Introduction

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πῶς δ᾽ ἄν᾽ κε γένοιτο; εἰ γὰρ ἔγεντ᾽, οὐκ ἔστ᾽, οὐδ᾽ εἴ ποτε μέλλει ἔσεσθαι.
τὼς γένεσις μὲν ἀπέσβεσται καὶ ἄπυστος ὄλεθρος.
(How could [what is] come to be? For if it came into being, it is not: nor is it if it is ever going to be in the future. Thus coming to be is extinguished and perishing unheard of.)

Parmenides, from Simplicius, *In Phys*. 78, 5; 145, 5, 19–21.

οὐσια δε ἐστιν ἡ κυριώτατά τε καὶ πρώτως καὶ μάλιστα λεγομένη, ἣ μήτε καθ᾽ ὑποκειμένου τινὸς λέγεται μήτ᾽ ἐν ὑποκειμένῳ τινί ἐστιν, οἷον ὁ τὶς ἄνθρωπος ἢ ὁ τὶς ἵππος.
(Substance in the truest and strictest, the primary sense of that term, is that which is neither asserted of nor can be found in a subject. We take as examples of this a particular man or a horse.)

Aristotle, *Categories* 2a 11–14.

At first glance, the unifying theme of the essays collected here may easily appear to the historian of philosophy to reside in one of the narrower alleyways of this history and certainly not along one of its grand avenues. By the nineteenth century, to be sure, embryology had come into its own as an area of scientific investigation, one whose questions were to be answered by experiment and whose answers were not seen as granting insight into any deep and timeless philosophical mysteries.

The perception could not have been more different in classical Greek thought. Parmenides, for example, offered perhaps the most hard-line formulation of a widespread pre-Aristotelian conviction that whatever *comes to be* can never really be said to be at all. Plato shared in this view, to the extent that for him particular creatures, like you and I, are approximations of what truly is, and what truly is is, among other things, eternal and unchanging. A significant aspect of Aristotle's revolutionary stance vis-à-vis his forebears

consisted in his rejection of the absolute dichotomy between being and becoming, between that which fully is and that which can never quite get there. For Aristotle, through matter as the vehicle of change, what at one point existed merely potentially can at a later point exist actually – and thus generable entities, like horses and men, are thought by Aristotle to participate fully in being, to be *ousiai* or substances in the truest sense.

But if the door be opened to coming-into-being, and if entities such as horses that earlier did not exist and now do are to be granted the status of full-fledged beings, then it is not hard to see why attention would soon turn to the details of biological reproduction – for here something of tremendous metaphysical significance takes place, and it behooves any philosopher, such as Aristotle, who bites the bullet and admits that horses *are*, to determine how it is they got to be that way, that is, to determine what takes place at the moment of conception and in the subsequent stages of fetal development that brings about this ontological event consisting in the addition of one more entity to the list of what there is. Thus, the horses and men cited as examples in the *Categories* are the same horses and men that figure, along with all the eels, fish, testacea, etc., in *On the Generation of Animals*. In the one work, it is simply posited that this is what is meant primarily when one speaks of *ousia*; in the other, Aristotle sets about explaining, by careful observation of minute details – if not by experiment in the sense of modern science – how it is that these creatures attain this status.

What we would like to show in this volume – with each contributor doing so in a very different way – is that even in the early modern period embryological investigations, no matter how much they were motivated in many respects by a fierce rejection of Aristotelianism, remained Aristotelian at least to the extent that their results were seen as bearing on a cluster of distinctly philosophical questions inherited from the Greeks concerning the nature and origins of substances or beings. The name by which the study of animal reproduction and fetal development was called up through the eighteenth century, the "science of generation," reminds us of its philosophical legacy. This volume has as its concern the way in which the early modern science of generation, which included the study of animal conception, heredity, and fetal development, influenced the contemporaneous treatment of traditional philosophical questions, and, conversely, the way in which philosophical presuppositions about, for example, mechanism, substance, and cause, informed the interpretations offered by those conducting empirical research on animal reproduction.

In this brief introduction, we shall seek to sketch out in somewhat more detail how the distinctly philosophical problem of animal generation emerged

in classical Greek thought, how it developed over the course of the next several centuries, and, finally, how it was addressed in the early modern period by thinkers who shared some of the same concerns the Greeks had but also came to have several of their own, new questions about the nature and mechanisms of generation.

