SEMINAL IDEAS: THE FORCES OF GENERATION FOR ROBERT BOYLE AND HIS CONTEMPORARIES

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Dedicated to my family

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Seminal Ideas: The Forces of Generation for Robert Boyle and his Contemporaries

This dissertation looks at the life and work of famed English Aristocrat Robert Boyle. Specifically, I examine his treatment of generation and its organizing forces—seminal principles, plastic powers, and petrifick spirits. Generation, I argue, provided the context by which Boyle was introduced both to chymistry and anatomy. The problem of generation would remain at the forefront of his concerns as he experimented in chymistry, pneumatics, minerals, anatomy, transmutation, and plants. Looking at the various communities in Europe with which Robert Boyle interacted, I show that the mechanical philosophy was actually quite diverse. As one of the most influential scholars of his time, Boyle presents a distinctly mechanical account of generation that would have a profound effect upon Western science.

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Chapter 1. The Forces of Generation: *A Brief Overview*

1.1 What is the problem of Generation?

1.1.1 *A Monstrous Birth*

On November 2, 1664 a group of English gentleman attended a meeting of the Royal Society where they listened as a letter from the Honorable Robert Boyle was read aloud.[1] The young Aristocrat told the group of a "Monstrous" birth that had recently taken place in the town of Fisherton and had been brought to his attention by the physician Daubney Tuberville. The birth that Boyle describes was one of conjoined twins, connected at the waist, and thus having four arms, two heads, and a shared pair of legs, "Navell, [and] a Womans part."[2] So piqued was Boyle's interest by the event that he included with his letter the following note and drawing:

Sir[3]

> After the sealing of my letter I shadowed the Children as well as my fancy enabled mee & have sent it to you inclos'd for your better satisfaction. I had forgot to tell you that both heads doe suck well, & they avoid their Excrements well.

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1 Boyle et al, *The Correspondence of Robert Boyle*: v. 2, p. 374n.

2 Ibid. p. 374

3 Boyle is addressing the Royal Society's secretary, Henry Oldenburg.

Though their fascination was due to the rarity of conjoined twins, the truth is that the mysteries of birth had long confounded investigators of nature since antiquity. And their ideas about that process were, in many respects, remarkably different from our own.

1.1.2 *Generation and Reproduction*

When present-day commentators study the production of new offspring, they typically describe the process as "reproduction." We talk about how animals reproduce—be it sexual or asexual—and even now "reproductive rights" remain an emotionally charged topic in political discourse. But consider the meaning of 'reproduction.' To re-produce a thing is to replicate it, typically be creating a copy. Prior to nineteenth-century cell theory, discussing procreation in this manner made little sense. Instead, any new creature or offspring was described in terms of *generation.*[4] Whereas reproduction involves copying, generation involves the construction of an entirely new being.

In natural philosophy, 'generation' denotes the process by which things in nature—be they animal, mineral or vegetable—come to be. In the Western tradition, ideas about generation were informed by Aristotle's *Generation and Corruption.* Aristotle describes generation, or coming-to-be, as the movement of a thing from potential existence to actual existence.[5] This actualizing happens by means of four causes:

1. a material cause, or the matter from which a substance is made
2. a formal cause, or the form that the substance takes
3. a final cause, or that for the sake of which a substance comes to be, and
4. an efficient cause, or how the thing came to be.

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[4] For similar discussions see Cobb, *Generation*: p. 10; Gasking, *Investigations into Generation*: p. 7

[5] Aristotle, Gen. et Corr., 317 b: 15-25

The efficient cause is arguably the most complex of these because it involves some force(s) physically acting upon and organizing passive matter. Generation long posed a problem for natural philosophers because any kind of formative process requires something to organize matter: to organize matter into that which will become. Historically, the forces of generation have been conceptualized a number of ways. But underlying all of them is the attempt to explain how matter is organized when substances come-to-be.

The seventeenth century saw the rise of the mechanical philosophy, generally understood as the attempt to explain phenomena in nature in terms of inert, particulate matter and motion. Because all things in nature are understood in terms of generation, it encompasses a vast range of phenomena- from the unexpected birth of child to the production of precious metals such as gold. The problem of generation consequently presents a unique intersection of medicine, anatomy, chymistry[6], metaphysics, and theories of matter. As such, it serves as an interesting and useful test case for how seventeenth-century contemporaries understood the parameters of the mechanical philosophy. Given that generation requires some kind of organizing force, the mechanical philosopher attempting to explain the generation of animals, plants, or even minerals has the task of describing precisely what is doing the organizing. Simply stated, how does inert matter organize itself?

That task would arguably present the biggest challenge that its proponents would attempt to tackle, including the eminent English chymist Robert Boyle. This dissertation looks at Boyle's treatment of generation and its organizing forces—seminal principles,

[6] For use of this term, see Newman, Principe: *Alchemy vs. Chemistry, The Etymological Origins of a Historiographic Mistake*

plastic powers, and petrifick spirits. As one of the most influential scholars of his time, Boyle presents, in his own terms, a distinctly mechanical explanation for these generative principles that would have a profound effect upon Western science. But first, we must briefly examine the concepts involving the forces of generation.

1.2 Galeno-Aristotelian Efficient Cause:

1.2.1 *Aristotle*

As stated earlier, the concept of generation was informed by Aristotle. For plants and animals, generation is closely linked to Aristotle's concept of *pépsis*, literally, "cooking" or "concoction."[7] The process of *Pépsis* involves heat that results in coagulation to a perfected *end*, which is determined by the form and final cause of the substance. Aristotle employed the notion of *pépsis* to explain generation[8]; the ripening of fruit[9]; digestion[10]; the transformation of the sweet and nutritious part of food into blood[11]; the transformation of blood into seminal fluid[12], menstrual blood[13], and milk[14]; and the production of both wine[15] and cheese[16].

7 Cf. Aristotle, Meteor., 379 b: 10 ff
8 Ibid. 381b: 7; GA, 725 b:20, 753 a:20, 765 b: 20, 775 a: 17
9 Ibid. 380a: 11-25; GA, 715 b: 20
10 Ibid. 381b: 7-10; PA, 675 a 10 ff.
11 Aristotle, PA, 631, 650 a: 30-35, 668 b: 5-10
12 Aristotle, GA, 725 a: 20 ff.
13 Aristotle, GA, 727 b:30
14 Aristotle, GA, 739 b: 25
15 Aristotle, On Plants, 821 b: 28-824b: 2
16 Aristotle, GA, 729 a: 10-15

In sexual generation *pépsis* is the process by which the vital heat contained within semen organizes passive matter (i.e. menstrual blood) via coagulation. Aristotle compares the process to the production of cheese, stating that

> The male provides the form and the "principle of the movement,"" the female provides the body, in other words, the material. Compare the coagulation of milk. Here, the milk is the body, fig-juice or the rennet contains the principle which causes it to set.[17]

Thus, the formative power in semen, largely derived from the vital heat, acts as the efficient cause.[18] The female in turn provides menstrual blood that acts as passive matter, or the material cause. Aristotle compares that process to a carpenter working on timber, or a potter upon clay, as in each example there is something actively shaping the passive material.[19]

1.2.2 *Galen*

This formative agent was later taken up by second century Alexandrian physician and anatomist, Galen of Pergamum, in the notion of the formative faculty. In adapting this power, however, he also changes it by making the agent a faculty not of the soul, but of nature. [20] Further, Galen explains the formative faculty within the context of seeds: Genesis, by this account, is the result of the mixture of two seeds, as seen in the Hippocratic tradition. In explaining genesis, Galen appeals to two faculties: alterative and formative. Where the former differentiates matter, the latter molds it. In describing that formative faculty, Galen goes so far as to allude to Aristotle's own imagery, stating that, "One would be justified in

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17 Aristotle, GA, 729 a: 10-15

18 Cf. Aristotle, GA, 716 a: 5; 729 a: 10; 785 b: 10

19 Aristotle, GA, 729 b: 10-18

20 Galen, *On the Natural Faculties*, II: 5

calling this substance which undergoes alteration the *material* of the animal, just as wood is the material of a ship, and wax of an image."[21]

1.2.3. *Formative Faculty as Plastic Power*

The Galeno-Aristotelian[22] efficient cause eventually became known as a kind of *plastic faculty*. Something that is plastic (as understood in early English) is simply something that molds. Its defining characteristic is its capacity to mold or shape formless materials such as clay or wax.[23] The first application of the term 'plastic' to the formative faculty is likely to be found in Schegk's 1580 treatise, *De plastica seminis facultate.*[24] Despite its present scarcity, Schegk's treatise was widely known among various Protestant natural philosophers such as Daniel Sennert and William Harvey, each of whom radically changed contemporary notions of generation. The latter physician did so through his the publication of his 1651, *De Generatione*, in which he presented the earth-shattering thesis that all life comes from eggs.

When Harvey describes the process of animal generation in *De Generatione*, he appeals to the faculties of the soul. Thus, when he uses the term 'plastick', he uses it to describe an immaterial, formative force which is related to these faculties. He writes about them in the context of the Aristotelian efficient cause, (boldface mine)

> Since therefore in the Generation of Animals (as in all other things of which we covet to know any thing) every inquisition is to be derived from

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21 Galen, *On the Natural Faculties*, VI: 19

22 The integration of Aristotelian natural philosophy with a Galenic conception of the body, of nature, and with medicinal practices created a distinctive Galeno-Aristotelian tradition to which physicians such as William Harvey belonged. For an excellent discussion of the Galeno-Aristotelian approach of Fabricius (Harvey's anatomy professor) see Distelzweig , "Fabricius's Galeno-Aristotelian Teleomechanics of Muscle," in *The Life Sciences in Early Modern Philosophy*.

23 OED Online :"plastic, n. and adj." Oxford University Press, December 2016.

24 Hirai, *Invisible Hand of God in Seeds: Jacob Schegk's Theory of Plastic Faculty: 379.* See also Hunter, *Plastic Natures in the Seventeenth Century*: p. 199n.

> its *Causes,* and chiefly from the *Material* and *Efficient;* it seems fit to me, looking back on perfect animals (namely by what degrees they are begun, and compleated) to retreat, as it were, from the end to the beginning: that so at last when there is no place for farther retreat, we may be confident we have arrived at the principles themselves: and then it will appear, out of what *first matter,* **by what *efficient,* and what *procession* the *plastick power*** hath its original; and then also what progress Nature makes in this work. [25]

Throughout its various instantiations, the formative or plastic principle is essentially the efficient cause in generation. It is the active principle that operates on passive matter. But that agent has explanatory power only insofar as it can do so with the form and to a specific end. Hence, this plastic or formative power is generally discussed in the context of the faculties of the soul, which are closely tied to formal and final causes.

1.3 Logoi Spermatikoi

1.3.1 *Logoi Spermatikoi and Stoicism*

The second kind of organizing principle, *logoi spermatikoi* (seminal reasons or seminal principles) originates with the Platonist-influenced Stoic authors. The historical question of how Stoicism was influenced by Platonism is a difficult one. Early Stoics do, nonetheless, use imagery from Plato's *Timaeus* for explanatory principles in generation. Namely, they present a pantheistic universe in which the Demiurge, the World Soul, and the Forms are collapsed into a single active principle that is the ultimate source of change called 'god.' [26]

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[25] Harvey, *Anatomical exercitations concerning the generation of living creatures to which are added particular discourses of births and of conceptions, &c.*: preface. For more on Harvey's debt to Aristotle on the subject of animal generation, see Lennox, "The comparative study of animal development : From Aristotle to William Harvey's aristotelianism," in *The Problem of Animal Generation in Early Modern Philosophy.*

[26] Baltzly, "Stoic Pantheism": p. 6

God, or nature, is understood as "a force moving of itself, producing and preserving in being its offspring in accordance with seminal principles [*logous spermatikous*]." [27]

This pantheistic, universal god is both seminal and reason in that he acts as the universal seed from which things originate, and he contains within himself the determination of form and qualities of all that will become. The *logoi spermataki* are then the generative powers derived from this being and act upon matter as efficient, formal, and final causes combined.[28] The Stoics further identify this god as the vital heat or *pneuma* from which life originates, echoing Hippocratic theories of medicine.[29] On this topic, they share some similarity with Aristotle, who also describes the vital heat of the soul that seminal fluid contains as the active, efficient principle in generation.

1.3.2 *Plotinus*

The doctrine of *logoi spermatikoi* had become an integral part of the Platonic tradition of Stoicism when Plotinus appeared on the scene in third century AD.[30] Plotinus adapted the concept within his own discussion of the *Timaeus,* beginning the World Soul, or *logos,* which serves as the generative principle for all things. In sexual reproduction, Plotinus evokes the notion of immaterial seeds, *logoi spermatikoi,* which are endowed with the power to generate from the *logos*. He writes

> The powers of seeds are each of them one whole *logos* with the parts wrapped up in it; the bodily has a matter, for example some fluid, but the *eidos* itself is the whole and a logos, being the same in the *eidos* as the soul in the generator, which is an image of another better soul. Some call this power in the seeds 'nature'.

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27 Diogenes Laertius, as quoted in Horowitz, *Seeds of Virtue and Knowledge*: p. 28
28 Horowitz, *Seeds of Virtue and Knowledge*: pp. 28-29
29 Baltzly, "Stoic Pantheism": p. 24
30 Hirai, *Le Concept de Semence*: p. 24

> Which was driven thence form those prior to it, as light from fire[31], and it turns and enforms the matter, not relying on the help of those mechanisms, but by imparting the *logoi*. [32]

His theory of immaterial seminal principles is inextricably linked with his positing of the *logos*, and it is this which gives the seeds their power or faculty for bringing the material parts of matter into being. This theory of seeds is, moreover, curiously coupled with his theory of intellection and of the mind.[33]

1.3.4 *Augustine*

The imagery of seminal principles was later taken up by Augustine, who employs the concept in order to resolve a conflict of Biblical exegesis regarding the story of creation as described in the books of *Genesis* contra *Ecclesiasticus*. The problem is that creation occurs consecutively over several days in *Genesis* but simultaneously in *Ecclesiasticus*. Seminal principles solve this problem on account of their having been created simultaneously despite their effects occurring in succession over time.[34] Thus, Augustine single-handedly introduces immaterial seminal principles into the Christian creation story. On this view, God filled the world with seminal principles, or immaterial "'seeds' of things to come," one for each species. Endowed within matter, each seminal principle will fully develop into its species given the proper circumstances.[35]

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31 Here, he is invoking the Platonic idea of emanation.

32 Plotinus, *Enneads* V.9.6, as quoted and translated in Preus, "Plotinus and Biology"*:* p. 46, in *Neoplatonism and nature: studies in Plotinus' Enneads*.

33 See Preus, *Plotinus and Biology:* pp. 47 ff, in *Neoplatonism and Nature*.

34 Coppleston: *A History of Philosophy*: v. 2: p. 91, *Mediaeval Philosophy*

35 Maurer, *Medieval Philosophy*: p. 15

1.3.5 *Semina in the Renaissance*

Neoplatonic and Hermetic influences in the Renaissance saw that the imagery of immaterial seminal principles reappeared with even greater intensity. Hiro Hirai, in particular, has demonstrated the prolific influence of *semina* and seminal reasons in Renaissance writers from Ficino to seventeenth-century authors such as Van Helmont and Gassendi.[36] An especially influential example can be found in the iconoclastic Paracelsus, who employed the notion of *semina* as the ultimate origin of all objects in nature.

Additionally, he described three principles that serve as the basic constituents or "prime matter" of other substances: sulphur, mercury, and salt. Individual substances, then, are generated by the *semina*, "which contain soul-like impulses".[37] Thus, Paracelsus extended the idea of metallic seeds to all of nature. These "metallic seeds" are, moreover, closely related to what he calls the *archeus*, which is a spiritual entity responsible for the particular species of an object, and thus responsible for substantial change.[38] The Paracelsian notion of *archeus* and its relationship to substantial change would later influence the early modern iatrochemists, most notably Danish physician Petrus Severenius and the Flemish physician Jean Baptiste van Helmont.

