱ δημιουργοῦσαι) we have already seen that this cannot be what Aristotle has in mind. For he insists that the offspring is responsible for the construction of its own body (save its heart).

A second interpretation, suggested by Morsink, identifies the κινήσεις in question with the actual motions and changes that make up the process of development. On this reading the "movement" corresponding to Socrates' nose is just the development of a nose.[22] The picture Morsink has in mind thus looks something like this: Among the potentials that make up Socrates' genetic nature is a potential for the formation of a snub nose (of which his own nose is a product). During reproduction this potential (or a copy

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[21] This is how Cooper and Furth read the text.

[22] See Morsink 1982, 133: "the movements (κινήσεις) which cause the parts to develop from the embryo come from these δυνάμεις." Peck also appears to hold this reading (e.g. 1990, lii-liv (§29; §31; §35)). In the previous chapter I treated reading 1 and 2 as roughly equivalent. However, we can now see that they differ insofar as reading 2 does not take the κινήσεις that build the embryo to be actual formative movements of the father's sperm. Rather, each κίνησις refers to the development of a specific part of the offspring's body which occurs independently of the action of the sperm. In this way reading 2 (unlike reading 1) is consistent with claim that the embryo is responsible for the construction of its own body.

of it) is transmitted to the female inside Socrates' sperm.[23] Once inside the menstrual blood, that potential initiates a change which terminates in a snub nose resembling Socrates'.

While I think this picture is right insofar as the changes that physically transform the embryo into its adult form are initiated and controlled by a corresponding set of potentials in the embryo itself (the components of its own genetic nature), these cannot be the κινήσεις Aristotle has in mind in 767b35-768a2. For those κινήσεις are said to be present in Socrates' sperm (ὑπάρχουσιν αἱ κινήσεις ἐν τοῖς σπέμασι; 768a11-14, b7-8: ἔνεισιν) whereas the motions and changes that make up the process of development are located in the menstrual blood.[24]

Whatever the spermatic κινήσεις turn out to be, Aristotle is clearly referring to things which are present *inside* Socrates' sperm (presumably) while in transit into the female. This suggests a third possibility: the sperm acts as a vessel for carrying the motions and changes that make up the process of development into the female.[25] Although there are some texts that might suggest this (e.g. *GA* 734b7-9, 737a18-24), this interpretation encounters several problems.

Aristotle tells us that there are both actual and potential κινήσεις in the sperm. At 768a11-14, for example, we are told the κινήσεις of the father and of the universals are present "in actuality" while those of the ancestors are "in potentiality" (cf. 767b35,

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[23] Morsink 1982, 135.

[24] While I take ἡ τοῦ ἄρρενος κίνησις at 767b18 to be the process of development initiated by the sperm, this is not identical with ἡ ἀπό τοῦ ἄρρενος κίνησις at 768a28. The latter is a κίνησις in Socrates' sperm derived from a corresponding potential in his body, whereas the former is a change occurring in the embryo (it is the development *of* the embryo into a male). And Aristotle denies that the sperm is the thing that undergoes development. Eventually I shall offer a picture of how I think this whole mechanism works that accommodates this reading of 767b15-20.

[25] Balme 1972, 157; 1987a, 281-2; 1987b, 292; King 2001, 29; Coles 1995. I eventually reject this.

768b5-7).[26] Any reading that identifies these κινήσεις with ordinary Aristotelian changes thus runs up against the following problem. An ordinary Aristotelian change is a process whereby a material subject, in this case the sperm, changes from one thing into another. However, Aristotle denies that the sperm is the subject of change. It is not the thing that develops into the adult at the end of the process (see esp. *GA* 1.21). This means that the actual κινήσεις in Socrates' sperm cannot be actual (or even potential) changes *of* his sperm.[27]

One might respond here by suggesting that the κινήσεις in Socrates' sperm are the changes that *cause* the parts of the embryo to develop and that these simply do not produce their *effects* until they are installed in the menstrual blood.[28] However, talk of changes that "cause" the parts to develop is misleading. The change and the process of development do not stand to one another as cause and effect. Rather, the process of development *is* the change. And it is equally misleading to talk about the process of development independently of the thing which is in the process of developing. For we cannot separate a process of change from the subject of that change.[29] The point is that

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[26] I shall explore this in the next chapter.