1. ARISTOTLE AGAINST THE PANGENESISTS

In ancient generation theory, much effort was devoted to discovering the nature of semen or seed (in Greek, as in Latin and French, there is no distinction between the two terms). The seed of a thing was presumed to be its first cause, that beyond which one could not inquire about the thing's coming into being. Two questions dominated the discussion of semen:

1. Does each of the parents contribute semen or only one of them?
2. Does the semen originate in a certain part or system of the body or does it originate from all parts?

Aristotle's great legacy in the history of generation theory is a result of his firm answers to both of these questions: As regards the first, he maintained that only the father contributes semen while the mother contributes only matter for the fetus's body. As regards the second, Aristotle maintained that the semen does not come from all parts of the body, as had the Hippocratics. The two issues are intimately connected for Aristotle. Pangenesists – those who thought that semen must come from all parts of the body – believed that it contained miniature particles or traces of all of the bodily organs and even of the particular features of each parent's face, skin, etc. This was the only way, they presumed, that a creature's resemblance to its parents could be explained. But if this materialist account of like begetting like was correct, then, as Aristotle perceived, the mother would have to contribute particles of her face, skin, bones, etc., as well. Thus, for Aristotle the rejection of a maternal semen stands together with the rejection of pangenesis.

Darwin, in offering his own pangenetic theory of "cell-gemmules," traced the theory back to Hippocrates, and indeed is the one who introduced the term "pangenesis" in the 1860s. 1868. Among ancient writers, the theory enjoys its most complete articulation by Aristotle, who in *On the Generation of Animals* offers an account of it only in order to argue against it. Aristotle himself sees the theory as distinctly atomistic and attributes it, as did other ancient thinkers, to Democritus. Hippocratic pangenesis is rooted in the theory of the four humors. Blood, gall, mucus, and water are extracted from all parts

of the bodies of both the mother and father in order to combine as semen. Inherited illnesses, like illnesses in the parents, arise from an imbalance of the humors. We do find some reference in the Hippocratic corpus to the separation off of "hard" (πυκνόν) and "soft" (ἀραιόν) particles from the parents' body parts that enter into the constitution of the semen; but it was the atomistic version of pangenesis offered by Democritus that rooted the theory in distinct physical units, the true forerunners of Darwin's gemmules.

For Democritus, writing in the fifth century BCE, atoms are infinite in number and of the smallest conceivable mass, and each has its own unique figure. As Aristotle understands Democritean atomism, atoms and the void together constitute the material cause of all things. All modification of things in the world can be traced back to three basic ways in which atoms in the void can differ from one another: shape, arrangement, and position (*Met.* A 4 985b4). Aristotle, as reported by Simplicius, worries that on this pared-down view of the variety of nature, atoms might be able to become entangled and cling closely to one another but could certainly never "form one substance . . . in reality of any kind whatever; for it is very simple-minded to suppose that two or more could ever become one" (*De caelo* 295, 11; KRS 425 f.).

In sum, pangenesis theory is well able to account for the fundamental problem in ancient thinking on generation concerning the resemblance of offspring to parent, for in a very literal, physical sense, the developing fetus begins from a number of chips off the old parental blocks. There is no lingering mystery of how, to speak anachronistically, "information" about the traits of the parents is conveyed to the fetus; the traits of the parents are conveyed directly rather than being somehow encoded and then recreated out of a material that, while from one or both of the parents, does not in any way resemble the parts of the parents that the offspring will later, evidently, share by way of replication. What pangenesis could not do, though, is ensure the sort of substantiality or true being that Aristotle believed needed so urgently to be secured for all those creatures subject to generation and corruption. It is not surprising, then, that pangenesis enjoys its greatest revival in the mechanism of early modern thinkers such as Gassendi and that it retreats from view only after the rise of Mendelian genetics and the development of an account of the inheritance of traits in terms of genetic information.

But if pangenesis is rejected, as in Aristotle, and if it is determined that the semen comes from the male alone, there is still the question as to the particular system of the male body from which the semen is extracted or concocted. The three most common options were the encephalomyelogenic seed doctrine, the

hematogenic seed doctrine, and the pangenetic seed doctrine.[1] The pangenetic theory, as we have seen, has it that the differentiated organism can only develop from seed if the seed actually contains traces of each of the bodily organs. According to another view, the male semen is a product of the brain and bone marrow, which were seen in ancient medicine as part of one and the same bodily system. This view is attributed to the Pythagoreans; a succinct aphorism preserved by Diogenes Laertius has it that "the semen is a drop of the brain [τὸ δε σπέρμα εἶναι σταγόνα ἐγκέφαλου]."[2] The hematogenic theory, in turn, identifies the blood as the source of sperm.