Severinus was responsible for further connecting the immaterial *semina* of Parcelsus and Plotinus to the experimental practices of chymistry. Generation, on this view, is a kind of "unfolding" of the seed from potency to actuality, a process which Severinus describes as "mechanical" (*mechanicus processus*).[39] Jole Shackelford explains that mechanical here is

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36 See Hirai, *Le Concept de Semence*

37 Pagel, *Paracelsus:* p. 103

38 Ibid. p. 85

39 Shackelford, "Seeds with a Mechanical Purpose": pp. 22-23, in *Reading the Book of Nature: The Other Side of the Scientific Revolution*

in the sense of a craftsman, or mechanick, whose mechanical knowledge (*scientia mechanica*) allows him to guide and carry out the mechanical process. For Severinus this role is filled by the Paracelsian *archaeus,* which acts as an inner agent who is responsible for generation. This interpretation of the *archaeus* allows him "distinguish his view of generation from those philosophers that consider generation as the imposition of form onto matter by an external agent, by stellar aspects, or by chance meeting of atoms." [40] Severinus also helped to establish Paracelsus as a Christian philosopher and to make sense of his abstruse terminology, especially when it came to the Biblical story of Creation. [41]

Van Helmont later adopted Paracelsus's *archaeus,* as well, stipulating that it produces seed by means of a ferment, which gives off an odor. This odor in turn attracts the generating spirit of the *archaeus*. Even metals are formed from seeds, which propagate themselves like the light which emanates from God, the principle agent in illumination.[42] Whereas the ferment provides the formal cause, the seed (as with previous authors) is the efficient cause- thus acting as the driving force in generation.[43]

Following Plotinus, the seminal power or principle is an agent that acts as an intermediary between the immaterial world (of God) and the material Earth. As this intermediary, it has the capacity to act upon matter as the organizing principle in generation in accordance with God's plan. Thus it often acts as more than simply the efficient cause

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40 Ibid. pp. 25-26

41 Walton, "Genesis and Chemistry in the 16th Century": pp. 6-7, in *Reading the Book of Nature: The Other Side of the Scientific Revolution*

42 Hirai, *Le Concept de Semence*: p. 454; Pagel, *Joan Baptista Van Helmont: Reformer of Science and Medicine*: p. 80

43 Hirai, *Le Concept de Semence*: p. 455; Partington, *A History of Chemistry*: v. 2., p. 236; Roger, *The Life Sciences in Eighteenth-Century French Thought*: p. 79

alone. In the Christian tradition, the seminal principle further became an important part of the biblical Creation story. Similarly, it would become part of an important chymical tradition within the context of generation and transmutation.

1.4 *Semina* and Plastic Powers

During the course of the Middle Ages and the Renaissance, the Galeno-Aristotelian plastic force became increasingly associated with the *logoi spermatikoi* of the Neo-Platonists. Their mutual identification with each other stems largely from efforts in the Middle Ages from Arabic and later Latin, Catholic scholars to make Aristotle, Galen and Neoplatonist authors cohere within a single account. Aquinas flipped the concept on its head, so to speak, in a move typical of Scholastic writing in which he forces coherence between St. Augustine and the Philosopher Aristotle by re-defining the former's *logoi spermatikoi* as a "passive virtue", essentially reducing it to Aristotelian potentiality of matter.[44]

His teacher, Albert the Great, further complicated the issue by using the notion of a formative faculty, as explicated by Aristotle, and applying it to the production of minerals in the extremely influential *De Mineralibus.* In a chapter on the efficient cause of stones, Albert describes the mineralizing power as an active power that is "common to the production of both stones and metals, and of things intermediate between them."[45] He goes on to describe its function by analogy, stating that just as just as an animal's semen has a force that is "capable of forming an animal," so too is there a mineralizing power contained within matter suitable for stones that "forms and produces stones."[46]

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44 Aquinas, *Summa Theologica*: I a 115. Cf. Hirai, *Le Concept de Semence*: p. 28; Horowitz, *Seeds of Virtue and Knowledge*: p. 51.

45 Albertus Magnus: *Book of Minerals*: p. 22

46 Ibid.

Many of these ideas come together in the work of the sixteenth-century Flemish physician and mineralogist, Anselm Boethius de Boodt who, in giving an account of creation, writes (boldface mine)

> In the beginning, when Holy and Almighty God created the entire universe out of nothing, by means of his infinite power, he created the Earth and the water… At first, the Earth was barren and empty, that is, without being either truly furnished or fecundated by the *semina.* [But] after this on the third day of creation, the Earth manifested, by means of the Creator, **a seminal and formative faculty** by which all of the plants, and trees, and every vegetation grew.[47]

The formative power in this context is not at all a faculty of the animal soul, but of God. And in this sense, it seems to reflect Neoplatonic authors. One last interesting thing to note is that Catholicism had a longstanding tradition of *semina* following Augustine, whereas a "plastic faculty" seems to have been more popular among Protestant authors prior to the dissemination of Boyle's writings.

1.5 Atomism and Corpuscular Theories of Generation

1.5.1 *Epicurean Atomism*

A final tradition from antiquity to address the problem of generation is that of Epicurean atomism. The most comprehensive account of this tradition is arguably provided by Lucretius' *De rerum natura*, which presents an account of seeds that are devoid of any powers, owing their efficacy instead to the swerve of atoms. Seeds, on this view, are ""matter" or "generative particles of things" or "seeds of

[47] Cum D. Opt. Max. ab initio totum hoc universum ex nihilo infinita sua potentia creasset, terram & aquam … Terra primo fuit inanis, & vacua, hoc est, nulla prorsus ne ornata, neque semine turgida. Postmodum di creationis tertio seminalem & formatricem facultatem, quia herbas, & arbores, omneque vegetabile protulit, a Creatore suo obtinuit. (De Boodt, *Gemmarum Et Lapidum Historia:* p. 22-23)

things.""[48] These seminal clusters of atoms are used to explain the production of all things in nature, from minerals, plants, animals, humans, and disease. In the seed of animals, Lucretius—not unlike the Hippocratic corpus—holds the view that seed is derived from all parts of the body. In the case of sexual generation, heredity and gender are determined by whichever parent had the overpowering seed, admitting that offspring may take after their grandparents because "their parents often keep concealed in their bodies many elements, mingled in many ways, that are derived from ancestral stock and transmitted..." [49]

But in the seventeenth century, few were willing to commit themselves to the sort of godless world that Epicurean atomism entailed. Generation, in particular, was thought to be implausible on this account because the random swerving of atoms could not explain complex organization. Even Gassendi, who presented a modern incarnation of Epicurean atomism, attributed a "seminal force" to the *semina rerum*, or seeds of things, in order to explain generation.[50] And as for the seeds, "Gassendi does not tell us, for either sort of generation [i.e., spontaneous or pre-organized], precisely how the right sorts of matter come together in just the appropriate configuration..." [51] Lucretius had a strong account of sexual inheritance, but he could not explain how atoms know where to go without some guiding principle to direct them.

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48 Carus Lucretius, *On the Nature of Things*: Bk. I, 55-60.

49 Ibid. Bk. 4, pp. 1210-1230.

50 Cf. Adelmann, *Marcello Malpighi and the Evolution of Embryology* v. 2: pp. 798-799; and Hirai, *Le Concept de Semence*: pp. 463-491.

51 Fisher, "Gassendi's Atomist Account of Generation and Heredity in Plants and Animals," p. 493.

1.5.2 *Cartesian Mechanism*

In the early seventeenth century began a movement that vehemently rejected the scholastic forms of the universities, opting instead to conceive of the world as a well-ordered machine whose parts, not unlike the complex gears of a clock, were capable of maintain the regularity of nature without the aid of Aristotelian forms. On this view, the universe is made up entirely of inert matter in motion. This school of thought became known as the mechanical philosophy, for which the French philosopher René Descartes is often given as a canonical example as an early, major proponent.

Descartes attempts to provide foundations for science and mechanistic accounts of physical phenomena culminated his composition of *Le Monde* (The World) which can essentially be broken up in to two parts: *Traité de la lumière* (Treatise on Light) and *Traité de l'homme* (Treatise on Man).[52] The latter is Descartes' attempt at defending the plausibility of a mechanistic anatomy, in which he imagines man's body to be a functioning machine. But when Descartes considered the subject of generation, he immediately recognized the challenge that lay ahead. He confessed as much to Mersenne, to whom wrote that he had given up on the subject entirely when composing *Traitée de l'homme* as he was unable to find the causes of formation. [53]

Eventually, however, Descartes composed *De la fomatione de l'animal*, which would be published as an addendum to his posthumous *Traitée de l'homme.* Whereas *Traitée de l'homme* follows the processes of the body as described Galen, providing instead a

[52] Garber, "Descartes' Physics": pp. 289 ff., in *The Cambridge Companion to Descartes*

[53] Roe, *Matter, Life, and Generation*: p. 4

particulate and mechanical account of them, so too does *De la fomatione de l'animal.* Thus, like Galen, Descartes considers sexual generation to result from the mixing of both male and female seeds. Whereas Galen describes the resulting formative process in terms of the faculties, Descartes appeals to fermentation.[54] Specifically, he describes the seeds of animals as "…very fluid and ordinarily produced by the coming together of sexes…" These liquors, he continues, seem to be, "a mixture compounded of two liquors which, serving each as a ferment to the other, are so heated..." that some of the particles will act with the same agitation as those in a fire and press up against each other. Descartes goes on to compare the process to old dough that can "make new dough rise again" and the fermentation of beer. [55]

While the mathematical laws of motion could account for the regularity of celestial bodies or terrestrial mechanics, they dealt with the processes of living organisms far less effectively. Thus, despite beginning with very different assumptions, Descartes and future proponents of a mechanical epigenesis (i.e. the view that an embryo develops gradually over time) ultimately ran into the same problem as did the Epicurean atomists: they cannot explain how motion alone could organize particles of matter into something as complex as a living being.

1.6 Conclusion

Such was the state of affairs preceding Robert Boyle's investigations into nature. Despite its being published in 1665 several years after his own death, Descartes had actually composed *Traité de l'homme* around 1640-1642. That very same time the young, relatively

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54 Ibid.

55 Fruton, *Fermentation: Vital or Chemical Process?*: p. 20

unknown son of a wealthy, British Aristocrat was touring Europe, oblivious to the fact that this problem of generation was soon to become his own. Chapter 2 begins with the teenaged Boyle's arrival to England and looks at the development of his experimental and mechanical program. I show that the problem of generation was at the very forefront of Boyle's introduction to anatomy, chymistry, and natural philosophy. Seeing how Boyle grapples with the generation of plants, animals, and minerals within his earlier works is then essential for understanding the development of his ideas, his appropriation of sources, and his overall world view, more generally. This chapter ends when Boyle moves to London in 1668, at which point he had become a world-renowned scholar.

Chapter 3 takes place at Cambridge, which was home to a group of scholars later known as the Cambridge Platonists. Boyle engaged in a highly public controversy with Cambridge Platonist Henry More, and the nature of their dispute speaks volumes about Boyle's stance on the ontological status of chymical powers, such as plastic powers, and the mechanical affections of matter. It further illustrates the relationship that Boyle assumes between his experimental approach and his commitment to the mechanical philosophy. In this chapter, I argue that the best way to understand chymical powers is in terms of supervenient qualities that are not necessarily reducible to matter and motion.

Chapter 4 follows Boyle to London, where he resided until his death in 1691. Here we take an in-depth look at the agents of generation—seminal principles, plastic powers, and petrifick spirits—and consider how Boyle's views on generation change over time. I show that Boyle had considerable influence on theories of fossil formation and consider how he distinguishes the production of minerals from the generation of life. Whereas the previous chapter examines the British Aristocrat's ontology, this chapter focuses largely on his

epistemological approach to mechanical explanation. I argue that Boyle provides a distinctly mechanical account for the processes of generation, as understood within the context of his own framework.

Finally, Chapter 5 examines Boyle's profound influence on theories of generation among the community of Italian anatomists, most notably Bolognese physician, Marcello Malpighi, who was one of the most prolific and influential medical writers and anatomists of his day. Because of his inclusion within the Royal Society, Malpighi's correspondence serves as a link between members of the Royal Society in England and the community of other Italian anatomists. Included in this discussion is of Malpighi's interaction with those vehemently opposed to the mechanical philosophy, such as Giovanni Sbaraglia, a self-described Galenist. In 1704 Sbaraglia published a rather harsh criticism of Malpighi's account of plastic powers. His response, we shall see, is an important one for understanding the episode, too, because it offers the modern reader a unique, contemporary perspective.

I intend to focus on the interplay between Boyle's sources, writings, and reception. In doing so, my aim is to provide a meaningful context and framework by which to analyze Boyle's work. Reading Boyle's works in the context of both the early Cambridge Platonists, whose prolific writings made them responsible for promoting and reifying a plastic nature associated with an immaterial world soul; and the Italian anatomists, most of whom shared a dedication to a restricted mechanical philosophy; allows the modern reader to assess Boyle's work without anachronistically measuring it by our own rubrics or against or own standards.

Thus, my goal is to triangulate among these sources to gain a more in-depth and well-rounded contemporary perspective. My analysis will show, then, that by his death in 1691, Boyle provided a conception of the agents of generation that was recognized by several of his contemporaries—both those in favor of and ultimately opposed to the mechanical philosophy—as being mechanical.

Chapter 2. The Development of Boyle's Program: *From Dorset to Oxford 1655 – 1668*

2.1 Robert Boyle in Dorset

2.1.1 *Hartlib and the Theological Applications of Natural Science*

The youngest son of Richard Boyle, 1st Earl of Cork, was seventeen in the summer of 1644 when he returned to an England engaged in the later stages of a civil war. Robert Boyle managed to evade the more devastating elements of the war by spending the previous five years touring Europe with his tutor, Marcombes, where he spent time in Geneva, France and Italy.[56] After his arrival in England, Boyle eventually settled in Dorset during the summer of 1646. Shortly after his arrival to Dorset, Boyle began corresponding with the German merchant and polymath Samuel Hartlib, as well as other members of the "Hartlib circle."[57]

Boyle most likely made their acquaintance through his elder sister, Lady Katherine Ranalaugh.[58] In his early participation with the Hartlib circle, Boyle's interests seemed mainly to deal with the social and religious aspects of that community. Certainly, Boyle adhered to the ideals of, "ascetic and philanthropic Protestantism" that were promulgated by Hartlib and his circle.[59] His early writings, such as his *Moral Epistles*, reflect that interest.[60]

An early turning point in Boyle's life seems to have occurred when he visited Holland in 1647, during which time he became preoccupied with the theological use of

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56 Hunter, *Boyle: Between God and Science*: pp. 43-57

57 Hunter, *Boyle: Between God and Science*: p. 65

58 For an in-depth discussion on Lady Ranalaugh and the Hartlib Circle see Harris and Scott-Baumann, eds. *The Intellectual Culture of Puritan Women, 1558-1680*: chapter 12

59 Webster, *Samuel Hartlib and the Advancement of Learning*: p. 39

60 See Boyle et al, *The Works of Robert Boyle*: v. 13, p. 45

natural philosophy.[61] One indication of such a shift in interests can be found in a 1647 letter to his elder sister, Katherine, where he laments the shattered arrival of his new Earthen furnace, "whose conveying hither has taken up so much… care…" It had arrived to Boyle's hands, "crumbled into as many pieces as we into sects; and all the fine experiments, and castles in the air… have felt the fate of their foundation."[62] This concern with the applications of theology to natural philosophy would remain a prevalent theme for Boyle's discussion of generation. Boyle most frequently references seminal forces within the context of theology and the Genesis story of creation.

