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Writing Sample

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A Dark Business, Full of Shadows: William Harvey's Analogy of Last Resort

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Abstract: In this essay, I analyze an instance of the use of an analogy as a model for understanding and explanation in early modern natural philosophy. Specifically, I am concerned with a case of a *failure of explanation*, namely, William Harvey's attempt in his (1651) *De conceptione* to explain the generation of animals (i.e., reproduction) by arguing that the womb is like the brain, and that conception happens there analogously. I argue that, because of his desire to find some speculative explanation for generation, and because of two important empirical findings he has made, Harvey is forced to resort to this analogy—no means of direct explanation are left to him. After describing in detail this analogy and Harvey's reasons for it, I turn to its evaluation and analysis. Using Mary Hesse's (1966) notions of positive, negative, and neutral analogies, I argue that Harvey's analogy is a failure on its own terms and in its own historical context. Indeed, the historical record shows almost no interest in this analogy by scientists or historians from Harvey's period onwards—Harvey's is an analogy of last resort. I conclude by showing how this analogy in turn forced Harvey to embed his theory of generation in a larger theological and cosmological context, wherein God's design of nature is needed to understand natural processes such as generation. In so doing, Harvey fits into a larger pattern of early modern philosophy and science, in which God becomes a central explanans in the study of life.

Keywords: analogy, early modern natural philosophy, explanation, generation, teleology, theology and science, William Harvey

Analogy has long been a mainstay of the history and philosophy of science.[1] Some have suggested that analogies are useful for scientific discovery,[2] or that they are an essential component of scientific theories,[3] or that they are used as models for understanding and explanation.[4] I am here interested in the last, but with one important modification: I am interested in a case where analogy is a mark of a *failure* of explanation, when a phenomenon is too complex, and one's explanatory resources too meager, for an analogy to be helpful—when there is no precise theory.[5] There have been few analyses of such failures, yet there is much to be learned from such instances, for it shows how scientists and philosophers confront a problem that is difficult if not impossible for them to understand. The histories of philosophy and science are just as much histories of failure as of success.

I have three goals in this essay: first, I hope to understand the details of an interesting case of this sort of failure, what I call an analogy of last resort. I describe a specific failed[6] analogical explanation elaborated by the early modern physician and philosopher William Harvey.[7] Though best known for his work on the heart and the circulation of the blood in his (1628) *Exercitationes*

[1] I understand analogies as part of the broader category of the philosophy of metaphors and models, which is now too
[2] Duhem, Pierre (1916 [1954]), *The Aim and Structure of Physical Theory,* Princeton: Princeton University Press, 96-97. See also Bailer-Jones 2009, 51.
[3] Campbell, N.R. (1920 [1957]), *Foundations of Science,* New York: Dover Press, 129. See also: Bailer-Jones 2009, 51-52; and Mellor, D.H. (1968), "Models and Analogies in Science: Duhem versus Campbell?" *Isis* 59, 282-290.
[4] Bailer-Jones 2009, 51, who points us to J.C. Maxwell as an example of this understanding of analogy; see also: Nersessian, N.J. (2002), "Maxwell and 'the method of physical analogy': Model-based reasoning, generic abstraction, and conceptual change," In: *Essays in the History and Philosophy of Science and Mathematics,* Ed. D. Malamant, Lasalle: Open Court, 129-166. I must leave understanding and explanation unanalyzed, as to go into specifics here would take us too far afield.
[5] This is similar to what W.V.O Quine says in his (1978) "Postscript on Metaphor," In: *Critical Inquiry* 5(1), 161-162, reprinted in his (1981) *Theories and Things,* Ch.22, Cambridge: Harvard University Press.
[6] As will become clear from my discussion below, 'failed' here means a failure of the analogy on its own terms and in its own time period.
[7] Philosophers' analyses of analogies tend to be, not only on a later period, most often the nineteenth century, but also about the role of analogy in the physical sciences, e.g., Maxwell's 'lines of force' and so on. However, do see: Statile, Glenn (1999), "The Necessity of Analogy in Cartesian Science," *Philosophical Forum* 30(3), 217-232.

anatomicas de motu cordis[8] Harvey also published a treatise on the problem of animal reproduction, the (1651) *Exercitationes de generatione animalium.* In the *De conceptione,* a short treatise appended to the end of that work, Harvey employs a rather curious analogy: he argues that the womb is like the brain, and that conception happens analogously in both places. I argue that Harvey resorts to this analogy because two of his findings have, given his set of metaphysical and epistemological commitments,[9] undermined all available theories, demonstrating one philosophically interesting way in which empirical investigation and analogical explanation are linked.

Second, using the work of Mary Hesse on analogies in science, I critically evaluate Harvey's analogy, demonstrating that, despite its initial its initial plausibility and connections to the sciences of the day, it fails on its own terms and in historical context. Third and finally, I conclude by describing an interesting feature of this case, namely that Harvey ultimately turns from analogy to theology to understand the causes of generation, thus illustrating a larger pattern found in early modern natural philosophy.[10]

1.0. Problematic Findings

Two of Harvey's empirical findings are needed to understand his use of analogy: (1) that there is no matter in the womb prior to conception, and (2) that development of the fetus happens

[8] In a later work containing his letters to Riolan, the (1649) *De circulatione sanguinis*, Harvey makes a very good analogy, namely, he compares the heart to the water pump used to put out fires. Contrary to what is commonly believed, he does not make this analogy in the *De motu cordis.*

[9] One might describe these commitments as 'eclectic Late Renaissance Aristotelianism.' The best discussion of this diverse set of philosophical commitments is found in Schmitt, Charles (1981), *Studies in Renaissance Philosophy and Science,* Variorum Reprints. Further, Harvey desires to give at least some speculative explanation for generation, for reasons unknown though likely having to do with the criticism he received after failing to provide an explanation in the case of the circulation. I discuss this below.

[10] In this way, the *De generatione animalium* is a quite different work than the *De motu cordis*. See, for instance, French, Roger (1994), *William Harvey's Natural Philosophy,* Cambridge: Cambridge University Press, 43, 313-316, who comments on just this point.

part by part, over time.[11] The first, based upon dissections upon many animals performed immediately after coitus, undermined all explanations available to Harvey. These explanations depended upon there being some material present in the womb, either semen or something upon which semen acts. Since Harvey found no such material, nor any trace of the male's semen, his explanation of generation necessitated an immaterial causal transmission from the semen to the egg. Second, Harvey found that the process of development, which he termed *epigenesis*, happened in a regular order, this part coming to be, then this part, and so on, in all the animals observed.[12] Harvey thus had to explain how the fetus could be constructed in this regular and orderly manner, and here he deployed the brain/womb analogy as an explanatory model.

To set the stage, I start with the egg, for the egg is both the site of fertilization and of the construction of the embryo.

1.1. The Setup: Egg

Exercise 26 of the *De generatione* is entitled "*Quid sit ovum* (What an Egg is)." On the basis of comparative work on many sorts of animals,[13] Harvey theorized that all animals come from eggs.[14] Harvey introduces a new concept of the egg: it is the *combination* of the male and female, the first conception of the offspring. The matter of the egg is amongst the female's contributions to generation, along with a principle of growth—a soul, a formal Aristotelian nature: "An egg,

[11] I note that one might frame Harvey's observations here in terms of Kuhnian anomalies, and, indeed, this might be a profitable mode of analysis. However, as my focus is here upon analogies, and not on the status of Kuhn's account of science, I set aside these issues.
[12] Indeed, Harvey introduces the term into Latin. See Harvey 1651, Ex.45.
[13] Harvey performed dissections on many animals, including chickens, geese, ducks, parrots, deer, fish, crustacea, sheep, goats, pigs, dogs, cats and others.
[14] Though he did not use this phrase at all, later in the seventeenth century Harvey became associated with the dictum '*ex ovo omnia*', displayed prominently on the frontispiece of the *De generatione*. This dictum was extremely important to future developments in embryology, such as Regnier de Graaf's argument that human females have ovaries (*ovaria*) and not female testicles (*testes muliebres*). See: de Graaf, Regnier (1672), *De mulierum organis generationi inservientibus*

therefore, is a natural body endowed with animal power, that is, with the principle of movement, transformation, rest and conservation."[15] This principle is responsible for the egg's growth in the ovary.[16]

To understand this soul the reader must turn to Aristotle's *De anima*, since this notion of soul is Harvey's chief explanatory resource for understanding life.[17] Aristotle characterizes the soul (*anima*) as: "… the cause and principle of the living body…the soul is defined by the three ways something is called a cause: it is the cause of movement, it is the cause for the sake of which, and the soul is the cause of the living body, as its substance."[18] The soul, then, is a sort of triune cause: it is the efficient, final, and formal cause of the living body (remembering that, in natural things, the final and formal cause coincide).[19] For an Aristotelian like Harvey, the soul is the form and actuality of the living body, its very essence, the source of its capacities—nutrition, growth, sensation, and generation.[20] There are two relevant forms here, that of the mother and of the father. Parting from Aristotle, Harvey argues that because the offspring resembles the mother, the egg must

[15] Harvey 1651, Ex.26, 77. "Ovum itaque est corpus naturale, virtute animali praeditum; principio nempe motus, transmutationis, quietis, & conservationis." Due to a printing error in the first edition of this book, Ex.4 is repeated twice, and so the subsequent numbering of exercises is incorrect. Although I quote the Latin from the first edition, I have corrected the numbering.