Aristotle was a hematogenesist who believed semen to be a concoction out of the blood produced in the male body, but not the female, due to the greater heat of the former. Significantly, in this connection, the semen is not for Aristotle of a totally different kind than the female's menstrual blood; it is simply more refined by the male heat and thus a suitable vehicle for the *pneuma* that will ultimately impart the form to the mother's menstrual blood and set fetal development in motion. Aristotle himself understood hematogenesis first and foremost as constituting a part of his extended argument against pangenesis. For Aristotle, again, pangenesis had to be refuted lest the essence of the individual human substance amount to a mere coming together of material parts rather than being identified with the form.

For Aristotle, the bodily material is contributed exclusively by the female's menstrual blood. The male contributes, through the material vehicle of the semen, a source of change, the *pneuma*, which prompts the blood to form into a being of a certain kind. There is no material within the semen that combines with the menses to bring about a new material being; rather, the *pneuma* possesses an inherent warmth that stimulates growth in the way that sun brings about growth in plants. As Aristotle explains, "[T]he body of the semen, in which there also comes the portion of the soul source . . . dissolves and evaporates, having a fluid and watery nature."[3] The semen carries the immaterial soul source, delivers it to the menses, and, having done its job, simply disappears.

In this connection, Aristotle has occasion to deny explicitly the actual preexistence of the future numerical individual in the semen, arguing instead that the individual can only potentially preexist: "And has the seed soul or not? The same reasoning applies to it as to the parts. For there can be no soul

[1] For a detailed discussion of these different theories, see Erna Lesky, *Die Zeugungs- und Vererbungslehren der Antike und ihr Nachwirken* (Mainz: Steiner, 1951).
[2] Ibid., 1235.
[3] *On the Generation of Animals* II 3 737a 8–12.

in anything except in that of which it is in fact the soul. . . . Clearly therefore it does have soul and exists potentially."[4] Aristotle's theory of potentiality enabled him to believe in a sort of preexistence that did not require the actual form of the future individual to be there and localizable in either of the parents. Instead, what preexists for Aristotle is the kind, say, humanity as such, and this kind only yields a particular human once the semen goes to work on the portion of matter contributed by the mother.

The result of the male's contribution is what Lennox calls *formal replication*, whereby the offspring reproduces its progenitor in kind though not in number.[5] Aristotle holds that, at least in sexual, nonspontaneous generation, particular individual substances reproduce their kind – but not themselves – because this is, in a sense, as close as they can get to sustaining themselves in existence. Perpetual generation of a kind by the individual members of the kind is the next best thing to eternity for each and every creature. The capacity for reproduction softens the misfortune of death. In other words, although absolute being is best, since some things "are too far removed from [this principle]" God has instead "filled up the whole in the only way that remained by making generation perpetual. This was the way to connect being together as much as possible, since coming to be continually and generation are the nearest things there are to being."[6] The closest thing to being that the individual primary substance can attain is a temporal, finite, embodied being; and just what it is to be a substance is to be a perishable, embodied soul, a soul no more capable of eternal existence independent of the body than, as Aristotle suggests in one memorable passage, a wax impression is capable of existence independent of the wax.[7]

2. GALEN'S TWO-SEED THEORY AND AVICENNA'S SYNTHESIS

If Aristotle's greatest battle in the debate over generation concerned the origins of semen within the body, setting himself up in opposition to Democritus and others, the third-century physician and philosopher Galen would set himself up, in turn, in opposition to Aristotle on the question whether one or both parents contribute seed. Galen would maintain that both parents are capable of contributing a formal principle to the development of the fetus, in contrast to Aristotle, who, again, thought the mother alone could contribute matter.

[4] Ibid., 735a 5–10.
[5] Ibid., 731b 35.
[6] *On Generation and Corruption* 336b 25–35.
[7] *On the Soul* II 1 412b 5–10.