The earliest recorded mention of a seminal force in Boyle's work can be found in his, "Of the Study of the Book of Nature," composed in the early 1650's, possibly as early as 1649. Michael Hunter describes this treatise as the earliest writings among Boyle's "early scientific phase" and as a sort of transitional text from the young Boyle's early interest in moral philosophy to that of natural philosophy. [63] In rejecting that there is, "any Danger that too profound Knowledge of the Creature shud lead us to disbeleeve the Creator," he argues that "the invisible things of [the Divine Architect] from Creation of the world are clearly seen, being understood by the Things that are made ." [64] He continues this line of argument by appealing to Francis Bacon, stating that, "a slighter Knowledge of Nature is apt to seduce men to Atheisme, but a profounder Insight brings them back to Religion." [65]

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61 Hooykaas, *Robert Boyle: A Study in Science and Christian Belief* : p. 9

62 Boyle et al., *Correspondences*, v. 1: p. 50

63 See Boyle et al, *The Works of Robert Boyle:* v. 13, p. 145, *Of the Study of the Book of Nature*

64 Ibid. pp. 157- 159

65 Ibid. p. 157

It is in this context—that of understanding the creations of the divine architecht—in which Boyle writes (boldface mine)

> For the suttlest Filosofer in the World shall never be able to assigne the true and immediate Cause of the outward shape & Bulke, the Inward Contrivance of the Parts, & the Instincts & Sympathys of any one Animall, the Primitive formes & **seminall Energys of things depending wholly upon the Will of the First Creator**. [66]

The take away from this episode is that Boyle's motivation behind stipulating a seminal or plastic power lay not in the complexity of the corpuscular processes of generation, but rather his own theological motivations. Larry Principe summarizes those motivations nicely, stating that "Robert Boyle was above all other things a Christian. His solid and unwavering devotion to biblical Christianity constitutes the backdrop for all his other actions and pursuits. Boyle's interest in the defense and propagation of Christianity runs as a strong, uninterrupted current throughout his life."[67] That strong current of biblical devotion is apparent in his treatment of generation, which he ultimately understands in terms of the Creation.

Hartlib's correspondence with Boyle at this time indicates the latter's introduction to several prominent scientifically minded thinkers. Perhaps an irony considering present literature on the matter is Hobbes's reception of the young Boyle. Hartlib tells Boyle in a 1648 letter, "I shewed Mr Hobbes your letter, who liked it so well, that he desired me to lend it to him, which I did." Hartlib's correspondence, moreover, shows that Boyle was also

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66 Ibid. This line is followed by a Latin quote from Galen: "Etsi enim per certam Demonstrationem liquet, divinum nos Opificem procreasse, nulla tamen ratione aut mente percipere possumus, quae sit eius essentia & quomodo nos ipse fecerit. Quia longè discrepant, scire aut demonstrare quòd quaedam Providentia nos condiderit, & animæ nostræ, ejusve mentis, quæ nos condiderit, substantiam cognoscere & demonstrare posse."

67 Principe, *The Aspiring Adept*: p. 201

introduced to the astronomical works of Pierre Gassendi, whom Boyle described as a "great favourite."[68] Boyle's general knowledge of experimental natural philosophy remains fairly unsophisticated, however.

2.1.2 *Atomicall Philosophy*

One of Boyle's earliest attempts at natural philosophy came in the form of an essay written the following year, his 1649 "*Of the Atomicall Philosophy"*. The essay, of which we have only fragments, is frequently considered among his commentators to be that of a rather juvenile Boyle.[69] Boyle presents a relatively unsophisticated account of his matter theory in the essay. More problematically, he presents a view that ultimately came to reject.

Previous literature has convincingly argued that Boyle's early atomism exposited in this essay was from his own appropriation of seventeenth-century physician and corpuscularian, Daniel Sennert.[70] One key feature is that in this early work, Boyle fails to consider the hierarchical nature of matter described by Sennert in his discussion of atoms and corpuscular matter.[71] A look at Boyle's earlier writings suggest that his interest in Sennert may have developed through his ideas about generation. Boyle's introduction to both the topic of generation and the work of Sennert came through his neighbor, Nathaniel Highmore.

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68 Boyle et al, *Correspondences,* v. 1: p. 59. See also, Ibid. p.66

69 This description seems to be one that Boyle himself shared, as he emphatically wrote on its cover in a later hand "These Papers are without fayle to be burn't." No doubt discussion of it among scholars now would give Boyle cause to roll in his grave. See Boyle et al, *The Works of Robert Boyle*: v. 13: p. 227, *Essay of the Atomicall Philosophy*

70 Newman, *Atoms and Alchemy:* pp. 160 ff.

71 Newman, *Atoms and Alchemy:* p. 173

2. 2 Highmore, Sennert, and the Problem of Animal Generation

2.2.1 *Boyle's Introduction to Highmore*

While living in Dorset, Boyle became friends with his neighbor, the English physician Nathanial Highmore. Over the course of their friendship, Highmore and Boyle experimented together upon animals, and Highmore encouraged Boyle in the study of their generation.[72] Karin Ekholm has discussed at length Harvey's and Highmore's joint experiments together and the radically different views regarding animal generation which each derived from them.[73] In the case of Harvey and Highmore, a chiefly influential factor was their different conceptions of matter. As we saw in the previous chapter, Harvey's references to any kind of plastic power appeal to an immaterial, formative force which is related to Galeno-Aristotelian faculties. Highmore's work, however, sought to eliminate such forces. Instead, he aims to explain generation in terms of the, "changing arrangements of atoms."[74] The interaction of these generative atoms, moreover, Highmore explains descin terms of "seminal principles." Contextualizing the various experiments with animal generation, however, proved to be problematic for Highmore. His frequent collaborator in experiments on animal generation in the late 1640s, the young Robert Boyle, would inherit that same problem.

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72 Hunter, *Between God and Science:* p. 75

73 See Ekholm, *Generation and its Problems: Harvey, Highmore and their Contemporaries*.

74 Ibid. p. 7

2.2.2 *Hypomnemata Physica*

Particularly influential to both Highmore and the young Boyle was Daniel Sennert's 1636 *Hypomnemata Physica.* In *Hypomnemata Physica,* the German physician presents an idiosyncratic Aristotelianism in which atoms are endowed with forms. While *Hypomnemata Physica* maintains a hylomorphic view of nature, the matter of that pairing is understood in terms of atoms. What makes Sennert's particulate matter unique, moreover, is that this matter is informed at the atomic or corpuscular level. The result was a theory of matter that was simultaneously reductionist in terms of structure yet "stubbornly wedded to the view that there were irreducible qualities lodged within the corpuscles of matter, which 'flowed from' the substantial form."[75]

In the case of living creatures, their seeds are corpuscles composed of primordial atoms and ensouled.[76] Forms then are always *in actu* by means of the seminal, formative powers of seeds.[77] By endowing creatures with forms (i.e., their souls), God gave living beings the means to replicate themselves and perpetuate the course of their own generation without His further involvement.[78] Not unlike inanimate substance in Sennert's ontology, seeds are ensouled at the particulate level. The soul of an individual atom, however, is not sufficiently powerful to inform or organize the matter. Sennert considers the generation of mushrooms in *Hypomnemata Physica,* explaining that, "… the soul of one single atom is so weak that it can neither vivify and inform the matter of the mushroom nor perform what can

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75 Newman, *Atoms and Alchemy:* p. 129

76 Roger, *The Life Sciences in Eighteenth-Century French Thought*: p. 84; Hirai, *Medical Humanism and Natural Philosophy: Renaissance Debates on Matter, Life and the Soul*: p. 169

77 Stolberg, *Particles of the Soul: The Medical and Lutheran Context of Daniel Sennert's Atomism*: p.179

78 Newman, *Atoms to Alchemy*: p. 147; Hirai, *Medical Humanism and Natural Philosophy: Renaissance Debates on Matter, Life and the Soul*: pp.153-54.

be done by the souls, gathered from many [souls] of numerous atoms united into one body."[79]

Distinctive to the *Hypomnemata Physica* is Sennert's account of spontaneous generation, or what he calls "equivocal (æquivovo) generation." So-called spontaneous generation on this view is more frequently caused by imperceptible seminal corpuscles, such as those of future worms or lower insects that found their way into putrefying matter. The generation of these lower animals is consequently neither spontaneous nor equivocal.[80] Instead, so-called spontaneous generation is in actuality the "unfolding of preexistent subordinate forms."[81] Once the dominant form of the living being—a plant, for example—began to decay, the subordinate form of the underlying seminal principles could then take effect and inform the matter accordingly.

Sennert describes the production of mushrooms and moss, what he takes to be imperfect plants, in much the same way as he does the generation of lower animals like maggots or worms: They generate from some seed lurking within the matter from which they generate. In the case of mushrooms, this matter usually exists in parts of trees and becomes actualized as the bark decays.[82] He defends this position by arguing that

> … this is the nature of these more ignoble forms—that they are able to remain whole in even the smallest corpuscles and juices—and afterwards find a suitable place, are excited by some ambient heat, thrust (or uncover) themselves, and are fashioned into the body of a fungus. For, since a soul is able to exist within in the smallest seeds of plants and, when it gets place

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79 See Hirai, *Medical Humanism and Natural Philosophy: Renaissance Debates on Matter, Life and the Soul*: p. 169

80 Sennert, *Hypomnemata Physica:* pp. 380-382, Bk.5, ch.2*;* Cf. Stolberg, *Particles of the Soul: The Medical and Lutheran Context of Daniel Sennert's Atomism*: pp. 181 ff.

81 Newman, *Atoms and Alchemy:* p. 147

82 Sennert, *Hypomnemata Physica:* pp. 427 ff., Bk.5, ch .6

> and matter, able to form a large plant: why can't these more ignoble forms exist entirely within the small bodies or atoms of plants? [83]

To sum up, Sennert appeals to a sort of analogy. Just as the seeds of plants exist in in the small bodies of plants, so too do more latent seeds exist complete within the smallest of corpuscles, latent and lurking until the matter in which they are subordinate allows them the opportunity to prevail.

In some instances, Sennert grants that an *analogical seed,* or seminal principle, may be responsible. Hiro Hirai has shown how Sennert was influenced by the view of Fortunio Liceti, "according to whom [spontaneous] generation is realized by an internal principle lying hidden in matter." [84] Sennert, however, takes this view a step further and argues that even in the case of so-called spontaneous generation the analogical seed (*quod semini proportione respondeat*) is univocal. This analogue to a seed carries no soul but only the living or seminal principle requisite to carry out the functions of the soul when it finds suitable matter. It nonetheless remains univocal because all of the lower animals resulting from this "equivocal" generation are each of the same species.[85] Sennert further argues that the seminal principle that lay concealed within in putrefied matter (such as horse manure) is no more concealed than the seeds of non-spontaneously generated beings such as corn of

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83 "Ita siquidem formæ illæ ignobiliores comparatæ sunt, ut in minimis etiam corpusculis & succis inregræ permanere possint, quæ postea, ubi locum idoneum nactæ sunt, & à calore ambienitis excitátur, sese exserunt, & corpus fungi formant ac fabricantur. Cùm enim in minimis plantarú seminibus anima consistere , & locum & materiam nacta grandem plantam formare possit: quidni hæ formæ longé ignobiliores in minimis plantarum corpusculis servari integræ possint?" Sennert, *Hypomnemata Physica:* p. 428, Bk. 5, ch. 6.

84 Hirai, *Medical Humanism and Natural Philosophy: Renaissance Debates on Matter, Life and the Soul*: p. 162

85 Ibid. p. 163

wheat, onion or garlic. [86] This point is an interesting one in that it brings a special emphasis to the latent aspect of seminal principles and thus further underscores his theory of subordinate forms.

2.2.3 *Hypomnemata Physica and Highmore*

In 1651—the same year that William Harvey published his seminal work, *Exercitationes de Generatione Animalium*—Nathaniel Highmore published two treatises that focused on the problem of generation: *History of Generation* and *Corporis Humani Disquisito Anatomica*. A close look at both treatises strongly suggests the influence of *Hypomnemata Physica* upon Highmore's own work. To begin, Highmore shared Sennert's hylomorphic view of matter as corpuscles or atoms endowed with forms. Like Sennert, moreover, Highmore rejects that heterogeneous bodies have forms.[87] Both argue that God joined both forms and particles of matter together at Creation. As such, forms are God's way of ensuring regularity in nature *ab initio.*[88] This distinctive view of matter had strong implications for Highmore's views on generation.

Highmore defines generation early in the *History of Generation* as the "production of all Creatures, after the first Omnipotent *Fiat* was executed." He defines their seed as that by which "the Individuals of every Species are multiplied" and from which all creatures take

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86 " Fortunius Licetus, lib. 2 de spont. Vivent ertu, cap. 2 statuit, spontaneum viventium ortum provenire á principio occult, eoque latent in materia, è qua generatio fieri debet; atque a deo á principio interno ipsimet rei generantur sed latente. Verum nõ satis clarè adhunc á spontaneo viventiũ ortu hoc modo spontaneus distinguitur; cum & in nõ spontaneo viventium ortu principiũ rei generádæ occultũ in materia (semine puta) lateat. Æquè n. occult sensibus est principiũ generationis in bulbo cępę vel allij, aut grano tritici, aoin stercore equino è que scarab generator." Sennert, *Hypomnemata Physica:* p. 378, Bk.5, ch.2

87 Ekholm, *Generation and its Problems*: p.112

88 Highmore, *History of Generation:* 4; Cf. Adelmann, *Marcello Malpighi and the Evolution of Embryology:* 778, and Ekholm, *Generation and its Problems:* p.128

their beginning.[89] Sennert's possible influence is visible when Highmore discusses the latent seeds responsible for so-called spontaneous generation. These creatures, he explains, occur when

> … some diffus'd Atomes of this extract, shrinking themselves into some retired parts of the Matter; become as it were lost, in a wilderness of other confused seeds; and there sleep till by a discerning corruption they are set at liberty, to execute their own functions. Hence it is, that so many swarms of living Creatures are from the corruption of others brought forth: From our own flesh, from other Animals, from wood, nay from ever thing putrefied, these imprisoned, seminal principles are muster'd forth, and oftentimes having obtained their freedom, by a kind of revenge feed on their prison; and devour that which preserv'd them from being scatter'd. [90]

Highmore's description of "imprisoned seminal principles" that come about after the corruption of putrefaction of another substance strongly resembles Sennert's own description. Highmore provides a similar account that comes out of Book II of *Corporis humanis disquisitio anatomica* with the chapter, *On the Nature of the Blood*.[91] In the chapter, he wants to argue that seminal principles remain "latent" and "subjugated" for a long time. As evidence of this fact, he appeals to "the dissection of the suckers of those trees from which these shoots grow freely" as within them grows bright green moss that is scattered.[92]

This issue of the blood relates to a unique part of Highmore's account of generation. Highmore, not unlike Sennert, denies that matter can change into different substances. Instead, he posits "atoms of specific kinds that continually join and separate to form and

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89 Highmore, *History of Generation:* p. 26

90 Ibid. p. 26-27; Cf. Adelmann, *Marcello Malpighi and the History of Embryology:* p. 778

91 *De natura sanguinis*

92 Highmore, *Corporis humanis disquisition anatomica*: p. 192; Cf. Boyle et al., *The Works of Robert Boyle*: v. 13, p. 283

maintain bodies." [93] Generation, then, is less of a coming-to-be than it is a re-arrangement of informed matter. In the case of humans, these atoms are circulated within the blood and extracted within the genitals of the parent, retaining their form.[94] These forms direct the atoms of seminal fluid within a parent's genitals to form a miniature fetus.[95]

Finally, this unique hylomorphic view of matter seems to have influenced Highmore's views and interest in palingenesis, or the breaking down of plants so to reconstitute their composition. As Karin Ekholm points out, "The reconstitution of plants has far-reaching implications for Highmore: it provides empirical evidence about the substructure of living matter and a way to observe the earliest stages of generation that are usually hidden from view… Since the corpuscles can organize themselves, they must be endowed with forms."[96]

There is an interesting parallel between Highmore's emphasis on palingenesis as "empirical evidence about the substructure of living matter" and Sennert's experiment on the dissolution of silver as a reduction to the pristine state, as both involve a kind of re-emergence of constituent atoms or corpuscles that remained unchanged.[97] Further, they both provide experimental evidence for an otherwise unobservable theory of matter. Robert Boyle expressed an active interest in both palingenesis and experimental reduction to the pristine state, undoubtedly due (at least in part) to his experience with Highmore and Sennert, respectively. Yet, curiously Boyle will ultimately come to reject the very

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93 Ekholm, *Generation and its Problems:* p. 224

94 Highmore, *History of Generation:* pp. 40 ff.

95 Ekholm, *Generation and its Problems*: p. 212

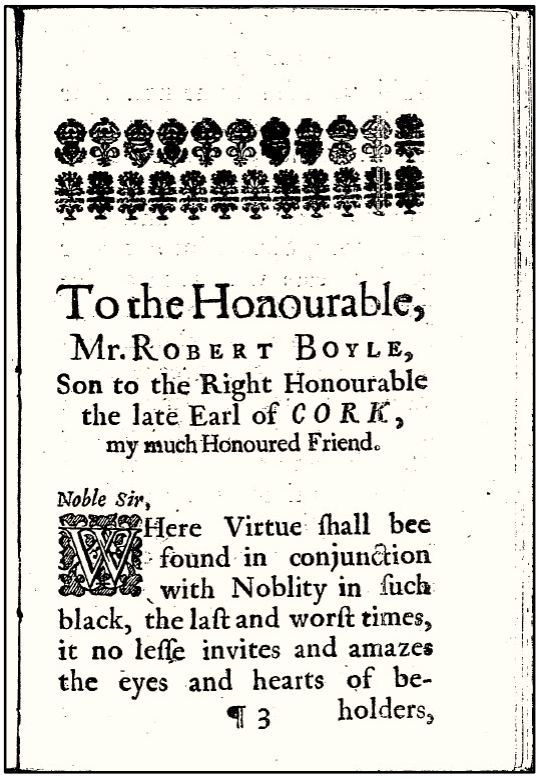
96 Ibid. p. 122

97 For a comprehensive account of Sennert's own views on palingenesis, see Klein, *Chymical medicine, corpuscularism, and controversy*: pp. 291 ff.

conclusion that each promotes: that these experiments demonstrate that corpuscles or atoms must be endowed with forms.