[27] In the previous chapter I argued that the mother also supplies a set of spermatic κινήσεις which have the same hereditary function as their paternal counterparts (whatever that function turns out to be). As such, we can extrapolate the conclusions of the present chapter to the spermatic κινήσεις in Xanthippe's menstrual blood. I have been speaking exclusively in terms of the father's spermatic κινήσεις since it avoids confusion. For in the case of the mother we would have to distinguish between the actual changes *of* her menstrual blood (those that constitute the process of development) and the spermatic κινήσεις *in* her menstrual blood (assuming her spermatic κινήσεις are supplied through her menstrual blood). Since the father's sperm does not undergo developmental changes, this confusion does not arise.

[28] cf. Morsink 1982, 133.

[29] See *Physics* 3.3, 200b32: "There is no such thing as change over-and-above the things [sc. the subjects of change]"; 201a1-3: "Hence, neither will motion and change have

Socrates' sperm cannot contain actual changes which are not actual changes *of* his sperm. And this is something Aristotle denies: the menstrual blood, *not* the sperm, is the thing that changes into the offspring.

So if the κινήσεις carried in Socrates' sperm are ordinary Aristotelian changes at all, then they must be changes of Xanthippe's menstrual blood (not changes of Socrates' sperm). But this leads to even more difficulties. First, it makes no sense to say that there are *actual* changes of Xanthippe's menstrual blood inside (ἔνεισιν) Socrates' sperm. So at best we could say his sperm carries *potential* changes of Xanthippe's menstrual blood into her womb. But this still leaves the *actual* changes in the sperm unexplained. Second, the potential changes would have to be separable from Socrates' sperm (the vessel that carries them). For those potential changes have to be transferred *from* the sperm *into* the menstrual blood in order to become actual changes of the menstrual blood. But in that case we are no longer talking about ordinary Aristotelian changes. For ordinary Aristotelian changes cannot be separated from their subject in this way.

It seems that the best we can do with reading 3 is to take the κινήσεις in Socrates' sperm to be some special kind of pre-packaged bundle of changes that the sperm imports directly into the menstrual blood. Development on this reading would be the process whereby those different packets of preset changes gradually manifest themselves as changes of the menstrual blood.[30] However, again we would no longer be talking about ordinary Aristotelian changes. (Moreover, this still leaves the actual κινήσεις in Socrates' sperm unexplained, since "preset" changes would be potential changes.)

So far I have considered three possibilities for what the spermatic κινήσεις in *GA* 4.3 could be:

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reference to something over-and-above the things mentioned; for there is nothing over-and-above them". See also *Metaphysics* Z1, 1028a20-31.

[30] This seems to be Balme's view. For example, Balme (1987a) talks about "continuing changes" being transmitted from the father's body to the menstrual blood inside the father's sperm (282). Gradually these "latent movements" are said to "become actualized into bodily parts as growth proceeds".

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Introduction

This study is divided into two parts. In the first part I examine Aristotle's concept of the "organism" and its role in his account of embryonic development. In the second part I turn to the question of how exactly an organism's form is passed on to its offspring in the act of reproduction. What are the mechanisms underlying the transmission of biological form? Although I shall draw on several texts in the Aristotelian corpus, the primary focus of this study is Aristotle's ontogeny as presented in the *Generation of Animals*.[1]

Chapter one addresses what has come to be seen as the fatal paradox of Aristotle's natural teleology.[2] The paradox in question is supposed to arise from Aristotle's claim that the "nature" of a biological substance (or organism) is *both* the source *and* end of its development: it is the internal principle of motion that directs the process of development towards the adult form *and* the form of the creature when fully developed. Thus it would appear that one and the same thing ("nature") is the cause of its own existence, which is absurd. By way of introduction to the main project of part one I consider – and subsequently reject – one of the more popular interpretations of Aristotle's ontogeny, what I call "formal preformationism". According to this interpretation, Aristotle holds that the offspring's adult form pre-exists in the embryo in a state of potentiality. On this reading development becomes the gradual actualisation of a pre-existing potential form, which is transmitted to the embryo inside the father's seed.

In chapter two I develop an alternative solution to the paradox of teleology suggested by a key passage in the *Parts of Animals*. There Aristotle divides "nature understood as substantial being" (formal nature) into "nature as mover" and "nature as end" (641a27-33). What I argue is that these two natures are numerically distinct principles that stand to one another as cause and effect. Straightforwardly, nature "as end" is the adult form at the end of development while nature "as mover" is the moving cause that directs the process towards that end. Finally, I argue that by

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[1] The second half of this study is focused almost exclusively on the *Generation of Animals*, while part one is a more general philosophical discussion.

[2] This same paradox has been addressed most recently in King 2001. My own discussion of the paradox of teleology arises in part out of a dissatisfaction with King's solution.