[16] That is, the unfertilized egg of, say, a chicken grows into the shape of an egg, though no fetus is formed. See Harvey 1651, Ex.27, 88.

[17] For an excellent account and summary of Aristotle's concept of the soul and its relation to biology, see: Leunissen, Mariska (2010), *Explanation and Teleology in Aristotle's Science of Nature,* Cambridge: Cambridge University Press. This tradition of understanding life through the concept of soul was continued well through the Renaissance, and, indeed well into the eighteenth century, transformed, at this point, into what becomes known as Vitalism. Harvey's conception, however, has much more in common with Aristotle than with Stahl.

[18] I quote and translate from the edition of Aristotle that Harvey is known to have used in order to trace some linguistic connections between Aristotle, the Latin Aristotelian tradition and Harvey. Aristotle 1552, *De anima,* Lib.II, Cap.4, In: *Aristotelis libri omnes…cum Averrois Cordubensis variis in eosdem commentariis*, Volume 11, Venice, 68. "…viventis corporis causa & principium…anima secundum determinatos tres modos causa dicitur: etenim unde motus causa est & cuius causa & sicut substantia animatorum corporum anima causa." I should note that Aristotle, and Harvey, thought that plants, too, had soul, but I ignore this irrelevant complication.

[19] See: Aristotle, *Physica* Lib.II, Cap.7, Volume 4, Venice, 24ff. To review: the formal cause is the essence of the object, the efficient cause the source of motion, and the final cause the end towards which that motion acts.

[20] See *De anima* Lib.II, Cap.1. In fact, for both Aristotle and Harvey, nutrition, growth and generation are all one and the same faculty.

contain some part of her soul, her form, as well.[21] Yet this contribution from the mother is incomplete without the male's form, since an unfertilized egg creates no offspring, and so both forms are needed.[22]

Given this background, I turn to the problems Harvey's empirical research generated.

1.2. Empirical Problems: Sperm and Epigenesis

Two major problems arose for Harvey as a result of his empirical investigations. The first problem concerns the causal efficacy of the sperm: though Harvey knew the male provides semen, he never saw any trace of it in the womb after coition.[23] All Harvey knew was that, once transmitted to the female during coitus, the male's sperm—somehow—caused the egg to become fruitful without direct contact. Its action, he concluded, must be immaterial.[24] He writes:

> From the male proceeds only the procreative or molding power which renders the egg fertile but constitutes no part of that egg. For the geniture[25] which is emitted by the male…in no wise enters the womb[26] (in which the egg is perfected), nor indeed…can it by any means penetrate into such places, much less reach the ovary near the middle of the body...[27]

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[21] C.f.: Aristotle, *De generatione,* Lib.I, Cap.20, Volume 11, 213v.

[22] Harvey 1651, Ex.26, 76. "Est enim ovum, conceptus aliquis a mare & foemina proficiscens, utriusque partier virtute praeditus, ex quo uno unuum fit animal." Harvey uses 'vis' and 'virtus' interchangeably, and I render them both as 'power'.

[23] See Harvey 1651, Ex.6.

[24] Of course, because he worked without a microscope, Harvey's observations here led him astray, as Leeuwenhoek and others would show towards the end of the seventeenth century.

[25] Harvey uses the term geniture since, strictly speaking, semen is not a true seed.

[26] One must distinguish between the vulva and the womb, the latter of which is where the egg is located. Harvey's research convinced him that the male's semen could not pass from the vulva to the womb. See Harvey 1651, Exs.5-6. I use 'womb' and 'uterus' interchangeably.

[27] Harvey 1651, Ex. 26, 80. "Quippe a mare procedit duntaxat vis procreativa, sive plastica, quae ovum foecundum reddit; nullam vero ejus partem constituit. Nam genitura, quae a mare in coitu emittitur, matricem (in qua ovum perficitur) nequaquam ingreditur; nec sane…in ista penetralia ullo pacto subire potest: multoque minus ad ovarium, juxta corporis praecincturam, asscendit..." Harvey here uses the Galenic 'vis plastica' (ultimately derived from Galen's *dunamis diaplastike*), which I here translate as 'molding power' but which I take to be equivalent to the constructive power or virtue or faculty (vis/virtus/facultas opifex). In the late Renaissance and early modern periods, there were an abundance of terms referring to this and related powers, and these were understood in different ways by different philosophers. Harvey understands this power, which is responsible for the growth of the egg and the fetus, as related to soul, and not, as some more neo-Platonic writers might have it, as having to do with divine spirits or the like. See: Harvey 1651, Ex.27, 82ff; and also: Hirai, Hiro (2007), "The Invisible Hand of God in Seeds: Jacob Schegk's Theory of Plastic Faculty", *Early Science and Medicine* 12: 379.

So the male's semen imparts what Harvey calls a constructive power (*plastica vis*) that acts upon the female's womb and, from there, upon the unfertilized egg.

Importantly, Harvey found no material *whatsoever* in the womb prior to conception![28] The lack of any material in the womb presented a deep epistemological and ontological problem for *every theory of generation available*: all philosophers argued that there must be *some* material transmission of the fertilizing power of semen, as well as a material for the semen to act upon. In agreement with both Aristotelians and even most mechanical philosophers, Harvey refused to countenance action at a distance, and thus he was at a loss as to how the male's sperm fertilizes the egg. It must act immaterially, transmitted through the medium of the female's body: it must affect the female *herself*, rendering her whole uterus somehow fertile and able to transmit its fertility to the egg. Harvey writes: "…it will at the same time be apparent that everything that has been handed down to us from all antiquity concerning the generation of animals is erroneous, and that the foetus is made neither from the seed of the male nor of the female, nor from a mixture of both of them, nor is constituted out of menstrual blood…."[29] Aristotle's account of generation could not be correct, as he had argued that the matter of the fetus is provided by the female's menstrual blood.[30] And Harvey's research similarly falsified Galen's theory of the two seeds as well, along with those derived from them.[31] Thus Harvey found himself without a causal explanation of fertilization.

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[28] So, even in egg-laying animals, there is no matter in the womb that can be worked upon by the sperm after coition, since the egg does not descend until after coition.

[29] Harvey 1651, Ex.40, 109. "…clare simul apparebit, quae hactenus ab omni antiquitate, circa animalium generationem, nobis tradita fuerunt, erronea esse; foetumque, nec ex spermate maris, aut foeminae; nec ex utrisque simul mistis; neque ex sanguine menstruo constitui…."

[30] Aristotle 1552, *De generatione animalium,* Lib.I, Cap.20, Volume 6, Venice, 213v.

[31] For the edition of Galen that Harvey knew, see: Galen (1549), *De foetum formatione,* and *De semine,* In: *Galeni Peragameni…opera quae nos extant omnia*, Volume II, Basel. For a quasi-Galenic theory, though one that is in many ways very different than Galen's in its invocation of divine spirits, and, see: Fernel, Jean (1560), *De abditis rerum causa,* Paris. The latter was quite influential, not only on Harvey's work, but on many late Renaissance and early modern theories of generation.

The second problem concerns the process by which the embryo is formed. Harvey states that the fertilized egg is an intermediate sort of entity, at once an origin and an end: it is the end of the process of the interaction between male and female, yet it is also the origin of the fetus, whose own end is the completed offspring. [32] In terms of soul, the fertilized egg, with its combination of male and female forms, does not have the full actualized soul of the offspring, but is rather intermediate between animate and inanimate:

> Because soul is the act of an organic body having life *in potentia*, it is incredible that the soul should be in the chick before any part of its body has been organized. Nor is it more credible that the soul of the egg and of the chick should be one and the same soul, for the soul is the preserver of that thing only whose soul it is...[33]

Remember that Harvey conceived of the soul according to Aristotle's metaphysics: it is the actuality of the living body, and thus the soul of an offspring can only be present when the offspring is complete and living. The fertilized egg has a minimal soul, as mentioned—a vegetative soul—responsible just for growth and generation.[34] So what happens during generation is a gradual process by which the body of the offspring comes to be organized with its requisite parts and configuration, a process by which the soul of the offspring comes into actuality.