2.2.4 Boyle and the Problem of Generation

Robert Boyle was unquestionably familiar with the work Nathaniel Highmore. Highmore, in fact, dedicated *History of Generation* to "the Honorable, Mr. Robert Boyle… my much Honoured Friend." [98] At the time, Boyle was only twenty-four years old, and it was the first treatise of many that would be dedicated to him. In the dedication Highmore lauded Boyle's rigorous investigation of nature, as Boyle had enriched his own "tender years with such choice principles of the best sorts, and even managed them to the greatest advantage…"[99] Highmore introduced Boyle to sophisticated experiments on animals regarding their generation, to the works of William Harvey and his then very recent discoveries on animal generation and anatomy more generally, and a context for understanding the work of Daniel Sennert.



To the Honourable,
Mr. ROBERT BOYLE,
Son to the Right Honourable
the late Earl of CORK,
my much Honoured Friend.

Noble Sir,

WHere Virtue ſhall bee found in conjunction with Noblity in ſuch black, the laſt and worſt times, it no leſſe invites and amazes the eyes and hearts of be-

¶ 3 holders,

Highmore's shared experience with Boyle undoubtedly helped to spark Boyle's interest in the subject of generation, especially that of animals. The production of a new

[98] Highmore, *History of Generation:* p. 3; Hunter, *Boyle Between God and Science*: 75

[99] Highmore, *History of Generation:* p. 4

being from undifferentiated material requires some kind of organizing. The main problem for the mechanical philosopher—even more so for one with an interest in medicine and the life sciences—became the problem of eliminating an immaterial force from any account of generation. Boyle's interactions and experiments with Highmore, moreover, made him acutely aware of the difficulty in accounting for the generation of animals while eliminating any appeal to the soul or immaterial faculties. Generation is essentially the process by which a thing is formed. In Boyle's view, any kind of formative process requires something to organize the matter from which it is made. Given that requisite, anyone attempting to eliminate discussion of immaterial forces has the task of describing what, precisely, is doing the organizing. How does inert matter organize itself?

For his own part, there is little question that this episode had a significant impact upon Boyle's early scholarship and research interests. Indeed, the direct influence of both Sennert and Highmore is readily apparent in Boyle's unpublished notes on spontaneous generation, composed several years later in the late 1650s. But first, his knowledge about chymistry and various alchemical theories of matter would expand exponentially over the next several years, beginning with his introduction to the American chymist George Starkey.

2.3 Boyle's Introduction to Chymistry

2.3.1 *George Starkey and Chymical Semina*

Boyle and Starkey met through mutual acquaintances of the Hartlib circle months earlier in January of 1651, and the two began corresponding.[100] This meeting proved to be a decisive one for the young Boyle, as most of Boyle's early chymical and laboratory

[100] Hunter, *Boyle: Between God and Science*: 75

knowledge stems from that correspondence. Previous scholarship has pointed out the crucial significance that Starkey played in Boyle's early intellectual development, particularly in terms of his introduction to actual laboratory and experimental practices.[101] It is not my objective to reiterate these arguments here. Rather, the key feature that I wish to emphasize is the centrality of both *semina* and generation to Boyle's intellectual background and early chymical pursuits.

Starkey shared Van Helmont's conception of seeds as having a fermental power by means of their luminosity. Moreover, they both argue that all things ultimately are derived from water. [102] Starkey goes on to explain the transmutation of metals in terms of *semina,* and the famed elixir responsible for turning base metals into gold *is* highly digested gold that contains within it the *semina* responsible for transmutation.[103] This unique theory of matter, in which *semina* and their respective power to organize matter play a crucial role, was communicated to Boyle along with his own introduction to van Helmont over the course of the next few years via his mutual correspondence with Starkey. [104]

Starkey's first letter to Boyle was written shortly after their introduction in the spring 1651.[105] This letter, which reads like something out of an exotic recipe book, is laced with

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101 For more on Starkey's chymistry and his influence on Boyle, see Newman and Principe, *Alchemy Tried in the Fire: Starkey, Boyle, and the Fate of Helmontian Chymistry*. See also Newman, *Gehennical Fire: The Lives of George Starkey, an American Alchemist in the Scientific Revolution:* pp. 159 ff,

102 Newman, *Gehennical Fire*: p.155

103 Ibid. p. 156 ff.

104 See Newman, Principe, *Alchemy Tried in the Fire*: p. 207 ff.

105 Boyle et al, *The Correspondence of Robert Boyle*: v. 1: pp. 90-103. See also Newman, *Gehennical Fire*: p. 209 n.6

alchemical symbols and references to Starkey's secret *Adeptus*.[106] There is little doubt that Boyle, who was then barely twenty-four, could but find Starkey's letter all together enticing. More striking, however, is the overall sexual tone to Starkey's imagery and language. Starkey speaks of the marriage of various substances, spiritual seeds, and impregnations that are ultimately linked to the secrets of transmutation. Consider, for example, Starkey's instructions regarding vulgar mercury. "Wonder not at the weight of the powder for the seed or virtue which is but of a small pondus is in thy mercury & if you please to persue the noble Polonian you shall see how litle a part of the concrete the Seminal Vertue even Seeds is[.]"[107] Thus, Starkey's correspondence served both to introduce Boyle to Helmontian chymistry and to provide him with the notion of *semina* that organize matter and ultimately allow for the generation of minerals and transmutation of metals. That fact is interesting because it places generation at the center of his chymical pursuits. Boyle would maintain this fruitful correspondence with Starkey until the latter's own imprisonment the following year.[108]

2.3.2 *Boyle in Ireland*

In late 1652, disruption caused by the Civil War required that Boyle leave his home in Dorset and remain for some two years in Ireland—a place in which he considered himself "kept prisoner"—in order to maintain control over his estates. Starkey, ironically, had at

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106 This Adeptus was actually none other than Starkey himself. For more on this dual identity, see Newman, *Gehennical Fire: The Lives of George Starkey, an American Alchemist in the Scientific Revolution.*

107 Boyle, *The Correspondence of Robert Boyle*: v. 1: pp. 97-98; Starkey is referring to Michel Sendivogious. See Ibid, n. Sendivogious is also part of a tradition involving seeds in a corpuscular theory of matter. For more on this, see Jole Schakleford's *Seeds with Mechanical Purpose.*

108 There is evidence that Starkey and Boyle continued to communicate until at least 1655. See Newman, *Gehennical Fire.*

that very same time been placed into an *actual* prison on account of his debt. [109] One interesting development from their simultaneous circumstances is the resulting correspondence. In late February of 1654, Hartlib wrote a rather long letter to Boyle in which he details the personal and intellectual developments of both the various members and persons of interests to the Hartlib circle.

The most exciting news was of George Starkey, whom writes is, "altogether degenerated," and in-and-out of debtor's prison. The horrid Dr. Stirk had "secretly abandoned his house in London" and begun, "living obscurely." [110] This news of Starkey is curiously placed in contrast to Hartlib's rather excessive and lauding praise of his newly acquired son-in-law, Frederick Clodius, who had himself developed a chymical laboratory in Hartlib's home.[111] Another item of interest in this letter is Hartlib's inclusion of an expanded "experiment, or secret" in its "original Latin", the translation of which Hartlib had published and sent to Boyle in a treatise on husbandry, *A Discoverie for division or setting out of Land as to the best form.* Hartlib writes:

> The sort of corn [or seed-corn] that should be chosen is weighty and masculine. For this sort alone, when it is thrown into earth (that is feminine) has the power needed for generation. The corn that has been chosen in this way should be placed in a rich [lit. 'fat'] and foetid liquid made from horse manure, in which there should be dissolved as many pounds of salt of the earth, as there are acres that are to be sown; let it macerate over a period of twenty-four hours. If this operation is correctly performed, the middle part of the corn will be enough for the process of sowing [to be carried out successfully]; and so far as this matter is concerned, it will be a task for [only] a single plough, nor will one need to use any other fertilizer, even on barren

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109 Boyle et al, *The Correspondence of Robert Boyle*: v.1, p. 167.

110 Boyle et al, *The Correspondence of Robert Boyle*: v. 1, p. 156.

111 Clodius was also in communications with Starkey, perhaps holding aspirations of winning over Boyle's patronage after Hartlib's falling out with Starkey. See Newman, Principe, *Alchemy Tried in the Fire:* pp. 263 ff.

> earth. The corn, therefore, should come to a suitable state one month before the harvest; and as a result of the fact that the salt of the earth has been mixed in with it, one will be able to keep it in store for a period of ten years. I assure you to press on further with business and to give your encouragement to this useful agricultural invention."[112]

The included expansion, apparently from Dr. Robert Child[113], goes as follows:

> Now, on the subject of soaking of the seeds (a process which I consider to offer a great deal of advantage) I add the following note. One should, above all other considerations, beware of having them macerated or cooked in hot water, let alone near the fire. For people who are experienced in these matters have told me that all the force and fertility of the seed perishes, if they are cooked, or even if they are soaked in rather hot water. These people do not know the reason for this [loss of fertility]. I myself think, however, that the reason is as follows: the seminal virtue consists in the salt. This salt is turned into a liquid and dissolved, as soon as it is mixed with warm water, and thus the grain, having lost its salt, perishes. But if a new set of grains are soaked in that same water in which the previous grains had been cooked up, after it is cooled down, then these new grains attract the salt that has been cooked up in the water, and thus increase in virtue. For one [new] grain attracts the salt of many others [of the previous grains] by magnetic force. And for this reason, it is clearly apparent that manure of the grain-eating sort of animals is to be recommended for fertility, just as you have in the past rightly stated in your writings, when you said that the middle vegetative life even of seeds remains in an exalted form in this sort of dungs. For this reason, grains which have been spoiled by some sort of imperfection in the air should not be thrown away, even if they could not be used for food, because they can nevertheless be boiled up so as to give their force to other grains, and if they are soaked properly can multiply their effect. [114]

The above passage is of interest for three reasons: First, this agricultural recipe is indicative of the relatively mundane prescriptions that frequented the Hartlib circle. Second, it provides real insight into the theoretical issues surrounding the generation of plants and the

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112 This translation is provided by the editors of Boyle's Correspondences, Michael Hunter, et al. Cf. Boyle et al, *The Correspondence of Robert Boyle*: v.1, p. 161.

113 See Ibid. n.

114 Ibid. v.1, p. 161, n.

distribution of agriculture.[115] Finally, it's worth noting the connection already drawn between manure and its fertile properties, a relationship that would become significant in later discussions of nitre. Hartlib, of course, ends his letter with a mention of the industrious Clodius in the context of Helmontian cinnabar.[116]

Boyle had already begun corresponding with Samuel Hartlib's "son", Clodius, a few months prior.[117] If we are to take him at his word, Boyle rather enjoyed the opportunity to correspond with Clodius, as it allowed him the opportunity to discuss all things Philosophical. In April (or May) of 1654, Boyle complains to Clodius that Ireland is, "a barbarous country, where chemical spirits are so misunderstood, and chemical instruments so unprocurable, that it is hard to have any hermetic thoughts in it, and impossible to bring them to experiment…"[118] After grousing for pages about the poor condition of his health and of Ireland, Boyle explains to Clodius that, since he cannot take to chemical analysis due to want of furnaces and glass equipment, he is instead, "exercising myself in making anatomical dissections of living animals."[119] Boyle started vivisecting and doing anatomical dissections with William Petty, who had been appointed to Ireland as the physician general.[120] In the letter, he illustrates his new understanding of the circulation of the blood, the *venæ lacteæ*, and the newly discovered reservoir for chyle (as they were described by Harvey, Asselli, and Pequet, respectively).[121] As a consequence, Boyle's working knowledge of anatomy—

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115 Most especially with the seminal power or virtue consisting in the salt, one could see the possible influence of Van Helmont.

116 Boyle et al, *The Correspondence of Robert Boyle*: v. 1, p. 162

117 Boyle et al, *The Correspondence of Robert Boyle*: v. 1, pp. 148-149

118 Ibid. p. 166

119 Ibid. p. 167

120 Ibid.

121 Ibid.

through his interactions with Petty—became increasingly sophisticated during his stay in Ireland.

Boyle was shortly thereafter able to escape the "barbarous" land which made him both prosperous and miserable so that he could return to England, where he eventually settled at Oxford. Yet, it's worth noting that his previous interactions with Highmore, and later (though to a lesser extent) Petty, illustrate Boyle's appreciation of the problem that animal generation posed for a more mechanical theory of matter. Boyle's chymical knowledge, moreover, had transformed over the course of just a few years from that of a mere novice with limited introduction at best to one that involved many technical laboratory practices. In that process, he was introduced to a large body of alchemical literature which appealed to the concept of *semina*, or seminal principles, as responsible for both the transmutation and the generation of minerals.

Despite the radically different areas of influence and research, they all shared the common theme of explaining just *what* exactly was responsible for the seminal or plastic power of seeds. Boyle's introduction to these sources, moreover, occurred during a time when he was still formulating his own theory of matter. Consequently, the problem of generation— be it of animal, mineral, or even vegetable—as well as the relevance of *semina* in his corpuscular theory of matter, would have been at the very forefront of Boyle's research interests even before his departure for Oxford in 1655.

2.4 Boyle's Early Years at Oxford

2.4.1 *Boyle and the "Oxford Circle"*

Robert Boyle moved to Oxford late in the winter months of 1655 in what his biographer, Michael Hunter, describes as a "momentous move" and one likely motivated by his own desire to alleviate the intellectual isolation which he had experienced while in Ireland.[122] Boyle remained there for thirteen years, during which time he became a prolific public figure and highly regarded for his extensive knowledge in experimental chymistry and natural philosophy. I examine the experimental community present at Oxford during the 1650s and 1660s, as well the role which the problem of generation had within that community.