Galen had more thorough anatomical knowledge than did Aristotle, as a result of his extensive observation of the internal parts of dissected animals. For better or worse, Galen was prevented from investigating human corpses by prevailing social taboos, and some of his errors concerning human anatomy result from excessive extrapolation from what he saw in pigs and Barbary apes to what he assumed would appear likewise within the forbidden human body. Most seriously, he mistakenly identified a fluid – the actual nature of which remains in dispute – in the "horn" of a Barbary ape's uterus as the female semen and presumed that such would be found in other similar species as well.[8]

In *On the Usefulness of the Parts of the Body* and much more extensively in *On Semen*, Galen elaborates a theory according to which the maternal semen is a residue of concocted blood, but is nonetheless distinct from the menstrual blood that Aristotle had thought was the sole contribution of the mother to generation. According to Galen, both parents are capable of contributing form – for seed remains for him, as it had been for Aristotle, the formal principle of generation. Galen saw this sort of equal partnership as the only way to account for the obvious fact that offspring are just as likely to resemble their mothers or their maternal ancestors as they are their fathers or their paternal kin.

Nonetheless, it would not do to overemphasize Galen's egalitarian view of animal generation. He believes that sexual difference is reducible to thermal difference: women are naturally colder than men and thus smaller, less hirsute, and have internal rather than external organs of generation (in men the organs are forced out by heat). The female testes (i.e., the ovaries) are thus smaller and their seed is less perfect, indeed so imperfect as to need the efficient-causal influence of the male seed in order for generation to take place and fetal development to commence. Of course, this is necessary for Galen, since if the female seed were not imperfect, since it is already in the womb, female animals would be able to generate on their own and males would become superfluous. Still, the attribution to the mother of any responsibility for the contribution of form to the offspring constitutes a significant departure from Aristotelian generation theory.

Both Aristotle and Galen held tremendous authority in the context of medieval Islamic medicine and natural philosophy. While a vast number of treatises were written in Arabic on the subject of generation, one of the most significant authors in this tradition to take on generation, and certainly the

[8] C. G. Kühn, *Galeni Opera Omnia* (Leipzig: C. Cnobloch, 1821–33, rpt. Hildesheim, 1965), 4: 600–1.

one who would turn out to have the most influence in the Latin tradition, was the eleventh-century Persian philosopher Avicenna. Avicenna's great accomplishment was to bring about a synthesis of Aristotle's and Galen's generation theories.[9]

Avicenna was impressed by what he perceived as Galen's greater authority in questions of anatomy, including the question concerning the function of the ovaries, but he was nonetheless committed in his natural philosophy to an Aristotelian picture that fundamentally distinguishes between form and matter and that assimilates the male principle to the former and the female to the latter. Avicenna's resolution of this conflict was to adopt Galen's two-seed theory but to fundamentally transform the notion of "seed," so that ultimately the maternal seed does nothing more than the menstrual blood had in Aristotle's picture.

From the eleventh century up to the sixteenth, first in the Arabic world and ultimately in the Latin West as well, Galen would reign supreme in medicine while Aristotle would be considered the authority on the great majority of questions of natural philosophy. As Jim Lennox discusses in Chapter 1 of the present volume, the Paduan school of medicine in the sixteenth century would constitute an exception to this general division of authority. In the work of Hieronymus Fabricius d'Acquapendente and others, an intense effort was undertaken to bring about an Aristotelian renaissance in the study of the parts, motion, and generation of animals. One of the most prominent students of this school was William Harvey.

3. THE BEGINNINGS OF MODERN GENERATION SCIENCE

Harvey is credited with the motto "Ex ovo omnia," and it is often assumed that the claim that all things come from an egg amounts to an explicit rejection of the theory of spontaneous generation. The real insight motivating the claim, though, was that many more entities in nature qualify as "eggs" than had previously been assumed:

> We, however, maintain (and shall take care to show that it is so), that all animals whatsoever, even the viviparous, and man himself not excepted, are produced from ova; that the first conception, from which the foetus proceeds in all, is an

[9] For a very good and significantly more detailed account of Avicenna's generation theory, see Basim Musallam, "The Human Embryo in Arabic Scientific and Religious Thought," in *The Human Embryo: Aristotle and the Arabic and European Traditions*, ed. G. R. Dunstan (Exeter: University of Exeter Press, 1990), 32–46.