This process of soul actualization is called by Harvey *epigenesis*, and although Harvey understands it this metaphysical light, his argument for it is based upon observation.[35] Key here is

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[32] Harvey 1651, Ex.26, 76. Note that the grammar here is a bit unclear, but Harvey does not maintain, as will be discussed below, that both the male and female contribute matter; the 'of both of them' refers only to the constructive faculty. "Videtur etiam ovum medium quid esse; non modo quatenus principium & finis est; sed tanquam opus utriusque sexus commune, & ex utroque compositum: quod materiam, & facultatem opificem in se continens, utriusque virtutem habet, qua alterutri simile foetum producat. Est quoque medium inter animatum & inanimatum; neque enim vita prosus donatum est, neque eadem omnino privatur." Again, Harvey uses 'facultatem opificem' here instead of 'vis plastica' or 'virtus', but I take all these terms to refer to the same power.

[33] Harvey 1651, Ex.26, 81. "Cum anima sit *actus corporis organici vitam habentis in potentia*, incredibile est eam pullo inesse, antequam quicquam corporis ejus organisatum fuerit. Nec magis credibile, eandem esse ovi, pullique animam: siquidem anima est conservative ejus duntaxat, cujus est…." Harvey here is paraphrasing Aristotle's *De anima* II.1.

[34] And eventually, the embryo gains a sensitive soul, and, in humans, a rational soul. The latter was the subject of much debate between theologians, physicians, and philosophers, and while it is an important issue, I don't have time to discuss it here.

[35] Harvey is especially interesting because, while he is a committed Aristotelian, he does not hesitate to disagree with Aristotle (or anyone else) should his observations indicate that the truth lies elsewhere. Methodologically speaking,

one of Harvey's experiments, in which he took a number of fertilized eggs from hens, incubated them, observed them backlit by candlelight, and by opening them on consecutive days. Thus Harvey constructed a detailed picture of the way in which development progresses, and determined that this process happens part by part, over time, starting with a spot of living blood with the rest of the organs coming into being in a specific and regular order.[36] He observed that the egg, prior to development, contains no tiny preformed parts, but consists of two homogenous parts, the yellow and the white.[37] The embryo therefore moves from being an unorganized, non-functioning body to an organized, functioning body with all the requisite parts: a body with a fully actualized soul. He writes that an animal created by epigenesis,

> ...draws in the matter and at the same time prepares and concocts and uses it; at the same time that the matter is formed, it grows…the molding power divides the same homogenous matter, arranges that which is separated off and renders it into members; and from the homogenous material it makes the heterogeneous, that is to say, out of the homogenous matter given to it, it makes the heterogeneous organs. Indeed in these, while it produces different parts in their due order, and those parts diversely placed, it requires also another matter, and this it makes...[38]

This process of coming into being is very complicated: it is a process by which a part comes into existence and grows, by which, for all intents and purposes, the matter of the embryo seems to organize *itself* into parts, moving from homogenous to heterogeneous. What is more, this process happens *in due order*, which is to say, it is *regular* and *systematic*, first this part coming into being,

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Harvey's approach is an eclectic mixture of Galenic and Aristotelian doctrines, emphasizing both logical rigor and broad, comparative observations across all sorts of animals, with a good helping of the post-Vesalian belief in anatomy as central to natural philosophy.

[36] See Harvey 1651, Ex.42-45, 113-125. Harvey introduces epigenesis in Ex.45.

[37] Again, some of Harvey's observations here are mistaken because he did not use a microscope, e.g., his observation that the blood is the first part of the fetus to come into being.

[38] Harvey 1651, Ex.45, 122. "… materiam simul attrahit, parat, concoquit, & eadem utitur: formatur simul, & augetur. In illis, plastica vis eandem similarem materiam secat, sectamque disponit, & in membra redigit; facitque ex similari materia, dissimilarem; sive ex subjecta materia similari, organa dissimilaria. In his vero, dum partes alias, aliterque dispositas ordine procreat; aliam quoque, atque aliter dispositam materiam requirit, ac facit…"

then the next, always in the same order in the same sorts of creatures.[39] Thus Harvey found himself having to explain an extremely complicated, systematic and regular process.

Finding such an explanation would be a struggle for hundreds of years, made more difficult by the mechanical philosophy, where everything had to be explained by matter in motion.[40] Harvey criticizes this new philosophy on just this point, writing that:

> The usual error of those who philosophize these days is to seek the causes of the diversity of the parts from the diverse matter out of which they arise[41]…But I have refuted this exceedingly widespread error elsewhere.[42] Equally deceived are those who make all things from atoms, like Democritus, or from elements, like Empedocles. As if generation were nothing other than the separation, or the collection, or the arrangement of things. I do not indeed deny that in order for one thing to be produced from another, all these aforementioned things are necessarily required; but generation is itself distinct from all of them… Moreover, those who philosophize in this manner assign only a material cause, and deduce the causes of natural things either from a concurrence of the elements happening by design or by chance, or from diverse arrangements of atoms. They do not touch on that which is special in the operations of Nature, and in the generation and nutrition of animals: for they do not recognize the existence of the divine Agent and the deity of Nature (who work with the highest skill, foresight and wisdom, and who produce all things to some certain end or for the sake of some certain good).[43]

Harvey, showing his metaphysical and epistemological commitments to teleology and teleological explanation, notes that what is so difficult to explain in generation, and what has been entirely neglected by the new philosophers, is how such an amazingly complicated and diverse thing as the

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[39] I note that Harvey used hens as a sort of model organism for oviparous creatures, and deer as a model of viviparous ones. Thus, assuming that these creatures represent their wider classes in terms of generation, he concluded that all generation in those kinds of animals proceeds in the same manner, as he observed the same sorts of processes and entities in both model animals.

[40]Descartes' attempt to explain epigenesis within his system was viewed by most as a failure, even by his philosophical followers. For an example of post-Cartesian difficulties in dealing with epigenesis and generation, see: Des Chene, Dennis (2003), "Life after Descartes: Régis on Generation," *Perspectives on Science* 11:410–420.

[41] Although who exactly Harvey has in mind here is unclear, the most likely candidates are various English corpuscularians such as Kenelm Digby, various physicians such as Fernel, and perhaps Gassendi.

[42] C.f. Harvey 1651, Exs.45 and 72.

[43] Harvey 1651, Ex.11, 28-29. "Communis eorum error est, qui hodie philosophantur, quaerere varietatis partium caussas, ex diversa material, unde oriantur.,.Nos autem errorem hunc nimis pervulgatum, alibi refutavimus. Nec minus illi falluntur, qui ex atomis omnia componunt, ut Democritus; aut ex elementis, ut Empedocles. Quasi generatio nil aliud foret, quam separatio, aut congregatio, aut dispositio rerum. Non est quidem negandum, ut aliquid ex aliquo producatur, haec quae dicta sunt necessario requiri; generatio tamen ipsa ab iis omnibus diversa est. … Praeterea, qui hoc modo philosophantes materialem duntaxat caussam assignent, & vel ex elementis sponte aut casu concurrentibus, vel ex atomis varie dispositis, caussas rerum naturalium deducunt; quod est in operibus naturae, atque in generatione & nutritione animalium praecipuum, haud attingunt: divinum nempe illud efficiens, & naturae numen, (quod summa arte, providentia, & sapientia operatur, omniaque in finem aliquem, sive boni alicujus gratia efficit) …."

fetus, something so clearly *designed,* comes out of something homogenous and simple. Given that Harvey thinks his research has demonstrated that the male's contribution must act immaterially, this is a problem of both material and efficient causation. It is also a problem of final causality, that is, a problem about how the entire process happens, as he later characterizes it, *as if by foresight.*[44] Generation is not just "separation, or the collection, or the arrangement of things," because these processes happen in an *orderly, regular manner* towards an appointed end (the completed offspring) as if guided by reason, and results in parts that have regular structures and definite functions.