Robert Frank's *Harvey and the Oxford Physiologists* depicts the effects that social and political changes of Restoration England had upon the scientific community at Oxford. Specifically, the Visitation of 1648 resulted in the removal of several students, professors, fellows, and heads of house that had, "refused to recognize Parliament's authority." The result was vacancies which were filled by those who were Puritan or moderate. By the 1650's, one result of these changes was a community of younger scholars united by a deep commitment to an experimental approach to medicine, the study of anatomy, and the investigations of both chymistry and physics. This community of scholars, frequently referred to as the "Oxford circle," included such members as John Wallis, Jonathan Goddard, Ralph Bathurst, Christopher Wren, Robert Hooke, Walter Needham, and Thomas

[122] Hunter, *Boyle Between God and Science*: p. 92

Willis.[123] Robert Boyle worked rather closely with the latter three members listed here. Upon his arrival at that university, it seems that Boyle immediately had an affinity with this group, as they shortly thereafter would meet at his own lodgings in order to conduct a number of experiments, which included the vivisection of dogs.[124]

2.4.2 *Essay on Spontaneous Generation*

Shortly after arriving to Oxford, Boyle composed around the late 1650s a treatise entitled "Essay on Spontaneous Generation." What remains extant is but a collection of unpublished and fragmented notes from a work that he most likely never finished. The collection is so fragmented, in fact, that most of the varying sections begin mid-sentence, leaving their contexts unclear to the present reader. Although the take-away from these notes is limited due to the disorderly state of their composition, they do nonetheless prove to be very insightful as to Boyle's early and developing thoughts on generation. Boyle's introduction describes the work as an attempt to explain generation "according to the Atomicall Philosophy". As a result, it can be best understood in the context of *Hypomnemata Physica*, Boyle's own experiments with Highmore, and his own attempt to strip Sennert's corpuscular theory of matter of its substantial forms.

To begin, the title is somewhat misleading. Boyle, like Sennert before him, flat-out rejects generation that occurs as the result of putrefying matter or chance. Instead, Boyle appeals to Sennert's description of the so-called spontaneous generation of plants and lower animals as resulting from, "seed properly soe call'd or something analogous or equivalent

123 Ibid. p. 94

124 Hunter, *Boyle Between God and Science:* p. 95

thereunto."[125] One motivating factor for this view, which Boyle explains in this section, is that he

> thought it not amisse to endeavour to invalidate the grand & almost sole considerable objection which Lucretius & the Epicureans oppose to their Arguments ‹who› justly deny the emergency of the world & especially of those animated bodys that helpe to compose it, from a casuall concourse of matter, which being on all hands confess'd to consist of Atoms or particles inanimate whilst such, I confesse I can by noe meanes conceive how such brute parts of matter should conspire to frame such curious Engines as Animalls plants &c without the guidance & conduct of an intelligent cause…[126]

Boyle states his rejection of the Epicurean account of generation repeatedly throughout the essay and in various sections. For example, in the following section, Boyle communicates the same view in the context of mice, which were once believed to be the result of putrefaction but are "indisputably generated by Male and female of the same kind & ordinarily found perfectly fashion'd in the wombs of their dames…" [127] In describing their propagation Boyle writes that he has

> … long insisted thus long on the origination of Animalls from their seminal principles in Opposition to the Epicurean opinion which referrs those creatures to chance. For if they spring from determinate seeds it is evident that they are not produc'd by a casuall shufleing of matter; & if it be said that though not the compleat bodys yet however the seeds of which they spring were at first soe produc'd. I reply that tis as litle to be believ'd & perhaps lesse, that ‹such curious Engines as› the seeds of Animalls & Vegetables should emerge from a fortuitous concourse of matter as that their perfect & full growne body's should As 'tis not more incredible that meere chance should make a clock then that it should make a watch.

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125 Boyle et al, *The Works of Robert Boyle*: v. 13, p. 276, *Fragments of Boyle's 'Essay on Spontaneous Generation*': Section I

126 Boyle et al, *The Works of Robert Boyle*: v. 13, p. 275, *Fragments of Boyle's 'Essay on Spontaneous Generation*': Section I

127 Ibid. p. 277, Section II

This point, which Boyle makes time and time again throeughout the fragments on spontaneous generation, is *mutatis mutandis* a point that he states later in *The Origin of Forms and Qualities*, in which he states that he does not

> at all believe that either these Cartesian laws of Motion, or the Epicurean casual Concourse of atoms, could bring meer Matter into so orderly and well contriv'd a Fabrick as this World; and there I think, that the wise Author of Nature did not onely put Matter into Motion, but when he resolv'd to make the World, did regulate and guide the motions of the small parts of the Universal Matter…into Seminal Rudiments or Principles …[128]

There is, however, one remarkable difference. His later comments include, along with the Epicureans causal interaction of atoms, the Cartesian laws of motion as a subject of criticism. In later works, Boyle would repeatedly distinguish both his theory of matter and his mechanical philosophy from those of Descartes. But, in his fragments on spontaneous generation, he makes no such attempt. This is likely due to Boyle's overall lack of familiarity with Descartes at this time.[129] Boyle does, however, make a short appeal to Descartes's *Passions de l'ame*, in which Descartes gives a mechanical account of human action that involves the soul. Specifically, Boyle mentions Descartes's description of an involuntary reflex, in which case the reflex is not "the worke of the Soule since it is preform'd against her Will…" Of this example, Boyle laments

> I wish that sharp sighted Philosopher had given us more Arguments to prove his Paradoxe. For it would make the contrivance of a seminall principle appeare yet more admirable if it could be clearly made out that not onely it soe comprehends the parts of the future Animall that the teeth & beard & gray haires of an old man were virtually in him whilst he was but an Embryo …

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128 Boyle et al, *The Works of Robert* Boyle: v. 5, pp. 353- 354, *Origin of Forms and Qualities*

129 Davis, '*Parcere nominibus': Boyle, Hooke, and the rhetorical interpretation of Descartes*: p. 159

Nonetheless, we can see from the text a more general lack of familiarity with Cartesian matter theory and his consistent rejection that ancient atomists can account for the kind of organization responsible for generation. That assertion is one that he shares with Daniel Sennert. Indeed, a closer look shows that many of the notes on spontaneous generation Boyle composed with Sennert in mind.

Daniel Sennert's influence upon Boyle is readily apparent in sections IV and V of his notes on spontaneous generation. Here, Boyle describes various instances of animals that seem to generate from putrefaction, including his own experience of finding fish in the belly of his dead bird.[130] In order to explain how these phenomena could occur, he appeals to plants, arguing

> That the seminall principles of some … plants reside in their sap seems probable from hence that if You take a branch of Willow & cut it slanting that the raine may not lye upon the tops into severall short pieces each of those pieces being stuck in a moist & convenient soyle will take root & grow up into a Tree sometimes with such celerity that I have not consider'd it without some wonder.[131]

Boyle continues to cite other vegetables that generate similarly, such as potatoes that will shoot stalks from eyes, before concluding that it "seem'd not impossible but that many of the creatures that suppos'd to be produc'd by the Putrefaction of the body juices or Excrements of Animalls may proberly enough be referr'd to a seminall Origination."[132] Thus, like Sennert, he argues by analogy.

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130 Boyle et al, *The Works of Robert* Boyle: v. 13, p. 283, *Fragments of Boyle's 'Essay on Spontaneous Generation*': Section VI

131 Ibid.

132 Ibid.

Previous research has shown that Boyle could be notoriously disingenuous with his sources and that he was apt to appropriate Sennert, in particular, without recognition. Boyle unsurprisingly makes no reference to Sennert but instead appeals to Highmore's *Corporis humani diquisitio anatomica* . Boyle quotes a rather long passage which begins, "That the atoms of this seminal principle can lie hidden and be subjugated for a long time can be seen from the dissection of the suckers of those trees from which these shoots grow freely…"[133] In this particular passage, Highmore is explaining how shoots grow freely from the small branches of trees in terms of seminal particles that are congealed in the sap. Likewise, Highmore explains moss and thyme dodder, and fungi in the same manner. Boyle expands upon this account to describe mushrooms as the result of wood "impregnated by some adventitious liquor containeining the seminall corpuscles of Mushromes or other plants…"[134] What's telling is Boyle's description of mushrooms, as this account comes out of Sennert's section on mushroom generation in *Hypomnemata Physica.*

In the following section, Boyle appeals directly to William Harvey when describing his own dissection of a pregnant mouse, stating that he had the opportunity, as he

> scarce ever had, at the Dissections of nobler Viviparous Animalls to see clearly in the Fœtus that litle panting Speck, or, as the learned Harvey calls it Punctum saliens… even after I had put it upon my hand discover'd it selfe to be the heart & to be alive though the rest of the fœtus included an almost ovall Membrane fasten'd to the wombe seem'd to be but an ordinary & unorganiz'd liquour …[135]

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133 Boyle et al, *The Works of Robert* Boyle: v. 13, p. 283, *Fragments of Boyle's 'Essay on Spontaneous Generation*': Section V

134 Ibid. p. 284, Section V

135 Ibid. p. 285, Section VI

Boyle's mention of an unorganized liquor may very well be of significance, as he immediately turns the discussion to the gelatinous frog eggs, which are also unorganized and unformed.

Not surprisingly, Boyle pays close attention the successive change that the embryonic frog undergoes from that of an egg, to a tadpole, and the gradual change to an adult frog. He describes with detail and delight how they are furnished with legs as their "temporary tale wears off". The appeal of frogs to Boyle, as he notes, is their transparency. Because the eggs are enveloped by neither shell nor uterus, Boyle is able to observe their development in great detail. He ends the discussion by an account of silkworms and butterflies, which develop similarly from eggs.[136]

The last remaining section in his notes on generation deals with this same topic of successive generation. Boyle begins by stating that although there are cases where living creatures seem to spontaneously generate

> … [they] could not be well deriv'd either from the proper thô latent seeds of Genitors of the same kind or from those analogicall seeds that in the Discourse we have called Seminall Principles; yet there will be noe necessity of ascribeing these Productions with Epicurus to blind chance.[137]

Accordingly, Boyle again repeats his conviction that Epicurean atomism is not sufficient to explain generation and also demonstrates his acceptance of Sennert's description of "seminal principles" as analogical seeds. Boyle appeals to the analogy of animals as clocks, and in this context articulates that seminal principles are responsible for changing putrefied

136 Ibid. p. 286, Section VI
137 Ibid. p. 286, Section VII

matter into the likes of maggots or worms, and for turning caterpillars into butterflies, with regularity.[138]

Here his discussion contains a noteworthy passage in which he compares successive generation to that of the chymist's production of vinegar from raisins by means of fermentation–a process which includes several successive stages from an infusion, to a must, to a wine, and only after these previous stages will the grapes become vinegar. He likens this process to the power of seeds by stating that, "a parcell of matter after having been brought upon the Stage under one forme, and finished the Course it had run in That capacity; should apeare anew upon the Stage in Another forme, and goe off to enter againe in a Third."[139] Boyle's appeal to a chymical successive change in this passage is likely an attempt to argue by analogy for successive generation—such as that of frogs or butterflies—as the kind of thing that can occur from inanimate matter.

Yet his very language gives away his debt to the likes of Sennert and Highmore, each of whom would describe this kind of generation in terms of subordinate forms. For the very capacity of the power of seeds to organize is described in terms of having been brought under one form, and then appearing, "apeare anew upon the Stage in Another forme" and then yet once again into a Third."[140] At no point in his notes on spontaneous generation does Boyle attempt to explain just how the structure of seminal principles is responsible for organizing matter, and this passage makes it clear that Boyle has yet to resolve this tension.

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138 Ibid. p. 287, Section VII

139 Ibid. p. 288, Section VII

140 Boyle et al, *The Works of Robert Boyle*: v. 13, p. 288, *Fragments of Boyle's 'Essay on Spontaneous Generation*' Section VII

Boyle's specific example may very well be from the influence of his good friend, Thomas Willis, who had published his own work, *De Fermentatione*, in 1658. Boyle discusses seeds in the context of both fermentation and a developing power towards a perfected end. *De Fermentatione* communicates a Helmontian account of fermentation contextualized in the corpuscular philosophy of contemporaries. Willis accomplished this by adopting the animal fermentations of Van Helmont, but ultimately rejected the *archaeus* of Van Helmont and Paracelsus before him. Fermentation, on this view, is the rearrangement of these atoms, caused by "… an intestine motion of Particles, or the Principles of every Body, either tending to the perfection of the Same Body, or because of its change into another. For the elementary Particles being stirred up into motion… do wonderfully move themselves, and are moved." [141]

An interesting feature of Willis's definition of fermentation is that it retains the idea, expressed in Aristotle, of something being perfected towards *its end.* Willis continues by later stating that the more subtle particles either, "frame the due perfection in the subject, or compleat the Alterations and Mutations designed by nature." Like Aristotle's *pepsis*, Willis's fermentation is responsible for natural processes, including digestion[142], precipitation of bodies[143], putrefaction[144], alcoholic fermentation[145], disease[146], the growth

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141 Willis, *Of Fermentation or the Inorganical Motion of Natural Bodies*: p. 8

142 Ibid. p. 32

143 Ibid. p. 38

144 Ibid. p. 15. Not all putrefied substances are the result of fermentation, however. For example Willis writes that milk, blood, and urine do not ferment but rather putrify. Curiously, that urine does not ferment is a view that Boyle later came to believe.

145 Ibid. p. 1

146 Ibid. Willis writes that, "Every Disease acts its Tragedies by the strength of some Ferment. For either the Sulphureous and Spirituous part of the blood, being too much carried forth, boyls up immoderately in the Vessels, like Wine growing hot, and from thence Feaver … and from thence it being made acid, austere, and sometimes sharp, is apt for various Coagulations; from which the Scurvy, Dropsie, Stone,

of plants[147], and other "causes of motion and alterations."[148] Perhaps as a result of his close friendship with Willis, Boyle was among the first to receive a copy, and consequently shared it with Hartlib.[149] Because Willis combines the chymical accounts of Van Helmont with a more corpuscular theory of matter, it comes as no surprise that Willis' views on generation and fermentation would be of influence to the younger Boyle.

All the same, Boyle's appeal to Willis would not fully absolve him. Willis' own corpuscular theory of matter does not account for the organizing power of seminal principles, nor does it explain Boyle's own appeal to successive forms. Yet that tension is at the very heart of his early thoughts on his mechanical philosophy, as he describes this successive development within the context of God as the artificer of a clock-like universe. Specifically, Boyle (like Sennert) wants argue that seminal principles are the manner in which God "had establish'd those laws of motion to which all the parts of matter that compose it should necessarily conforme…"[150] Boyle ends this particular section—the last among these fragments—with a passage which in many ways captures his overall attitude towards the problem of generation: "And shall we readily allow soe much foresight & contrivance to a Mechanicall artificer, and shall we scruple to allow much better Mechanismes to (the Author

Leprosie, and very many Chronical Diseases arise." From this description he later developed his theory of fever and fermentation (published in 1658), which received favorable attention from the medical community.

147 Ibid. p. 3

148 Willis, *Of Fermentation or the Inorganical Motion of Natural Bodies*: preface

149 Frank, *Harvey and Oxford Physiologists*: p. 167

150 Boyle et al, *The Works of Robert Boyle*: v.13, p. 287, *Fragments of Boyle's 'Essay on Spontaneous Generation*' Section VII

even of Artificers) the Omniscient God himselfe, in the Production of his Great *Automaton,* the World?" [151]

His use of the term 'Mechanismes' and notion of God as a "Mechanicall artificer" is particularly striking given how early he makes this reference. Recall that the notes on spontaneous generation were composed in the 1650s. One markedly telling feature of the text is Boyle's use of the word 'Automaton', which is a self-operating machine. 'Mechanismes' (at least in this context) has less to do with the sparse ontology of someone like Descartes, and more to do with the objects in nature moving like the well-regulated parts of machines, such as clocks.