> ovum of one description or another, as well as the seeds of all kinds of plants. Empedocles, therefore, spoke not improperly of the *oviparum genus arboreum*, "the egg-bearing race of trees." The history of the egg is therefore of the widest scope, inasmuch as it illustrates generation of every description.[10]

The difference between oviparous and viviparous animals, for Harvey, is just that the former "have their beginning within their parents, and there become ova, . . . [while it is] beyond their parents that they are perfected into the foetal state."[11] Viviparous creatures, on the other hand, "have their completion in the uterus itself." Finally, for Harvey the difference between spontaneous and nonspontaneous generation is not so great. He agrees with Aristotle that, in his own words, nature can allow to "take place by chance or accident [things] which otherwise are brought about by art," so that whether creatures derive their first matter from "putrefaction, filth, excrement, dew, or the parts of plants and animals," there is nothing fundamentally different going on.

> [M]any animals, especially insects, arise and are propagated from elements and seeds so small as to be invisible (like atoms flying in the air), scattered and dispersed here and there by the winds; yet these animals are supposed to have arisen spontaneously, or from decomposition because their ova are nowhere to be found.[12]

In the same chapter, Harvey suggests that conception is a sort of "contagion" and that it is of little import whether contagion spreads through the air or whether it is sexually transmitted.

Still working within the framework of Aristotelian substantialism, thinkers such as Harvey developed theories of what may be called microsubstantiality: the view that there are vastly more true, fully real, particular primary substances or individuals than meet the eye, indeed, than Aristotle had ever dreamed. This discovery had an important influence on the way people thought about the question concerning the ultimate starting point of generation and in fact seems to have motivated many to turn away from the Aristotelian commitment to a starting point for the existences of particular primary substances. Harvey identified the egg as the primordium of life and explained sexual reproduction and spontaneous generation in terms analogous to those of the reproduction of oviparous creatures. But he was unable to answer the question concerning the ultimate origins of the primordia of viviparous creatures,

[10] William Harvey, *On the Generation of Animals*, in *The Works of William Harvey*, trans. R. Willis (London: Sydenham Society, 1847), 170.
[11] Ibid., 171.
[12] Ibid., 321.

the discovery of the production of mammalian eggs in the ovaries being made centuries later (by Karl Ernst von Baer in 1827).[13]

Though Harvey's early works were written before the microscope was widely used, it was not until 1651 that he published *On the Generation of Animals*, decades after the new technology had begun to make its impact. The neologism "microscope" was coined by Johan Faber in 1625,[14] but Galileo had been looking through his "fly-glass," presumably as a form of recreation in between what he took to be the scientifically more important observations through the telescope, since at least 1610. Catherine Wilson reports that the Jesuit priest and *Universalgelehrter* Athanasius Kircher, who was to have a significant influence on the young Leibniz, "had microscopes in his possession by 1634."[15] Kircher devoted an entire chapter of his 1646 work *Ars magna lucis et umbrae* to the study of nature by means of the microscope. But for the most part microscopy appears to have been an activity that natural philosophers pursued in their spare time, without thinking to publish their findings in this area for the first several decades following the development of the technology that made their observations possible.

The founding document of early modern microscopy as a domain of scientific inquiry in its own right may fairly be said to be Robert Hooke's *Micrographia; or, Some Physiological Descriptions of Minute Bodies made by Magnifying Glasses*, which was not published until 1665. In this work, Hooke attributes to the microscope a significant role in opening up the secrets of nature as it really is:

> [We can add] artificial Organs to the natural, which has been of late years accomplisht with prodigious benefit to all sorts of useful knowledge, by invention of Optical Glasses. By means of Telescopes there is nothing so far distant but may be represented to our view; and by the help of microscopes, there is nothing so small, as to escape our inquiry; hence there is a new visible world discovered to our understanding. . . . By this Earth it self, which lyes so neer us, we now behold almost as great a variety of creatures, as we were able to reckon up in the whole Universe it self.[16]

Ancient medicine had treated biological individuals within or on other such individuals as outsiders. In the *On the Generation of Animals* Aristotle

[13] K. E. von Baer, *De ovi mammalium et hominis genesi* within the ovum (Leipzig, 1827). Translated by C. D. O'Malley in *Isis* 48 (1956): 148.

[14] For a nice sketch of Faber's work in this area, see Irene Baldriga, "Il museo anatomico di Giovanni Faber Linceo," in *Scienza e miracoli nell'arte del Seicento* (Milan, 1998), 82–7.

[15] Catherine Wilson, *The Invisible World* (Princeton: Princeton University Press, 1995), 76.

[16] Robert Hooke, *Micrographia; or, some Physiological Descriptions of Minute Bodies made by Magnifying Glasses* (London: Martyn & Allestry, 1665), preface. No page numbers available.