In sum, then, Harvey's empirical research has led him to the following problem: *how is the embryo immaterially fertilized and constructed by epigenesis as if by foresight?*

1.3. An Analogy of Last Resort

Harvey begins the *De conceptione* with the following plea:

> It is a dark business, full of shadows, and yet I will dare to put forward a suggestion by means of a problem, so that anyone may see that I don't only eliminate other's opinions, but also, in some way, to be seen to convey my own opinions to the community. And yet I do not wish the things I have to say about this business to be taken as though I believed them to be pronouncements of the Oracle, or as if I desired to extort every man's vote in my favor. I only ask as my just deserts the liberty I freely grant to others, to put forward as true those things which in this whole dark business seem probable until such time only as their falsity may be openly proved before all men.[45]

Harvey could not satisfactorily resolve the mystery of generation. But, unlike in the case of the final cause of circulation in the *De motu cordis*,[46] Harvey here does *not* refuse to speculate, and he turns to analogy in hopes of some understanding of generation. Harvey explains generation indirectly, not

[44] Harvey 1651, Ex.50, 144.
[45] Harvey 1651, *De conceptione*, 293. "Res sane est tenebrarum plena: & tamen audebimus aliquid problematice proponere; ut, non solum sentias alienas eliminatum isse, sed & nostrum quoque aliquo modo in medium attulisse videamur. Quae tamen a me super hac re dicentur, non ita accipi velim, quasi eadem e Tripode porlata existimem, aut aliorum omnium suffragia extorquere cupiam: sed libertatem illam, quam aliis libenter concedimus, nobis etiam jure merito poscimus; ut, quae in obscuris rebus verisimilia videntur, eatenus pro veris offerre liceat, donec manifeste de eorum falsitate constiterit."
[46] Harvey 1628, *De motu cordis,* Cap.VIII, 42.

by confronting it directly in terms of causes and powers he has observed or inferred, but rather in terms of the similarity between generation in the womb and conception in the brain: the powers and causes of the latter are taken as a model of the causes of the former.

Why exactly Harvey resorts to analogy is impossible to determine, but it was necessitated by his desire to produce some speculative answer, while giving due credence to the fact that his observations had undermined all available theories. Perhaps, in the wake of the criticism he received after *not* offering any such explanation in the *De motu cordis,* Harvey was keen to at least make some attempt to get to grips with generation, and analogy is what allows him this cognitive grip. We might surmise further that Harvey hoped that his suggestions would be at least somewhat fruitful in spurring further research, and in the following section I elaborate this in some detail. Harvey's use of analogy, and similar cases if any such exist, might be thought of as a stop gap measure employed where no direct explanation is possible, meant to simultaneously provide some limited understanding of a natural phenomenon, while also suggesting new avenues of investigation and explanation. A measure of last resort.

1.4. The Analogy: Womb as Brain

In Harvey's analogy, the female's contribution acts like the eye transmitting sensation to the brain. The female contributes a formal principle, but more importantly she contributes the matter. Harvey calls this material contribution the *primigenial moisture*,[47] which he describes as akin to the prime matter of the Scholastics:

> …the most homogenous, the purest and clearest body definable, in which all the parts of the chick are present *in potentia* but not *in actu*, Nature seeming to have granted it that which is common to the first material shared by all things, namely to be capable of all forms

[47] See: Harvey 1651, Ex.72, 252, the title of which is 'De humido primigenio.' Harvey names it 'moisture' after, as he puts it, "the Arab's" terminology, which in Latin is 'ros', meaning dew.

> potentially, but to have none actually. So the crystalline humor of the eye is itself devoid of color in order that it may be capable of taking on all colors….[48]

The primigenial moisture in the egg and uterus is the substance upon which the constructive power acts to form the parts of the embryo by epigenesis. This moisture has a power due to its material nature: just as the eye, when it views an object, somehow takes on the colors of that object, so too can the primigenial moisture take on the form transmitted by the male, which is understood as the image received by the primigenial moisture. As shown above, according to Harvey's research, the male's sperm must act immaterially. It must operate, in other words, analogously to vision, such that, just as an object viewed transmits its image through the medium of air and light, and is then conceived of and represented in the brain, so too is the male's sperm able to impart its image to the female's egg through the medium of her reproductive tract.[49]

In the *De conceptione* Harvey notes certain anatomical similarities between the impregnated womb and the brain, and he takes seriously that the products of both are called *conceptions*.[50] He draws on these similarities and argues that there are changes observed in the uterus when it is prepared for conception that make it even more brain-like: "…the uterus appears thicker and more fleshy, and (in so far as the inner surface is concerned, truly, the place of the future conception) it becomes more tender and is comparable in smoothness and softness to interior of the ventricles of

[48] Harvey 1651, Ex.72, 252. "Idem quoque est simplicissimum, purissimum, & sincerissimum corpus, terminabile; in quo omnes pulli partes potentia quidem sunt, actu vero nulla: videturque Natura idem ill concessisse, quod materiae primae, rerum omnium communi, vulgo tribuitur; ut potentia nempe sit omnium formarum capax, actu autem formam nullam habeat. Sic humor oculi cyrstallinus, ut colorum omnium susceptivus sit, ipsemet nullo colore praedistus est…."

[49] It seems at least mildly paradoxical to think that immaterial causation cannot act at a distance because it must be in contact with the body it is acting on, despite being immaterial. Remember, though, that in the Aristotelian context, forms can travel, but, at each point, they must have a 'location', so to speak, even though they are not strictly enmattered at each point. So the form transmitted by the male has a series of locations (first in the womb, then in the oviduct and finally in the egg), even though at each point this form is not restricted to the matter of the womb, oviduct, or egg. Still the idea remains a difficult probably paradoxical one, and it is no wonder that Harvey is at a loss here to understand it.

[50] The word 'conceptus' is used for both. This verges on taking a pun as evidence.

the brain…."[51] On the basis of this putative observation, and upon the assumption that structure and function are linked, Harvey argues that,

> …seeing that the substance of the uterus that has been made ready for the conception is so very like the constitution of the brain, may we not justly suppose that the function of each of them is also alike…?[52]

Harvey's argument is thus formulated as follows:

> P1. Womb and brain have similar structures when prepared for conceiving.
> P2. The product of both womb and brain is called a conception.
> P3. Similar structures imply similar functions and similar operations.
> C. Therefore womb and brain have similar functions and operate analogously.

Now, Harvey is here speculating, and thus so his argument here is, at best, only a likely one. Note, too, that without the third premise Harvey's argument loses its force.[53]

So far his analogy has been helpful only in accounting for the immaterial action of the male's sperm, but not in understanding epigenesis. For this, Harvey emphasizes how generation is like artistic production, in which the artist constructs the work in stages according to the idea of the artwork in her mind, which in turn is based upon her perceptions of the object to be represented. In the *Praefatio* to *De generatione*, Harvey writes explicitly on conception in art:

> …Art is the account of the work implanted in the artist's mind… that which we perceive in sensible objects differs from the thing perceived and is that which is retained in the imagination or the memory. The former, the thing perceived, is the exemplar, the idea, the form informing; the latter is the imitation, the *eidos*, the abstracted appearance. [54]

So the sperm transmits an 'idea,' an informing form, and this is the intentional object 'seen,' so to speak, by the uterus and transmitted to the primigenial moisture. When combined with the female's

[51] Harvey 1651, *De conceptione*, 294. "Uterus primum crassior apparet, & carnosior; posteaque (quoad interiorem superficiem, loco nempe conceptionis futuro) tenerior factus, laevitate pariter ac mollitie internos cerebri ventriculos aequat…"
[52] Harvey 1651, *De conceptione*, 295. "…cumque adeo substantia uteri ad concipiendum parati, sit cerebri constitutioni persimilis: quidni merito suspicari liceat, utriusque etiam functionem esse similem…."
[53] This premise is for Harvey more or less axiomatic, a commonplace background assumption of anatomical reasoning in the early modern period, and he never considers how or when it might lead him astray.
[54] Harvey 1651, *Prefatio*, B3. "…ars est ratio operis, in animo Artificis…In utrisque differt id, quod in rebus sensibilibus speculamur; a spectro ipso, quod in phantasia vel memoria retinetur. Illud exemplar, Idea, forma informans; hoc, imitamentum, Idos, species abstracta."

contribution, this produces the form of the future offspring *in potentia*[55], the *eidos.* That is, it is the abstracted representation of the male and female such that an offspring of the same kind can be constructed. Key here is the term "account" (*ratio, logos*), which, as Aristotle articulates in the *Organon*, signifies what something is, its essence.[56] *Logos* is central to understanding soul, for, as Aristotle writes in the *De anima,* soul is the "…substance [of the body] according to its account [*rationem*], and moreover this is the essence [*quod quid erat esse*] of such a kind of body..."[57] So what is transmitted by the male is soul, form, an account of the future offspring, an account of its very *essence.*[58] We might call this a plan, in the sense of a blueprint, for this *ratio* contains the information needed to construct the fetus. Indeed, Harvey elsewhere calls the male's contribution a 'precept [*praecepto*]' that grants "…the account [*rationem*], the form and laws of the future fetus…."[59] So the male's contribution provides the plan of the future offspring and the set of rules according to which it is constructed by epigenesis. Harvey calls this a *species*.[60] Harvey can thus use the brain/womb analogy and this 'precept' to explain the process of epigenesis: it is analogous to how an artist, with her conception of the future work in mind, goes about and builds that work:

> For just as we fashion from the conception of a form or an idea in the brain its likeness in the works of our hands, so does the idea or appearance of the genitor remaining in the uterus

[55] It is *in potentia*, because the actualized soul cannot exist without the completed body, as discussed above.
[56] Aristotle 1552, *Topicorum translatio Abrami* Lib.I Cap.4, In: *Aristotelis libri omnes…cum Averrois Cordubensis variis in eosdem commentariis*, Vol. 1, my translation, 257. "...definitio est oratio significans rei quiditatem, qua est ipsius essentia..." Note that the location of this passage in this edition is different from the modern one, where the passage is located in chapter 5. See also, *Meteorologicorum*, Lib.IV, Cap.12, In: *Aristotelis libri omnes…cum Averrois Cordubensis variis in eosdem commentariis*, Vol. 5, Venice, 222.
[57] Aristotle 1552, *De anima,* Lib.II, Cap.1, Volume 11, 52. "...est enim substantia quae secundum rationem: hoc autem est quod quid erat esse huiusmodi corporis…" Note that '*quod quid erat esse*' is the translation of '*to ti en einai*,' a very difficult phrase and concept in Greek, and which gave the Latin translators much trouble, hence their neologism of '*essentia*.' This was common practice, and translators as diverse as Melanchthon and Cardinal Bessarion understood the phrase as 'essence', even if they didn't always translate it using *essentia*.
[58] More properly, part of its essence, as it must be combined with the female's contribution. Furthermore, this cannot be the full essence, the soul of the future chick *in actu,* but only *in potentia,* for, as argued above, epigenesis just is the process whereby this essence comes into actuality.
[59] Harvey 1651, Ex.29, 89. "… rationem, formam, ac legem futuri foetus acciperet."
[60] Although he doesn't only use this terminology, it is more or less equivalent to form. Harvey 1651, *De conceptione,* 295, 301. He writes in the latter case, for instance, that "…inest species sive forma pulli in utero vel ovo…."…" (301). See also Ex.29, 88.

> generate a foetus like to himself by the help of the formative faculty, that is to say, by imposing upon its work this immaterial appearance. It happens in the same way as art, which is the *eidos* or appearance of the future work, produces its like when it is acting and begets it in the matter…So that what instruction effects in the brain…its analogue is bestowed on the uterus by coitus with the male…[61]

So in the same way that, in vision, just the form and not the matter of intentional *species* are transmitted from the object to the eye and then used by the brain to abstract concepts, the male sperm transmits his *species* through the female's reproductive tract without any material. The male's form is then abstracted in combination with the female's to create the form of the future offspring.[62] How these forms become abstracted is unclear, as Harvey does not discuss it, but what is important to note is this process of abstraction accounts for another aspect of generation: namely that the offspring's form is not just that of the male or female, but rather a combination of both. The egg, using its innate constructive faculty, builds the fetus, step-by-step, part by part, by following the *ratio* contained in itself.

Harvey describes this process in an Aristotelian manner, arguing that the final cause (the form of the future offspring) must exist before the efficient cause (the constructive virtue) such that it can move the efficient cause according to the *telos* of development:

> The efficient moves since it is impelled by the final cause. In every efficient there inheres, in a way, the account of the end; by this final cause, the efficient is moved, operating with foresight.[63]

Note, that, because of how the final cause directs the efficient cause, the efficient operates *as if by foresight*. The construction of the fetus is analogous to artistic production: just as the artist paints or

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[61] Harvey 1651, *De conceptione*, 295. "Nam quemadmodum nos, a conceptione formae, sive ideae, in cerebro, similem ei in operibus nostris efficimus: ita partier idea, aut species genitoris in utero existens, formatricis facultatis ope, simile foetum generat; dum speciem nempe, quam habet immaterialem, opera suo imponit. Non aliter sane, quam ars, quae in cerebro est eidos sive species operis futuri, simile in agendo profert, & in materia gignit…Ade out, quod disciplina in cerebro efficit…analogum ejus coitus maris in utero praestet…"

[62] Harvey does not call this process "abstraction" in the egg'abstraction'; in fact, he never talks about how the forms of the parents are integrated. Abstraction seems as good a term as any, especially given Harvey's larger analogy.

[63] Harvey 1651, *De conceptione*, 299. "Efficiens autem movet, quia a caussa finali impellitur. Inest enim quodammodo in omni efficiente, ratio finis; a quo illud, cum providentia operans, movetur."

sculpts her object according to the account of the artwork existing in her, so too does the uterus construct an egg by a set plan (epigenesis), according to the *ratio* of the future offspring that is contained, somehow, in the egg.

I now turn to evaluate and analyze this analogy.

2.0. Evaluating and Analyzing the Analogy

Harvey uses this analogy to describe a process for which no other terminology was available. Because his empirical and conceptual developments and difficulties undercut the available set of causes for understanding the processes of fertilization and epigenesis, he turned to analogy as a way of describing the unfamiliar aspects of generation in terms of the more familiar processes of artistic production. He knew, of course, that the analogy could not be exact—rather, he uses it as a speculative model upon which to provide *some* understanding of the phenomena at hand.[64] The task now becomes to evaluate and analyze this analogy, and see if it does, in fact, help explain generation.

It will be helpful here to use the Mary Hesse's work on analogy from the 1960s to organize my analysis. Hesse distinguishes between the *negative, positive,* and *neutral* analogies within a model. Using an example from the billiard ball model of the dynamical theory of gases, she writes,

> Let us call those properties we know belong to billiard balls and not to molecules the *negative analogy* of the model. Motion and impact, on the other hand, are just the properties of billiard balls that we do want to ascribe to molecules in our model, and these we can call the *positive analogy*. Now the important thing about this kind of model-thinking in science is that there will generally some properties of the model about which we do not yet know whether they are positive or negative analogies; these are the interesting properties, because…they allow us to make new predictions. Let us call this third set of properties *neutral analogy*. If gases are really like collections of billiard balls, except in regard to the known negative analogy, then from our knowledge of the mechanics of billiard balls we may be able to make new predictions about the expected behavior of gases.[65]

[64] MacLean, Ian (2001), *Logic, Signs, and Nature in the Renaissance,* 109.
[65] Hesse, Mary (1966), *Models and Analogies in Science,* South Bend: University of Notre Dame Press, 8-9.

I start by laying out schematically the analogy:

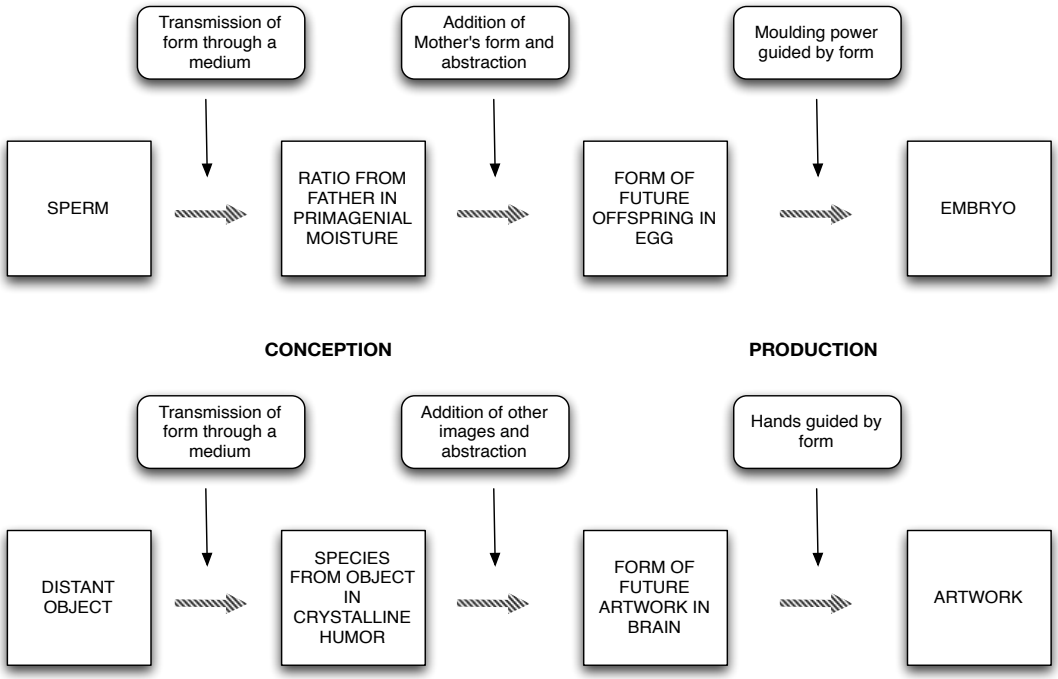

Fig. 1. A schematic overview of Harvey's analogy

A few things to note about the diagram: I have divided the analogy into two stages, conception and production. Each of the square boxes represents an entity or an entity in a state of affairs, such as the sperm, a distantly viewed object, or the *ratio* from the sperm inside the primigenial moisture. Each of the rounded boxes labeling the arrows represents a causal process involving those entities. From the diagram the two instances of conception and production, one natural and one artistic, seem quite analogous, at least initially. By understanding the causes of generation in terms of the causes of conception on the basis of this analogy, Harvey hopes to have provided some indirect explanation of generation, and here too there seems an initial fit. I start with the positive and neutral aspects of the analogy, assuming, for the moment, a minimum of negative aspects so that they do not undermine the neutral (and useful) aspects.