Boyle's account to Pyrophilus of the aims of this essay—"to explicate divers Phænomena belonging to Generation according to the Atomicall Philosophy" [152]—strongly suggests that this unfinished treatise should be viewed as that of a juvenile Boyle. Boyle's theory of matter underwent considerable changes in the late 1650s and early 1660s in which he came to reject the *Atomicall Philosophy* flat-out.

2.4.3 *Original Usefulness of Natural Philosophy*

Whereas his "Atomicall Philosophy" and Essay on Spontaneous Generation represent the developing thoughts of a juvenile Boyle, his original version of "Usefulness of Natural Philosophy" might be considered a more intermediary step towards the famed author of *The Sceptical Chymist.* This treatise was eventually published in 1663, but the earlier and unpublished manuscript has a number of significant differences. One such

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151 Ibid.

152 Boyle et al, *The Works of Robert Boyle* v. 13, p. 276, *Fragments of Boyle's 'Essay on Spontaneous Generation*': Section I

contrast includes a section on the generation of kidney stones, which he frequently describes as a "Lapideous Concreation."[153] Boyle compares their generation to that of limestone, which forms sometimes in "seemingly pure" waters that in actuality "containe in themselves a Petrifick Spirit, which will by any slight assistance manifest its nature as we have seene in stones, made of dropping water which being by its intrisicke Gorgon, coagulated before it could fall to the ground…" [154] The relatively short section has a few telling features. First, Boyle repeatedly uses the term 'generation' to describe the formation of stones and minerals, a view of which he later seems to become weary in the 1670s. Second, much of his discussion on the matter is in the context of Van Helmont. Perhaps most interesting, however, is that Boyle ends the passage by referring to chymistry as the "handmaiden" to physiology.[155]

2.5 Boyle's Early Publications: 1660- 1663

2.5.1 *The Great and Honorable Robert Boyle*

By 1660, Boyle had become an increasingly public figure in the community at Oxford and in the intellectual community of England, more generally. His *New Experiments, Physico-Mechanical, Touching the Spring of the Air and its Effects* was fresh from the press and was met with enthusiasm over the novel experiments that he performed with his famed air-pump. Further, he became associated with the development of the Royal Society, "the first public institution devoted to the pursuit of scientific research," also established in

153 Boyle et al, *The Works of Robert Boyle* v. 13, p. 291

154 Ibid. Boyle is most likely getting this term from Walter Charleton's 1650 *Spiritus Gorgonicus*, which discusses a stone-forming spirit responsible for both stones in the earth and those that develop in man. For more on this, see: Booth, *A Subtle and Mysterious Machine: The Medical World of Walter Charleton* and Kargon, "Walter Charleton, Robert Boyle, and the Acceptance of Epicurean Atomism in England."

155 Ibid. p. 295

1660.[156] Boyle received considerable fame the following year in 1661 upon the publication of the *Sceptical Chymist*, and it's easily one of his most important books. This seminal work was soon followed by the publishing of a compilation of papers entitled, *Certain Physiological Essays* in 1661 and his famed *Usefulness of Natural Philosophy* in 1663. Examining these three treatises closely together allows us to evaluate Boyle's attempt to contextualize the forces of generation within his increasingly sophisticated corpuscular and mechanical theory of matter.

2.5.2 *Boyle's Corpuscular Theory of Matter*

Exposited in these three treatises is a more complex and sophisticated theory of matter than that which can be found in Boyle's earlier writings. Whereas *Atomicall Philosophy* focuses on the atom as the smallest particle of matter, his later works describe a hierarchical ontology in which the smallest units of matter are the *prima naturalia.*[157] Boyle's avoidance to the term 'atom' is likely because of his "dislike of the seeming imprecision in this usage (since the term *atomos* originally meant "indivisible" in an unqualified sense) as well as an attempt to avoid an explicit association with Epicurus." [158] On this view, the *prima naturalia* come together to form clusters of matter, or corpuscles, which are somewhat analogous to the modern notion of molecule. The shape, size, and motion of these corpuscles—as well as the texture resulting from their various combinations—are responsible for the distinctive traits of various chemicals and substances, all of which are composed of otherwise uniform,

156 Hunter, *Beyond God and Science:* p. 131

157 William Newman convincingly shows that Boyle's terminology and main claim here are adapted from Daniel Sennert's *Hypomnemata physica.* See *Atoms to Alchemy:* p. 172

158 Newman, *Atoms to Alchemy:* p. 173

catholic matter. The project of Boyle's theory of matter, then, becomes one of explaining how the various chymical powers (including the plastic power of seeds) and non-mechanical properties are resultant from homogenous, quality-less matter.[159]

2.5.3 *Seeds and God*

Vis-à-vis generation, Boyle depicts seeds in his ontology as deriving from some of the first coalitions of matter. Further, he associates them with the divine intelligence of God. We can see Boyle's appeal to God for the powers of seeds in the *Sceptical Chymist* through the mouth of Carneades, who states that he is, in fact, not Epicurean, because the constitution of the world requires an "Architectonick Principle" by which to "turn that confus'd Chaos into this Orderly and beautifull World' and Especially, to contrive the Bodies of Animals and Plants, and Seeds of those things whose kinds were to be propagated." Matter, "[b]arely put into Motion," seems to him to be an utterly implausible explanation.[160]

Similarly, Boyle includes seminal principles among the more "Catholick and Primary causes of Things," in *Usefulness of Natural Philosophy.* These primary causes are either the laws of nature, or the size, shape and motion of "other primary Affections of the smallest parts of Matter, and of their first Coalitions or Clusters: especially those endowed with seminal Faculties or Properties…" [161] Boyle is rather explicit about his incentive for including a seminal property in certain parcels of matter, namely, that the random coalition

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159 Cf. Newman, *Atoms and Alchemy:* p. 180

160 Boyle et al, *The Works of Robert Boyle*: v. 2, p. 355, *Sceptical Chymist*

161 Boyle et al, *The Works of Robert Boyle*: v. 3, pp. 245-246; *Usefulness of Natural Philosophy*. This particular passage was from a chapter entitled, *"Containing a requisite Digression concerning those that would exclude the Deity from intermeddling with Matter."*

of corpuscles could not account for the complexity of living organisms. It would be "incredible" he says, if

> … an innumerable multitude of insensible Particles, as that a lesser number of bigger Parcels of Matter, should either conspire to constitute, or fortuitously justle themselves into so admirable and harmonious a Fabrick as the Universe, or as the Body of Man; and consequently it is not credible that they should constitute either, unless as their motions were (at least, in order to their seminal Contextures and primary Coalitions) regulated and guided by an intelligent Contriver and Orderer of things.[162]

He goes on to write that he finds it too incredible to believe that particles of matter could organize themselves to create something like the body of man without regulation by seminal principles ordered by God. That regulation, like his earlier writings, is one which is arranged at the beginning of creation. Boyle does not promote a kind of Occasionalism or a God that intervenes as the process of generation occurs. Rather, seminal principles are endowed with formative powers at the beginning of Creation and continue with regularity.

Boyle's conception of seminal principles as parcels of matter endowed by God with a formative power is consequently one that he consistently maintains throughout his career. As the earlier part of this chapter suggested, Boyle's appeal to seminal principles opposes the Cartesian explanations as well as the atomistic Epicureans. Neither, Boyle claims, can explain something like the generation of living organisms. For these reasons Boyle will never provide an account of generation without some appeal to God because to do so, in Boyle's mind, would make him akin to atheist. One must be careful, then, not to assume that his inclusion of God as the source of a formative power is the result of some failing of his mechanical philosophy. Boyle's own mechanical universe is one that will never be

[162] Ibid. p. 261

devoid of the God, and his thoughts on generation are, have been, and will be intricately tied to his understanding of the Creation story.

2.5.4 *On the Generation of Minerals*

Boyle deals with the generation of minerals in *Certain Physiological Essays* with a paper entitled, "History of Fluidity." In the text, Boyle discusses the coagulation of bodies, like the curdling of milk by saline liquors, and he combats the chymical theory that salts are the only agents responsible for hardening and coagulation.[163] One such counter-example he provides involves ice, which becomes hard by the cold rather than by salt. Boyle continues by considering, also, the nature of eggs. His first reference to eggs as a counter-argument involves their shells, which are soft immediately after being laid, but soon harden from their interaction with air. Boyle follows this claim, however, by stating that he has an even more convincing counter-example, namely the internal fluid of the egg. He writes that the white of the egg coagulates and grows to create the various parts of the chick, such as its beak and bones. All of that hardening from fluids occurs, argues Boyle, without salts.

Boyle elaborates on the production of minerals in a treatise originally intended to be an addendum to the *History of Fluids*, an essay, entitled "Thoughts and Observations about the Generation of Minerals."[164] A collection of notes, "Generation of Minerals" is essentially an unfinished work that was never published in his lifetime. It's disorganized, and its different sections were possibly not even written at the same time. Hence, the treatise must

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163 Boyle et al, *The Works of Robert Boyle*: v. 2, p. 187, *Certain Physiological Essays*

164 This treatise was published along with several other unpublished treatises of Boyle as part of the collection of Michael Hunter and E.B. Davis. For the remainder of the paper, its title will be abbreviated as "Generation of Minerals."

ultimately be taken with, as they say, a grain of salt. Nonetheless, "Generation of Minerals" proves to be a source of great insight into Boyle's earlier beliefs on the formation of minerals. Throughout the work, Boyle defends the thesis that minerals, and gems specifically, develop by hardening from a liquid state. He begins, however, by considering four possibilities by which minerals could be produced.

The first, which he considers unlikely, says that the creation of minerals occurred simultaneously with the creation of Earth, leaving their *production* per se unexamined. Also unlikely to Boyle is the second possibility he considers, that minerals are formed by the "casuall Coalition of congruous particles." Aside from being unlikely, Boyle complains of the Epicurean thesis that it could not give an account of the minerals which are "produc'd very deepe within the bowells of Earth." It is likely such metals that he has in mind when he considers the third possibility, that seminal principles developed by an internal heat.[165]

Boyle is most inclined to the last possibility he cites, which consists in the hardening from a liquid state. He appeals to a "lapidific or petrifick spirit" as the agent responsible for their hardening, formation, and complex organizations. Boyle defines this spirit as

> not only that which subsists in the form of Vapor or Steam, but that also, which appears under the form of a Liquor or other palpable body, in which sense the Chymists take the word when they speak of 1lb of high rectifyd [spirit of wine][166], or ‹of› Spiritus Vitrioli Coagulatus; Premising I say this explication of the Terme, I proceed to consider ‹the chief way› (for I pretend not now to treat of All) by which this Spirit may perform its operations.[167]

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165 Boyle et al, *The Works of Robert Boyle*: v. 13, p. 366, *Generation of Minerals*

166 Square brackets such as these have been inserted by the editors so to add transliterations for the convenience of the reader. See Boyle et al, *The Works of Robert Boyle*: v. 1, p. xcvii for more on editorial notations.

167 Ibid. p. 371

The petrifick spirit, Boyle explains, works as either a plastic agent, sensible ingredient, or like a ferment. In truth, Boyle sees each of these as different ways of describing the same properties of his Petrifick Spirit. The agent is plastic in the sense that it is a formative force capable of producing and solidifying new bodies. That the spirit acts like a sensible ingredient is on account of its being distinctly physical. Finally, it works like a ferment in the sense that it acts upon and coagulates passive matter. Each of these analogies illustrates the process which Boyle has in mind, namely that of matter acting upon matter and their resulting interaction.

Boyle gives two descriptions for the mode of operation of this petrifying spirit as the cause of more complex minerals: First, the agent (i.e., the petrifick spirit) is quite small in proportion to the mass of matter which it affects.[168] His second account, perhaps the more interesting, relates specifically to the manner in which he thinks that this agent works. That is, it does coagulate, but "less like that of the Cicatricula of an Egg" or even the seminal part of frog spawn. Rather, the manner in which the agent works, he thinks, is more like the coagulation of milk curds with rennet—that is, like a ferment. As we shall see in later chapters, this contrast is by no means an insignificant one.

2.6 Robert Hooke and Robert Boyle

2.6.1 *Boyle's Introduction to Descartes*

A great deal has been made of the relationship between Hooke and Boyle in recent literature, and their relationship is a somewhat precarious one for the intellectual historian. Throughout his life, Robert Hooke had a knack for the designing and manufacturing of

[168] Boyle et al, *The Works of Robert Boyle*: v. 13, p. 372, *Generation of Minerals*

scientific instruments, the enthusiasm for which, "runs throughout his spectacular range of interests in mathematical science and natural philosophy." [169] In addition to providing Boyle with the instruments necessary to conduct his experiments, Hooke was also instrumental in Boyle's early intellectual development. E.B. Davis has effectively shown that Boyle's introduction to Descartes's mechanical philosophy was through none other than Robert Hooke. A large part of his argument comes from John Aubrey, "who tells us that Dr Thomas Willis recommended Hooke 'to the Hon[oura]ble Robert Boyle, Esqre, to be usefull to him in his Chymicall operations. Mr Hooke then read to him (R.B. esqre) Euclid's Elements, and made him understand Descartes' Philosophy."[170] Davis couples this point with Boyle's remark in the fragmented Essay on Spontaneous Generation—mentioned earlier in this chapter—that *Passions* was the only book of Descartes that Boyle, "could remember [him]selfe to have read over."[171] These facts together make apparent that Boyle's familiarity with the Cartesian program came primarily through Hooke's introduction.

In late 1650's and early 1660's Hooke was under Boyle's employ, during which time Boyle made use of Hooke's mechanical talents, most notably by employing them for the production of Boyle's highly lauded air-pump, the instrument which made possible his 1660 *Spring of the Air and its Effects* mentioned earlier. [172] In 1662, however, Hooke was "released" of his duties for Boyle so that he could act as curator to the newly developing Royal Society.[173] Shortly thereafter he began to manufacture his microscopes at the behest of the Royal Society. This event soon led to the publication of his groundbreaking

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169 Bennett, "Hooke's Instruments for Astronomy and Navigation": p. 21, in *Robert Hooke: New Studies*

170 Davis, "'Parcere nominibus': Boyle, Hooke, and the rhetorical interpretation of Descartes": p. 159

171 Ibid. pp.159-160

172 See Jardine, *The Curious Life of Robert Hooke*: pp. 42 ff. for a detailed analysis.

173 Hunter, *Between God and Science*: p. 134

Micrographia, which stunned members of the Royal Society with its graphic portrayal of a microscopic view of nature.

2.6.2 *Background to Micrographia*

Micrographia is a text with a curious and socially complicated history. In early 1661, Christopher Wren gave to King Charles II illustrations of, among other things, a series of microscopical drawings of a flea, louse, and a fly's wing. The king, pleased with the drawings, requested through the Royal Society that more of them be made by Wren.[174] "The politics of the situation were grave. The Royal Society naturally stood to gain a great deal of favor through Wren, whose work greatly pleased the king, but they also risked disfavor if Wren did not comply with the king's wishes. Furthermore, they could not be assured that they would reap the benefits of Wren's talents if Wren did not choose to associate his gift with the Royal Society; however, they were almost guaranteed to lose favor with the king if they failed to carry out his request." [175] After Wren, who had sent the drawings to King Charles II without consulting the Royal Society, ultimately refused to comply with the request, the task of fulfilling the wishes of the king eventually fell upon the shoulders of the society's curator of experiments, Robert Hooke. In what was perhaps a brilliant move for social leverage, Hooke produced an ambitious and impressive folio, complete with thirty-eight copperplate engravings that bear testimony to his skills as an artist. That the Royal Society's agenda informed the development of *Micrographia* is certainly the case. Nonetheless, communicated in the *Micrographia* is Hooke's distinctive approach to Natural Philosophy, one which both influenced and was influenced by Boyle's own approach.