At the level of objects, Harvey's analogy seems at least initially reasonable (though I question these correspondences below). Turning to the causal side of the analogy, here too there is

an initial correspondence: first there is a causal process of transmission of a form through a medium—through the reproductive tract to the primigenial moisture on the one hand, and through the air and to the crystalline humor on the other. Interestingly, Harvey often uses the same term (*species*) to designate that thing which is transmitted to and retained in the primigenial moisture. It is the term that the Scholastics and other Aristotelians used for what was transmitted by light through the medium of air to the eye in vision: a tree distantly seen sends its *species* to the eye, where, once received, it can be conceived of in the mind.[66]

This neutral analogy where *species* are transmitted through a medium, formally and without matter, allows Harvey to explain the fact that corporeal sperm never reach the egg. Assuming negative aspects of the analogy do not undermine it, this correspondence might yield a further benefit, namely, connecting the science of vision to the science of generation. Though out of favor in the 1650s, Harvey's use of *species* connected his theory to contemporary theories of how vision and conception occur more widely, and also with Scholastic theories of immaterial form transmission. Here Harvey's use of analogy is similar to how John Herschel, writing in the nineteenth century, understood it: as enabling one to link together different domains of scientific inquiry.[67] Through his analogy Harvey provides a connection between his proposal and a body of pre-existing scientific theory, perhaps in the hopes of achieving a unified theory of conception. Further, while this analogy perhaps strikes us as bizarre, it does fit into the Aristotelian position prevalent at Harvey's time that Art and Nature operate alike—and, indeed, Aristotle's biological

[66] For a good overview of Renaissance theories and debates about vision, see: Hendrix, John and Charles Carman (eds.) (2010), *Renaissance Theories of Vision,* London: Ashgate. Of course, *species* could also indicate a kind, but it seems reasonably clear from the context that Harvey uses the term to indicate the form of a creature, its appearance (both internal and external).

[67] Herschel, John (1830 [1987]), *A Preliminary Discourse on Natural Philosophy,* Chicago: University of Chicago Press, 94. See also: Bailer-Jones 2009, 47-48. Now exactly how one would go about making predictions on the basis of this analogy and then testing its bounds are unclear, and Harvey never makes any suggestions.

works are filled with attempts to understand nature by comparing it to productive craft.[68] However, as I shall discuss in more detail below, there is an important disanalogy here, in that natural things do not operate by *reason,* but rather by their *natures,* by their own internal sources of change.

By explaining epigenesis through Aristotle's concept of a *logos* according to which the efficient cause operates, Harvey fits his explanation of generation into a larger framework of Aristotelian natural philosophy, while at the same time accounting for his new empirical findings. So another neutral aspect of the analogy relates to the causal correspondence on the basis of this art-nature comparison. Harvey's analogy provides a model by which to understand the complicated process of epigenesis, namely, by understanding it as following a plan, a *ratio,* contained within the egg. And since there is an intuitive understanding of how artistic productions come to be, some intuitive explanation of the process of epigenesis is gained through transference from the case of artistic production. Both productions happen by following an idea, a plan of both design *and* action, which instructs both artist and egg to construct their objects part-by-part, over time: the builder first constructs the frame, and then fills in the rest of the walls, while the egg first builds the blood and the frame of the heart, and then fills in the rest of the parts. Indeed, in some ways this is not so far from the modern analogy of the gene as blueprint—in both cases, there is the sense that the plan of the future offspring and how to construct it are contained, somehow, within the materials contributed by the parents.[69] In suggesting this analogy, then, Harvey has switched the problem from *how epigenesis occurs* to *how the final cause is contained in the efficient cause.* This suggested a new line of research, and in his annotations to his own *De generatione* Harvey writes that the problem has now become one of understanding the verb '*inesse* (being inside)*'* in the

[68] For instance, see Aristotle's discussions of natures in *Physica* Lib.II, Cap.1, Volume 4, 23, where he uses the example of a bed made from wood.
[69] Of course, the gene as blueprint analogy is deeply problematic, and I do not mean to endorse it in any way.

operations of nature.[70] Harvey's analogies might reasonably be seen as offering a limited, temporary explanation, as well as a new avenue of investigation afforded by reconceptualizing the problem.[71] It shifts the explanation from one of efficient causes that are impossible to understand, to a story about final causes that we can understand through the analogy.

However, turning to consider the negative analogies, it becomes clear that the superficial correspondences of the positive analogies are misleading, on their own terms and even within the confines of Harvey's Aristotelian philosophy. First, regarding the correspondence between objects in the analogy, though Harvey argues that it is brain and womb that are analogous, in the causal picture he develops, it is not the womb that is analogous to the brain, but rather the egg. For it is the egg that is truly the site of fertilization and conception, not the womb. Indeed, Harvey repeatedly stresses that the soul of the egg is responsible for the production of the fetus, and not the womb.[72] One problem here is that Harvey's conception of the egg is somewhat misleading to modern readers, noting that the mammalian egg would not be discovered until 1827 by Karl Ernst von Baer.[73] What Harvey calls the egg is, in fact, not an egg at all, but rather what today is termed the blastocyst, and it is a complex physiological system that is intimately tied to the mother and her womb. But set this aside, as Harvey cannot be convicted of not discovering things he couldn't be expected to discover. The problem is rather that, because Harvey is convinced on analogy with the situation in oviparous animals, that this 'egg' is entirely responsible for the creation of the embryo, his analogy between

[70] In the annotations to his copy of the *De generatione*, in the Pybus Collection in the library of the University of Newcastle upon Tyne, contained in Whitteridge, Gwenneth (1981), *Disputations Touching on the Generation of Animals,* Blackwell Scientific Publications 463. For instance, Harvey writes, and which concurs quite well with the account I have been elaborating, the following about one way to understand 'inesse': "Again, as in the case of potentiality and the performance of the act, or again in the first and second act, just as what is caused is in the cause, the effect or part of the effect in the efficient, and the suffering of an action is in action, and that which is mobile in motion"

[71] So it becomes an investigation on how final causes might be understood to inhere inside their efficient causes. It might proceed by attempting to fill in the details of the analogy, though one doubts that Harvey, or anyone else, would get terribly far with this project.

[72] See Ex.27, which is titled: "The egg is not the production of the womb but of the soul".

[73] Although in 1672 Regnier de Graaf had mistakenly taken egg vesicles to be eggs, he succeeded in convincing most that even non-oviparous animals had eggs.

the womb and brain falls apart. Rather, it is the egg and brain that are analogous in terms of function, the primigenial moisture serving as eyes that receive external forms. But this analogy has no legs to stand on, since even Harvey believes there are no structural similarities between egg and brain to support an inference to similar functions.

There is a further empirical problem here, one that concerns the similar 'smoothness and softness' that Harvey claims to have observed between the place of conception in the womb and the ventricles of the brain. A modern-day anatomist would note that the similarities between brain and womb are the sort of similarities one could find between all sorts of tissues in the body—indeed, this is the sort of observation that Harvey himself makes concerning other parts of the body.[74] As such, Harvey would have a basis for suggesting the same similarity between any of these tissues, which is surely much too wide a class to support his analogy. Indeed, the womb prepared for conception is a significantly more complicated physiological system than the ventricles of the brain and which is plain from visual inspection. It is surprising that an observer of Harvey's caliber was willing to argue this—a sign, perhaps, of his desperation.[75]

Further, even if womb and brain played analogous roles in Harvey's depiction of production, he would be doing no more than replacing one mystery with another: no one, Harvey included, had any idea how the brain worked, and how the structure of the brain was designed to complete its

[74] Personal communication, May 10 2011, Dr. Jody Gross, St. Joseph's Children's Hospital, Marshfield, Wisconsin. Harvey himself, following tradition, maintained that all the parts are ultimately constructed of the same, homogenous material: Harvey (1616 [1964]), *Prelectiones anatomie universalis,* Ed. Gweneth Whitteridge, Royal College of Physicians, 6-10. For instance, he notes that the muscles, the skin, and others parts have a similar softness (10).