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174 Neri, *Insect and image: Visualizing Nature in Early Modern Europe:* pp. 106 ff.

175 Ibid. p. 108

Important for our purposes is that Hooke's microscope provided a revolutionary view into nature, and his *Micrographia* consequently contains several significant contributions to the study of generation. Whereas Hooke introduced Boyle to Cartesian mechanism, so too did Boyle introduce Hooke to the value of even the tiniest of God's creations for illustrating divine wisdom. This value is articulated at length in Boyle's *Usefulness*.[176]

2.6.3 *Petrification in Micrographia*

Robert Hooke's discussion of fossils and petrified wood is arguably among the most important contributions contained within *Micrographia*. Hooke includes his account of fossils in the section on petrified wood, as wood is not "the onely substance that by this kind of transmutation be chang'd to stone …" Such minerals, he says, owe their formation and intricate figure

> "not to any kind of Plastic virtue inherent in the earth, but to the shells of certain Shel-fishes, which, either by some Deluge, Inundation, Earthquake, or some such other means, came to be thrown to that place, and there to be fill'd … and hardened in those shelly moulds into those shaped substances we now find them… " [177]

The origin of complex minerals such as fossils or petrified wood was a contentious subject of the seventeenth century. That controversy, moreover, was intimately linked with the problem of generation because of writers such as Albertus Magnus, Anselm de Boodt, and even Daniel Sennert.

Robert Hooke was "one of those responsible for the clarified understanding of the relationship between natural matter and its fossilised state."[178] Lisa Jardine explains that his

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176 Harwood, "Rhetorics and Graphics in Micrographia": p. 142, in *Robert Hooke: New Studies*

177 Hooke, *Micrographia*: p. 111

178 Jardine, *The Curious Life of Robert Hooke*: p. 38

interest in geology—in fossils, petrified wood, and in theories of mineral generation—stems from his childhood experiences at the fossil rich Freshwater Bay, just southwest of his boyhood home at the Isle of Wight.[179] In particular, it was his close attention to the stratified rock formation and geological properties of stone in the area.[180] The astute attention to rock formation and stone on Hooke's part would inform his 1668 *Lectures and Discourses on Earthquakes*, as well his later role in the so-called "fossil wars" of the 1680s.[181]

Finally, this explanation is related to another thesis promulgated by Hooke—one which is discussed in Boyle's unpublished *Generation of Minerals*—namely, that gems and precious minerals form from coagulated fluids. "Observation XIII. Of the Small Diamants, or Sparks in Flints" describes this formation, and Hooke is especially impressed by the regularity of their shape. In order to explain the geometrical shapes discussed in the chapter, Hooke appeals to the concurring of "coagulating particles," that determine the figure, "and this with as much necessity and obviousness as a fluid body encompast with a Heterogeneous fluid…" Hooke's mention of and appeal to heterogeneous fluids in the context of mineral formation proves to be complicated for the purposes of understanding Boyle because mineral formation from heterogeneous fluids prove to be a key feature of the latter's *Origin and Virtues of Gems*, published in 1672. Especially since Hooke's mention of heterogeneity in this context seems to be in elaborating on Boyle's own thoughts articulated in *Generation of Minerals*, it remains unclear whether priority between the two may ever be established.

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179 Jardine, *The Curious Life of Robert Hooke*: p. 120

180 Ibid. p. 38

181 Rossi, *The Dark Abyss of Time*: pp.12-17; Rappaport, *When Geologists Were Historians*: p. 108 ff.

Hooke maintains that same interest in the regularity of figures when discussing frozen figures in Observation XIV. In describing the figures, Hooke compares the branches of frozen urine-cicles to both the crystals that develop from *regulus martis stellatus* and those one would see in a fern.[182] One of the more curious things stated by Hooke in this comparison is that, "if the Figures of both [that is, frozen urine and fern] be well consider'd, one would ghess that there were not much greater need of a seminal principle for the production of Fearn, then for the production of the branches of Urine, or the Stella martis, there seeming to be as much form and beauty in the one as in the other."[183] Hooke seems to articulate in this passage an attitude similar to that ascribed by Anstey to Boyle, one of a "threshold of complexity" in which seminal principles are appealed to for those things in nature beyond which a mechanical explanation is no longer sufficient.[184] All the same, this idea of production through petrification is one that Hooke uses considerably, and he appeals to this kind of formation to explain not just minerals but, as we shall see, some kinds of organic life as well.

2.6.4 *Hooke and Mushrooms*

Another subject of Hooke's investigations was that of fungi, which he discusses at length in the section, "Of blue Mould, and of the first Principles of Vegetation arising from Putrefaction." Hooke seems expressly interested in the means by which mushrooms generate and develop. Here he explicitly denies that mushrooms have seeds, a view communicated earlier by Boyle in his *Essay on Spontaneous Generation*. Hooke writes

182 Hooke, *Micrographia*: p. 90
183 Ibid.
184 Anstey, "Boyle on Seminal Principles": p. 619

> … that as Mushrooms may be generated without seed, so does it not appear that they have any such thing as seed in any part of them; for having considered several kinds of them, I could never find any thing in them that I could with any probability ghes to the be the seed of it, so that it does not yet appear (that I know of) that Mushrooms may be generated from a seed, but they rather seem to depend merely upon a constitution of the matter out of which they are made, and a concurrence of either natural or artificial heat.[185]

Catherine Wilson considers this passage of Hooke's within the context of spontaneous generation, or those bodies which are generated out of putrefying or fermenting substances without a seminal principle. Continuing in that discussion, she writes that

> Mold and mushrooms, [Hooke] says, require no seminal principles, but spring directly from putrefying flesh or vegetable matter; they are like crystals in that their form can arise through ordinary laws, as one can see from the mushroom shape of the cloud of an extinguished candle.[186]

Although Wilson is right to characterize Hooke's theory of generation as strictly mechanical, there are some details in his account worth clarifying. First, though Hooke readily admits that mushrooms are derived from putrifying matter, he never appeals to the process of putrefaction as the formative agent responsible for that generation. Instead, Hooke states quite explicitly that a mushroom's origin is on account of, "concurrence of either natural or artificial heat." Now, to be sure, it is a curious feature of his chapter on mold and mushrooms that Hooke spends the majority of the discussion citing examples of minerals. Those minerals, however, are not crystals. Rather, they are examples of mineral formations that are the result of "growing" upwards: a feature which Hooke readily admits is the "contrary principle to that of petrify'd Iceicles".[187]

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185 Hooke, *Micrographia*: p. 127

186 Wilson, *Invisible World:* p. 199

187 Hooke, *Micrographia*: p. 130

Consider the specific examples cited by Hooke, several of which include figures, "guided with a congruous heat," that are the result of ebullition.[188] Likewise, he also references stalactites and stalagmites, or "the droppings or trillings of Lapidescent waters in Vaults underground [that] seem to constitute a kind of petrify'd body, form'd almost like some kind of Mushroms inverted…"[189] Particularly well regarded by Hooke—that is, "above all the rest"—is his "Silver Tree". The "tree" to which he refers, frequently called the "Tree of Diana", is actually is a kind of a crystalline growth that develops from an amalgam of silver and mercury placed within a solution of silver and mercury that has been dissolved in *aqua fortis* (nitric acid).[190] His reference to the amalgam becomes clear when Hooke writes that it is, "a very pretty kind of Germination which afforded us in the Silver Tree, the manner of making which with Mercury and Silver, is well known to the chymists, in which there is an Ebullition or Germination, very much like this of Mushroms, if I have been rightly inform'd of it." [191]

Only after the mention of this example does Hooke move onto the observations with candles under the microscope, whereby "partly from the sticking of the smoaky particles as they are carryed upwards by the current of the rarify'd Air and flame, and partly also from a kind of Germination or Ebullition…" that they form "pretty round and uniform heads" that

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188 Ibid. pp. 127 ff.

189 Ibid. p. 129

190 The "branches" which develop and the manner in which it grows look surprisingly plant-like as if guided by a kind of a faculty.
To see this experiment reproduced, see http://webapp1.dlib.indiana.edu/newton/reference/chemLab.do.

191 Hooke, *Micrographia*: p. 128

resemble those of mushrooms.[192] By looking at the specific array of examples in this discussion, we can better understand Hooke's concluding statements about mushrooms:

> We therefore have further to enquire of it, what makes it to be such a liquor, and to ascend, whether the heat of the Sun and Air, or whether that of firmentation or putrifaction, or both together; as also whether there be not a third or fourth; whether a Saline principle be not a considerable agent in this business also as well as heat…
>
> And in the mean time, I must conclude, that as far as I have been able to look into the nature of this Primary kind of life and vegetation, I canot find the least probable argument to perswade me there is any other concurrent cause then such as purely Mechanical, and that the effects or productions are necessary upon the concurrence of those causes as that a Ship, when the Sails are hoist up, and the rudder is set to such a position should, when the Wind blows, be mov'd in such a way or course to that or t'other place…[193]

Here, we are presented with a rich text and two key insights: First, we see how Hooke understood the process of generation to occur with regards to mushrooms. Further, we are given an example that Hooke took to be "purely Mechanical". Regarding the first part passage, it's important to note that putrefaction and fermentation here are cited as means of producing *heat*, and it is this heat which Hooke takes to be the primary agent of change here. Hooke's discussion suggests that he understood the development of mushrooms to be almost a kind of petrification, which would not at all be incompatible with a saline principle. In this sense, he provides a radically different account of mushroom generation. Whereas Boyle explains the generation of mushrooms and plants like mistletoe in terms of a particulate analogue to a seed, Hooke blatantly denies this and instead finds a way to mechanize the process by which putrefaction could be responsible for their generation: heat.

2.6.5 *Microscopic View of Insects*

192 Ibid.

193 Ibid. p. 130

Perhaps the most interesting of Hooke's findings are those related to insects. *Micrographia* is often cited as groundbreaking with regards to the life sciences on account of his coining the term 'cell'. This contribution, however, is incidental. Hooke was completely oblivious to the significance his observation would have for the cell theory of later biologists. *Micrographia* nonetheless remains one of the most historically significant texts to be published in the so-called life sciences because it acts as a previously un-opened window by which its readers could view the tiniest of creatures in nature.

Hooke's depiction of insects could, in fact, be said to be at the heart of *Micrographia*, given its origin with Wren's microscopical drawings of insects. Hooke's ambitious production of insect images had significant implications for the study of generation. As previously stated, Hooke—like Boyle—held that even the lowliest of God's creations could illustrate the brilliance of the divine Architect. Nothing could illustrate this point so effectively as Hooke's illustrations and discussion of the microscopic world of insects. The myriad of insect images produced in *Micrographia* nonetheless fueled an already developing interest in insects and would propel the study of their generation as a subject of inquiry well into the eighteenth century. In chapter 4, we will see the results of how (in only a few years) such a booming interest in insects and the dramatic implications that this research would have for the problem of generation more generally.

A major contribution of *Micrographia* is Hooke's previously unseen depictions of the means by which insects reproduce sexually, such as their eggs and larva. Observation 41, *Of the Eggs of Silk-worms, and other Insects,* gives a detailed account of insect eggs. Hooke compares the eggs of silkworms to those of hens or geese in terms of the shell, which

were both "very white" and "very brittle, and crack'd." [194] The eggs of other "Oviparous Insects"—like spiders or flies—are described as "exactly round" globules, and the eggs of flies are produced "neer four or five hundred" at a time.[195] Despite his description of fly eggs, as well as the detailed intricacy that composes a single fly that made spontaneous generation seem all the more unlikely, Hooke does nonetheless allow for the spontaneous generation of inferior animals or insects.[196] His discussion in Observation 21 has a good deal to say on the subject of generation from putrefying matter.

Noteworthy is Hooke's reference to "equivocal generation." Hooke uses the term when describing the generation of cod plants, which he likens to moss or mold by the manner in which the cod "breaks out in little scabs or spots." Of the plant, he writes that, "…it may have its equivocal generation much after the same manner as I have supposed Moss or Mould to have, and to be a more simply and uncompounded kind of vegetation, which is set a moving by the putrefactive and fermentive heat…"[197] His use of the term "equivocal generation" suggests that he may be under the influence of Boyle. It might be fitting, too, considering that he explains their generation through putrefying material in the context of how "unimaginably small must each of those seeds necessarily be" should the cods reproduce with seeds.[198] This would fit with Boyle's and Sennert's description of imperceivable seminal corpuscles as responsible for so-called spontaneous generations. We should note, nonetheless, that Hooke's reference to a putrefactive and fermentative heat in this passage sounds more reminiscent of his account of mushrooms. While he might have

194 Hooke, *Micrographia:* p. 181
195 Hooke, *Micrographia*: p. 182
196 Ibid. p. 123. Cf. Bertoloni Meli, *Mechanism, Experiment, Disease:* p. 179
197 Hooke, *Micrographia:* p. 122
198 Ibid.

taken from Boyle the notion of equivocal generation, he seems to have a different process in mind.

The majority of cases in which lower animals spring from putrefying matter, Hooke explains, occur when, the "putrifying substances on which these Eggs, Seeds, or seminal principles are cast by the Insect become, as it were the Matrices or wombs that conduce very much to their generation…" He further considers the possibility that the putrefying substances can add to the process producing a kind of monstrous hybrid like mules, in which cases the putrefying body becomes "more then merely a nursing and fostering helper in the generation and production…" In those kinds of cases, he emphasizes the parallel between the putrefying matter and a womb, which has the power to influence generation. Hooke ends the description on a more philosophical note, stating that "Perhaps some more accurate Enquires and Observations about these matters might bring the Question some certainty, which would be no small concern in Natural Philosophy."[199]

2.7 Walter Needham, Robert Boyle, and the Chick-Egg

2.7.1 *Walter Needham and Robert Boyle*

Walter Needham was an English anatomist and physician who would become a member of the Royal College of Physicians, where he eventually practiced medicine in London. Needham received a BA from Cambridge in 1654, and later a doctor's degree of Physick from that same institution a decade later. Yet, despite his association with the university, Needham spent most of the 1660's at Oxford. He left for Oxford in 1662, where he worked closely with Boyle and other members of the "Oxford circle."[200] In particular, Needham

[199] Hooke, *Micrographia:* p. 123

[200] Frank, *Harvey and the Oxford Physiologists:* p. 181

was interested in the new, experimental philosophy practiced by the group, including the vivisections which took place in Boyle's chambers.

The result of Needham's investigations with Boyle and other members of the Oxford group was his publication of *Diquisitio Anatomica de Formato Foetu* by the Royal Society in 1667. *Disquisitio Antomica de Formato Foetu,* which is dedicated to Boyle, is an impressive and rich embryological text despite its surprising lack of attention in the secondary literature.[201] *Disquisitio* focuses on the sanguification, respiration, and nutrition of the fetus in-egg or in utero. To fully appreciate the context of his work, two experiments conducted by his contemporaries must first be briefly examined. The first of these is a vivisection for which Needham was present that was conducted by Boyle, Hooke, and Lower, and that involved the cut-open thorax of a dog. This experiment demonstrated that the change in the color of the blood which occurs in respiration was due to neither a ferment in the heart nor any vital, internal heat. Rather, in their words, it happened on account of "the want of a sufficient supply of air." [202] The second involves an experiment conducted only a few years beforehand by French anatomist, Jean Pecquet. In his 1651 *Experimenta nova anatomica,* Pecquet established the existence of the thoracic duct, in which chyle by-passed the liver entirely and went instead to the heart through the subclavian vein. [203] His definitively linking the lacteals to the circulation of the blood gave further reasons for rejecting Galenic understandings of nutritive processes.

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201 For the most comprehensive treatment of Needham's treatise, see Needham, *History of Embryology*.

202 Bertoloni Meli, *Mechanism, Experiment, Disease:* p. 53; Frank, *Harvey and the Oxford Physiologists:* pp. 193 ff.

203 Guerrini, "Experiments, Causation, and the Uses of Vivisection in the First Half of the Seventeenth Century": p. 246. Cf. Bertoloni Meli, *Mechanisms, Experiment, Disease*: p. 114.