[75] This criticism may sound Whiggish, but I would argue that it is not, as the differences between the brain and the womb prepared for conception are extremely obvious even to those untrained in anatomical observation. It is, in fact, very surprising that Harvey would argue for this similarity between womb and brain, except in the context of the analogical explanation Harvey is trying to develop. Though I have no evidence for this claim, it seems likely that Harvey came up with the analogy *first,* and later tried to support it by this observation. The fact that no one, so far as I have been able to determine, made similar claims about ventricles and wombs before or after Harvey seems to demonstrate the desperation of these purported observations.

function of conceiving and thinking.[76] So, while it was obvious how the structure and composition of the skull contributes to its function of protecting the brain by being hard, by surrounding the brain, and so on, it was entirely mysterious how the "smoothness and softness" of the womb and ventricles (and other tissues) in any way contributes to conception, even putting aside that the womb does not play the analogous role Harvey gives it.[77]

A second negative analogy also stems from an empirical problem, one that concerns Harvey's comparison between the primigenial moisture of the egg and crystalline humor of the eye. Again, there is some reason to question the strength of this comparison, for in neither case is Harvey's description entirely accurate, even by the standards of his time. But, setting this aside, Harvey is drastically behind the times in locating the seat of vision in the crystalline humor: Kepler in his *Astronomiae pars optica* (1604) had shown on the basis of geometric reasoning that the crystalline humor is not where the image is projected, and that the image is actually sent to the retina.[78] Thus the analogy between the functionality of the crystalline humor in receiving the image and the primigenial moisture receiving the image from the semen breaks down.

Further, the way in which the primigenial moisture receives form is different than how the crystalline humor was thought to do so according to Harvey. Whereas the crystalline humor receives and then transmits the form of the object seen without taking on its shape or colors, on the contrary, it is the very purpose of the primigenial moisture to materially instantiate the received

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[76] For various suggestions of what the ventricles might do, see: Harvey 1616, 314. Here he recounts that they are somehow for intelligence, that they are for the easy movement of the brain in its systole and diastole, to prevent it from collapsing upon itself, and so on. Inspired by Harvey, later in the century Thomas Willis produces one of the first detailed anatomical and philosophical discussions of the brain, his (1664) *De cerebro et nervis.*

[77] Descartes thought the folds and crevices of the brain were where memories were stored. See: *L'homme*, AT XI:177, CSM I:107. There is, too, a further analogy here between *soul* as the essence and *ratio* of a creature, and soul as mind, noting that 'ratio' can often mean reason. I don't have room to discuss this in much detail, but I argue below that this is exactly what Harvey wants to avoid in his account of generation in his insistence that efficient causes do not themselves operate by foresight and reason.

[78] Kepler, Johannes (1604), "De Modo Visionis," *Astronomiae pars optica,* Cap.5, Frankfurt, 158ff. Somewhat earlier, in 1583, Felix Platter argued that the optic nerve was the primary organ of vision in his *De corporis humani structura usu libri III*, Basel. Kepler also mentions Johannes Jessenius' (1601) *Anatomia Pragensis*.

form. So, while instead of immediately taking up the shape of the parents,[79] it does so rather by epigenesis, there is still a negative analogy here. Indeed, it is the uterus, rather than the primigenial moisture, which seems to be the true analog, for, like the crystalline humor, the uterus somehow transmits the form to the egg without taking on its properties.

A further negative analogy concerns the nature of the efficient cause of epigenesis, the 'constructive power'—what is this power such that it can form the future fetus according to a final cause? The invocation of these sorts of occult faculties and powers was, as is well known, one of the mechanists' main criticisms of Aristotelian science. The analogy doesn't help: for, whereas in art it was understood how the painter uses her hands to move her tools, the brush, the hammer and nails, and so on, it is entirely unclear how the constructive virtue operates, even to Harvey or other Aristotelians.[80] Harvey does identify the tool used: it is an innate heat, inherent in the blood, which is the instrument of soul, and which constructs the fetus according to the *ratio* contained within it.[81] But how the constructive virtue operates by means of this heat is left unsaid, for there are no analogs of hands here, and how the heat operates is mysterious. Harvey, like many who had come before him, resorts to a pairing of an analogy and a disanalogy to explain the operation of the heat: it is like the heat of the sun, which causes growth, and unlike the heat of fire, which causes destruction.[82] But this set of analogies undermines the effectiveness of the overarching analogy, for how heat is related to the process of vision and conception in the brain is unclear. Perhaps a better

[79] I note that Harvey thinks that some insects *are* generated in this way, receiving their form all at once like a stamp into wax; he calls this sort of imperfect generation *metamorphosis*. See Harvey 1651, Ex.45, 121ff.
[80] While they were sure *that* such a power must exist, Aristotelians debated amongst themselves and with the Galenists about the nature of this power. See: Deer, Linda (Richardson) (1980), *Academic Theories of Generation in the Renaissance*, Dissertation, Warburg Institute.
[81] The *calidus innatus,* a staple of late Renaissance Aristotelianism and Galenism. See Harvey 1651, Ex.71. The best discussion concerning this heat is found in Deer 1980.
[82] On heating and cooling see: Aristotle's *De generatione et corruptione,* Lib.I, Caps.6, 7 on heat. C.f. Francis Bacon (1620), *Novum organon* LXXV, LXXXVIII, CXIX, CXXVII.

analogy to use would have been light, for then, at least, one can more easily fit it into the overarching analogy.[83]

Finally, Harvey's proffered replacement to explain *inesse* instead of epigenesis is not truly a helpful substitution. This is because the problem of how the final cause inheres in the efficient and guides its operation is one that had plagued Aristotelian philosophy from the beginning, and here Harvey's "solution" to generation seems entirely traditional, for Aristotle, too, had argued that the efficient cause is guided by *logos*.[84] So, while it is a strength to connect one's speculation to a larger body of theory about the nature of causation, connecting it to a doctrine that was found to be mysterious even by its supporters is hardly a welcome result.

What Harvey has seemingly suggested with his analogy is that nature operates according to reason, in just the same way that an artist operates according to reason. As I discuss below, in order to guarantee that nature doesn't *actually* operate according to reason,[85] Harvey trades in his analogy for theology.

3.0. God, Causality and the Generation of Animals

I have shown that when confronted with empirical findings that upset the available theories, Harvey resorted to analogies between generative phenomena and the phenomena of artistic

[83] Harvey does occasionally use this analogy—but he doesn't really fill in the details in any satisfactory way. This suggests another problem, namely, how one might integrate the main artistic analogy with other analogies Harvey uses, as he nowhere does this, nor is it clear that he even thinks it necessary. For instance, another analogy Harvey deploys in the *De generatione* is between the power of the male's semen on the female and the power of contagion to spread disease. Though I have not space here to discuss it, this analogy fares even worse than the brain/womb analogy. See: Harvey 1651, Ex.29**.** Harvey also mentions other analogies there, including magnetic phenomena, and the operations of sympathy and antipathy. Though he mentions magnetism, there is no indication he has read Gilbert; though I don't have space to discuss it, this analogy, too, fares poorly.

[84] For a Renaissance example, see the work of Jacob Schegk, a philosopher and physician at Tübingen in the late sixteenth century: Schegk, Jacob (1580), *De plastica seminis facultate libri tres* Strasburg, I sig. A1v. "Efficientium proinde causarum in natura duplex est genus, unum est ἄλογον καὶ ὑλικόν, ut si frigore aut calore alteratur quidpiam, alterum est, quod ut forma et logos generat quidpiam: ut σπερματικός λόγος, aut alias ἐν ὕλη λόγος, ut si simile generat simile sibi, aut si nutritum assimilat sibi nutrimentum."

[85] This theory, that in generation there are divine spirits that do operate by actual choice and foresight, was propounded by certain neo-Platonists and neo-Platonist influenced physicians, such as Jean Fernel. See also fn.17 and 53.

production. These positive analogies had the benefit of supporting neutral analogies that in turn allowed Harvey's work to fit into a larger body of Aristotelian theory about art and nature, as well as into the science of vision as understood by the Scholastics. Further, by understanding epigenesis as the following of a plan contained within egg, contributed by the male and the female, the analogy gives us some cognitive grip on how development occurs.

But as noted, this analogy was found to be lacking, both in terms of its empirical basis and in terms of its very logic. It did not fare well in the ensuing years. Indeed, in a 1674 edition of Harvey's *De generatione* published in Amsterdam by a Dutch physician named Justus Schrader, all the philosophical parts were excised, leaving only the observational parts.[86] This is an instance, then, of how a scientist uses an analogy as a last resort for understanding a complex phenomenon. Yet, though he ultimately failed in his attempt to understand generation, there is something admirable in Harvey's willingness to propose a speculative—some might even say crazy—analogy to explain the process of reproduction (something he refused to do in the case of the circulation of the blood). And, at least at first, there is an initial correspondence between the two sides of the analogy that must have made it seem worthwhile for Harvey to suggest and pursue. Harvey shows a remarkable willingness to follow where the evidence leads, though we know now that there were errors in his observations and his explanatory resources were inadequate.

However, Harvey's most complete explanation of generation is to be found not in his analogies, but in his conception of God and His relation to nature, a move quite characteristic of early modern philosophy and science. In fact, Harvey's analogy can be seen as having forced the issue in the following way. Since, on the one hand Harvey denies that natural things (like the womb) operate by means of reason (like artists do during conception), yet on the other hand, his

[86] See: Pomata, Gianna (2005)."*Praxis Historialis*: The Uses of *Historia* in Early Modern Medicine," In: *Historia: Empiricism and Erudition in Early Modern Europe*. Eds: Gianna Pomata and Nancy G. Siraisi. MIT Press: Cambridge: 121-122.

analogy seems to turn on exactly those sorts of processes which *do proceed by reason*, he is forced to offer some explanation as to how it is that these unthinking things—not even animals but *embryonic-animals*—can perform actions so complex that not even a human being with the full power of her reason could perform them. This significant negative analogy is thus part of the reason Harvey spends some time in *De generatione* describing how generation occurs within the larger metaphysical and cosmological order of God and nature. In so doing, Harvey beautifully illustrates a larger pattern in early modern natural philosophy that Jacques Roger has discussed: the fact that God becomes a central explanans of life and generation.[87] A key problem is the same as Harvey's: how to account for epigenesis.[88] It is no wonder, then, that, instead of trying to explain epigenesis, many philosophers after Harvey simply denied it, and instead used God to explain and justify the existence of infinite invisibly small preformed parts, explaining generation by growth, by preformation or embôitment as it would become known.[89] As we shall see, Harvey, though no preformationist, also invokes God in his account of generation.

The difficulty of explaining generation comes from what Harvey called the *foresight* displayed in the process of epigenesis. Harvey tries to explain this by means of a theological conception of the divinely wrought natures of the male and female contributions (an option not available to later philosophers who rejected the Aristotelian conception of natures). The foresight and art displayed by sperm and egg are to be understood, not in the way some neo-Platonists and other philosophers understood them, as actually employing reason, but as a secondary effect of God's miraculous design.[90] Thus the first efficient cause of generation could only be God and His

[87] Roger, Jacques (1963), *Les Sciences de la vie dans le pensée françaese du XVIIIe siècle*, Paris: Armand Colin.
[88] Harvey's other problem, concerning fertilization, was negated with the advent of microscopes and the discovery of spermatozoa.
[89] Pyle, Andrew (1987), "Animal Generation and the Mechanical Philosophy: Some Light on the Role of Biology in the Scientific Revolution." *History and Philosophy of the Life Sciences* 9(2), 225-254.
[90] Harvey has in mind, specifically, the doctrines of Jean Fernel. See his (1560) *De abditis rerum causis.*

wise design of nature. Harvey argued that the male and female are but *instrumental causes* of generation, the *primary cause* being God:

> … in the construction of the chick the first efficient is required to use skill and foresight, wisdom, goodness and understanding far beyond the capacity of our rational souls. For it is that account of the future work, which acts for some determined end and arranges and perfects all things; and which forms the parts of the chick, even the smallest, for the sake of some use and some action, and looks out for not only the structure of the work but also to its welfare, ornament and defense Now the male or his seed, either in coitus or after it, is not so qualified that to him can be attributed art, understanding and foresight.[91]

There is no foresight in the process of epigenesis itself: the egg does not reason or plan its way to the fetus. Rather, God acts through a series of instruments which are each natured by Him to progress, grow and act so as to accomplish the construction of the offspring, all in certain specific, regular ways. Harvey neither thinks that natural objects act with actual foresight and wisdom, as human beings do, nor does he argue that God controls the process of generation directly, guiding the process as the sculptor guides her chisel. Rather, God is the origin and ultimate cause of the natures of created things, not an active controlling force in the construction of particular animals. Harvey explicitly equates God with Nature,[92] and with this in mind, note that he writes that,

> …Nature, which is the principle of motion and rest in all things which she is in, and the vegetative soul, which is the first efficient cause of every generation, do both move and act by no acquired faculty (as we do) which may be distinguished by the name of art or prudence, but just as if by a certain order or mandate working according to laws: truly with a like vigor and similar manner to how light things are moved upwards and heavy things downwards. That is to say, the vegetative faculty of the parents generates, and the seed finally arrives at the form of the foetus, in the same way in which the spider spins its web, birds build their nests, incubate their eggs and protect them, and bees and ants prepare their habitations and hide their food for future use. Clearly they do this naturally and by their innate disposition, and not with any foresight, education, or deliberation.[93]

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[91] Harvey 1651, Ex.50, 144. "…in pulli fabrica artificio utatur, & providentia, sapientia item, bonitate, & intellectu, rationalis animae nostrae captum longe superantibus. Utpote, in quo sit futuri operis ratio, quodque in destinatum finem agat, disponat, & perficiat omnia; partesque pulli, etiam minimas, alicujus usus & actionis gratia efformet; & non modo operis fabricae, sed etiam saluti, ornatui, ac defensioni ejus prospiciat. Mas vero, aut illius semen, in coitu, vel post eum, ejusmodi non est, ut illi ars, intellectus, ac providential attribui possint."

[92] See for instance, Harvey 1651, Ex.41 and especially Ex.50.

[93] Harvey 1651, Ex.50, 146. "At vero Natura, principium motus & quietis in omnibus, in quibus est; & anima vegtativa, prima cujuslibet generationis caussa efficiens; movent nulla facultate acquisita, (sicut nos) quam vel artis, vel prudentiae nomine indigitemus; sed tanquam fato, seu mandata quodam secundum leges operante: simili nempe impetus, modoque,

God's instruments are not themselves capable of foresight, they merely display what appears to be wisdom as a result of God having designed them to act in such regular ways. Their natures are just such that they act in this way, and thus only God can truly understand how these processes occur.[94] Accounting for this regularity, or, perhaps better, embedding this regularity into his larger cosmological framework, is as close as Harvey comes to offering an explanation of how generation happens in the miraculous and regular way that it does.[95] In true early modern European fashion, it was *theology,* and not analogy, that was the best explanation Harvey could provide to the problem of generation, making clear that nature itself makes no use of reason.[96]

In the end, then, Harvey knew his solution was unlikely to win approval, yet he offered it all the same, supplying what answers he could that fit his observations. I've shown a philosopher struggling against a phenomenon too complex to understand without the help of theology, a problem whose empirical and conceptual contours could only be explained through a speculative analogy. This analogy of last resort, while providing some grip on generation, ultimately proved a failure, but one from which there is much of interest to philosophers and historians of science. Indeed, Harvey's epistemological and metaphysical difficulties would not be the last, and generation remained a stubborn problem for hundreds of years, the list of philosophers attempting to tame it including figures as diverse as Leibniz[97] and Darwin.[98] A dark business indeed.

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quo levia, sursum; gravia, deorsum feruntur. Scilicet, facultas parentum vegetativa eodem modo generat, semenque tandem ad formam foetus pertingit; quo aranea, retia sua nectit; aviculae, nidos exstruunt, ovis incubant, eaque tuantur; apes, & formicae habitacula parant, & alimoniam in futuros usus recondunt. Naturaliter nempe, & connato ingenio; non autem providentia, disciplina, aut consilio, quicquam agunt."

[94] Perhaps analogies are as close as we mortals can come to understanding generation.

[95] This would be a common refrain in embryological studies through the eighteenth century. See, for instance, Needham, Joseph (1959 [1934]), *A History of Embryology,* Cambridge: Cambridge University Press, 94, 236; and Pinto-Correia, Clara (1998), *The Ovary of Eve,* Chicago: Chicago University Press, 20ff, 149, 265.

[96] So one might compare Harvey's traditional response to this problem of understanding causality in relation to nature and to God with more radical responses that would become important after Descartes', such as Louis de La Forge's or Malebranche's occasionalism

[97] Leibniz (1714), *Monadology,* 73, 74, 76.

[98] Darwin, Charles (1868), *Variation of Animals and Plants under Domestication*.