Because the mechanisms of both respiration and nutrition remained unclear and a subject of contention at the time of Needham's investigations, his experiments on the fetus—itself a developing animal enveloped in amniotic fluid—are a rather ingenious attempt to understand more fully how these biological processes occur. For his part, Boyle was most certainly aware of each of the above experiments and their significance for anatomy. He was an active participant in the first, and we saw in the last chapter that Boyle had learned of Pequet's discovery through his frequent dissections with William Petty.[204] There is henceforth little doubt that Boyle would have had an active interest in Needham's findings given how frequently he is referenced by Needham.

It seems that Boyle had expressed some interest in both Needham and *Disquisitio Antomica de Formato Foetu* to Henry Oldenburg. Oldenburg takes the time to mention its progress to print on three separate occasions to Boyle, as well as Needham's election into the society in 1667.[205] Oldenburg makes no such references to others in his correspondence at that time. Indeed, a closer inspection of Boyle's own works suggests a strong influence from Needham and their joint experiments upon Boyle's developing ideas on generation and embryonic development.

2.7.2 *A Way of Preserving Birds*

Based on what was most likely a description of his earlier experiments with Needham and other observers in the Oxford circle, Boyle published some of his observations of the chick in the 1666 volume of *Philosophical Transactions*. The paper, "A

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[204] Boyle describes his anatomical learning in a letter to Clodius. Boyle et al, *The Correspondence of Robert Boyle*: v.1, p. 167.

[205] Oldenburg, et al. *The Correspondence of Henry Oldenburg*: p. 475; p. 504; p. 508.

Way of Preserving Birdes Taken Out of the Egge, and Other Small Faetus's," was extracted from a letter which is no longer extant.[206] In it, he describes his attempts to preserve embryos by soaking them in spirit of wine (ethyl alcohol, which he sometimes mixed with the Spirit of sal amoniack[207]) so that their embryological development could be captured in time and observed by a larger audience. Though he makes mention of pups who were preserved in this manner after their removal from the mother's womb, most of his experiments involved placing chick eggs into a container of spirit of wine in order to preserve them at varying stages. He writes

> … I did, when I was sollicitous to observe the Processe of Nature in the Formation of a Chick, open Hens Eggs, some at such a day, and some at other daies after the beginning of the Incubation, and carefully taking out the *Embryo's*, embalmed preserve each of them in a distinct Glass (which is to be carefully stopt) in *Spirit of Wine*: Which I did, that so I might have them in readinesse, to make on them, at any time, the Observations, I thought them capable of affording; and to let my Friends at other seasons of the year, see, *both* the differing appearances of the Chick at the third, fourth, seventh, fourteenth, or other daies, after the Eggs had been sate on, *and* (especially) some particulars not obvious in Chickens, that go about; as the hanging of the Gutts out of the *Abdomen*, &c.[208]

Boyle cites a couple of failed examples, where the specimen either remained gelatinous or became too difficult to work with. Before ending the discussion, he makes a brief reference to one of his experiments in *Usefulness of Natural Philosophy* involving sal Amoniack.[209]

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206 Boyle et al, *The Works of Robert Boyle*: v. 5, p. 512 n.
207 Ibid. p. 513
208 Ibid. p. 512
209 Ibid. p. 513

These experiments likewise seem to have influenced the experimental, or historical, section of his *Origin of Forms and Qualities.* A telling feature of why his experiences with the chick-egg would be of interest to this project of Boyle's can be found in his description of a newly-laid egg, which says is "but a little Organized Gelly."[210] The colorless, essentially quality-less white of an egg had become an example of substantial change with which Boyle, through his earlier experiments with Highmore and later Needham, had become wholly familiar. Looking at his *Origin and Forms of Qualities*, we can accordingly begin to see how Boyle's active interest in animal generation gave a point of reference for and direct influence upon his developing chymical theories.

2.8 Origin and Forms of Qualities

2.8.1 *An Introduction to the Corpuscular Philosophy*

Origin of Forms and Qualities, whose full title includes the parenthetical "According to the Corpuscular Philosophy," is an "Introduction into the Elements of the Corpuscularian Philosophy." The title page includes the Latin quote from Galen, "One must be daring and approach the truth: for even if we may not grasp it completely, yet we will get closer to it than we now are."[211] *Origin and Forms of Qualities* could be seen as an attempt to replace the Peripatetick doctrine with his own corpuscular philosophy, and thus explain how substantial change can occur from what is supposed to be uniform, homogenous matter.

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210 Boyle et al, *The Works of Robert Boyle*: v. 5, p. 512

211 Boyle et al, *The Works of Robert Boyle*: v. 5, p. 282

As such, generation becomes an important theme of the treatise, as generation and corruption are the basic modes of substantial change on the Aristotelian view. To that effect, Boyle complains of the Aristotelians that, "tis strange they should in Generation allowe every Physical Agent the power of producing a Form, which, according to them, is not onely a Substance, but a far nobler one than Matter, and thereby attribute to the meanest Creatures that power of creating Substances…"[212] Origin and Forms of Qualities is basically broken into two parts: the Theoretical Part, and the Historical Part. Where the former provides a detailed account of his views on nature, the latter provides examples from both observations and then experiments with which Boyle attempts to apply his corpuscular philosophy. In each of these parts, the problem of generation is explicitly addressed by Boyle.

2.8.2 *The Theoretical Part*

In the *Theoretical Part* of Boyle's *Origin and Forms of Qualities*, Boyle provides to the reader an account of views on nature, cause, and effect. An important feature of this discussion is that he reiterates the same view which he has espoused for the course of his career to this point. That is, of the world, Boyle writes that he does not

> at all believe that either these Cartesian laws of Motion, or the Epicurean casual Concourse of atoms, could bring meer Matter into so orderly and well contriv'd a Fabrick as this World; and there I think, that the wise Author of Nature did not onely put Matter into Motion, but when he resolv'd to make the World, did regulate and guide the motions of the small parts of the Universal Matter…into Seminal Rudiments or Principles, lodg'd in convenient

[212] Boyle et al., *The Works of Robert Boyle:* v.5, p. 343

> Receptacles, (and as it were Wombs[213]), and others into the bodies of Plants and Animals…[214]

2.8.3 *The Historical Part*

In *The Historical Part*, Boyle cites experiments involving substantial changes, which he attempts to describe in terms of his corpuscular philosophy. His first example involves the hatching of an egg, or the development of a chick from diaphanous fluid within the egg. Boyle explains that the substance of the egg undergoes a great change because of incubation and then is turned into a chick. [215] Here, he is quick to cite Fabricius (and likely William Harvey), stating that the observation is "familiar and obvious a thing …especially after what the Learned Fabricius ab Aqua pendente, and a recenter Anatomist."[216] And yet, that change had not "been taken notice of, for the same purpose," that Boyle had in mind, which is to explain its changes in terms of his corpuscular philosophy. To that effect, Boyle's emphasis on incubation, of course, is no accident. Incubation provides heat, which Boyle inevitably explains in terms of the motion of matter. By restricting the cause of changes in the egg to incubation, he essentially restricts them to matter and motion.

An interesting feature of this discussion is that Boyle's first description of the egg involves not its natural hatching, but his chymical experiments with the egg discussed in *A Way of Preserving Birds*. Boyle's focus is on the egg whites, wherein it "would be hard to prove, that one part of the White of an Egg will not be made to yield the same differing

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213 This does not necessarily mean the wombs of animals. Boyle frequently discusses the wombs and mineral veins underground. Cf. Boyle et al, *The Works of Robert Boyle*: v. 13, p. 369

214 Boyle et al, *The Works of Robert* Boyle: v. 5, pp 353- 354, *Origin of Forms and Qualities*

215 Ibid. p. 382

216 Ibid. p. 381

Substances by Distillation, that any other part does…"[217] His second example is perhaps the more obvious, which involves a whisk. Anyone who's attempted baking is intimately familiar with how, in Boyle's words, "you may reduce it from a somewhat Tenacious into a Fluid Body, through this Production of a Liquor…effected by a Divulsion, Agitation, etc. of the parts, that is in a word, by a Mechanical change of the Texture of the Body."[218] In truth, this is probably one of the more ingenious examples that Boyle provides, as it does in fact give a readily familiar case of how a change solely to the physical texture of a seemingly quality-less substance will produce an array of different qualities. From this example, he continues with the more complicated explanation of how the chick can develop from the egg whites and into something so complex as a bird.

2.8.4 *Seeds, homogeneity and transmutation*

Although Boyle never gives a detailed description of how these principles work at the corpuscular level, his references to seminal principles in his *Origin of Forms and Qualities* make it clear that Boyle conceives of their operations in terms of the homogeneity of matter and transmutation. The discussion of homogeneity of matter fits with the generation project of the *Origin of Forms and Qualities*, since Boyle is attempting to explain within the piece how qualitative changes can mechanically derive from some universal, homogenous matter.

He states that any part of the diaphanous white of the egg is like the other, emphasizing a "similarity of substance" and thus its homogeneity. It is similarly the case for the yolk. Appealing then to observations, he writes about the "Rudiments of the Chick, lodg'd in the Cicatricula." Given his views on generation, those rudiments are likely seminal

[217] Ibid. p. 382
[218] Ibid.

rudiments. The *cicatricula*, which he describes as a "white Speck up on the Coat of the Yolk," is nourished by the white of the egg until it becomes a chick. On this view, the *cicatricula* belongs neither to the white nor the yellow of the egg. Rather, its contents act upon the fluids of egg, both of which later act as nutriment.[219] He emphasizes the many different qualities that come from the uniform, diaphanous substance of the white of the egg, such as the various colors of the bird's parts, fluids and solid parts such as bones. The speck will become a chick with a head, beak and claws before turning to the yolk for digestion, which is "reserv'd as a more strong and solid Aliment".[220] Boyle's focus, however, is on the nutritive white of the egg, which he describes as being so soft

> … that by a little Agitation it may be made Fluid, and is readily enough dissolvable in cold water, this very Substance, I say, being brooded on by the Hen, will within two or three weeks be transmutated into a chick furnished with Organical parts…[221] so that here we have out of the White of an Egg, which is a Substance Similar, Insipid, Soft, (not to call it Fluid), Diaphanous, Colourlesse, and readily dissoluble in cold water, out of this substance, I say, we have by the new and curious Contrivement of the small parts consisted of, an Animal…[222]

Hence, Boyle describes the change of a quality-less, seemingly homogenous substance into the parts of the chick in terms of transmutation. He extends that reasoning to the buds of plants also, describing how the buds transmute the sap, a "flegmatick Liquor, that seems

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219 In a previous work, Boyle claims that Harvey made evident both that the cicatricula is the source of the chick. See Boyle et al, *The Works of Robert Boyle*: v. 6, p. 511, Usefulness II, 2: *Men's Great Ignorance*.

220 Boyle et al, *The Works of Robert Boyle*: v.5, p. 382, *Origin of Forms and Qualities*

221 Harvey also describes the chick's formation this way.

222 Boyle et al, *The Works of Robert Boyle*: v.5, p 383, *Origin of Forms and Qualities*

Homogeneous enough," into the bodies of plants which are endowed with various colors, medical virtues, and diverse qualities.[223]

In the *Origin and Forms of Qualities* we get a view of the seminal principle that differs from something like rennet in that it not only is the agent of active change, but it also acts as an organizing principle upon that matter. The formative power of that organizing principle, for Boyle, is unique to seeds. In sum, a seminal principle, or a seed, is a small parcel of matter, endowed by God with powers that work upon homogenous matter by means of transmutation.

2.8.5 *Boyle Responds to Harvey*

Boyle considers the possible objection that the chick is fashioned by the soul, "lodg'd chiefly in the Cicatricula, which by its Plastick power fashions the obsequious Matter…" In presenting that objection, Boyle very likely had William Harvey in mind: The passage bears a resemblance to Harvey's own passages on the chick-egg, and Boyle's explicit mention the *cicatricula* reinforces that likelihood.[224] To this complaint, Boyle answers that this objection does not invalidate his claim that the chick is a mechanically contrived engine. For, as he writes,

> let the Plastick Principle be what it will, yet still, being a Physical Agent, it must act after a Physical manner, and having no other matter to work upon but the White of the Egg, it can work up that Matter but as Physical Agents, and consequently can but divide the Matter into minute parts of several Sizes and shapes, and by Local Motion variously context them, according to the Exigency of the Animal produc'd, though from so many various Textures of the produc'd parts there must naturally emerge such differences of Colours, Tasts, and Consistencies, and other Qualities as we have been taking notice

[223] Ibid. p. 389

[224] Cf. Harvey, *Generation:* pp. 51-2, from "Exercitation XI on the egg-shell".

> of. That which we are here to consider, is not what is the Agent or Efficient in these Productions, but what is done to the Matter to effect them.[225]

Note how Boyle ends this discussion by emphasizing how the explanatory power of the plastic power comes from its physical effects upon matter. Boyle elaborates on that point, stating that,

> And when Man himself, who is undoubtedly an Intelligent Agent, is to frame a Building or an Engine, he may indeed by the help of Reason and Art, contrive his Materials curiously and skillfully, but still all he can do, is but to move, divide, transpose and context the several parts, into which he is able to reduce the Matter assign'd him.[226]

Boyle goes on to explain how the external heat of incubation puts the parts of the substance into motion so that, "the Formative Power (whatever that be) doth any more then guide these Motions, and thereby associate the fitted Particles of Matter after the manner requisite to constitute a Chick…" [227] In summary, throughout his response to what is most likely Harvey's view, Boyle places the explanatory focus upon the material effects and modes of operations.

2.9 Conclusion

In this chapter, we have followed Boyle's development from that of a teenager with relatively little knowledge of natural or experimental philosophy to that of a considerably more mature Boyle. By the time he left for London, Boyle was forty-one years old and world-renowned for his chymical and mechanical philosophy. One sample of the positive sentiment surrounding Boyle can be seen in a letter from Giovanni Cassini to Oldenberg,

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225 Boyle et al, *The Works of Robert Boyle* v. 5, pp. 383-384

226 Ibid. p. 384

227 Ibid.

dated May 25th 1668 on the subject of Boyle's recent departure to London: "You have found a way to make me regret my arrival in Paris, and… make me sigh for England by advising me of the celebrated Mr. Boyle's return from Oxford."[228]

Boyle's earliest exposures to natural philosophy and experiment came from a variety of sources, but they each shared the feature of making the problem of generation one of the foremost areas of research. Upon his arrival to Oxford, influenced by the distinctive experimental community there, we've seen how Boyle's views on matter, experiment, and generation evolved over time. Nonetheless, Boyle's incentive for including seminal principles (and their respective formative, plastic powers) in his ontology remains the same throughout this entire development. That incentive would be one that stayed with him throughout the rest of his career, namely, that "the wise Author of Things did …by guiding the first Motions of the small parts of Matter, bring them to convene after the manner requisite to compose the World, and especially did contrive those curious and elaborate Engines, the bodies of living Creatures, endowing most of them with a power of propagating their Species."[229] Boyle is, therefore, adamant in rejecting that either the random particles of the Epicureans or the Cartesian laws of motion can account for the intricacies of living creatures. Boyle maintains this position despite a dramatic shift and development of his theories of matter–one from a juvenile and relatively unsophisticated "atomist," to that of a complex corpuscular view from a highly regarded founding member of the Royal Society. Indeed, even as Boyle became more informed about the natural philosophy of his

[228] Oldenburg, et al., *The Correspondence of Henry Oldenburg:* v. 5, p. 411.

[229] Boyle et al, *The Works of Robert Boyle* v. 5, p. 306, *Origin of Forms and Qualities*

contemporaries, he quickly added the followers of “the Excellent Des Cartes” to those who could not give a satisfactory account of the formative forces involved in generation.

It is unlikely that Boyle’s motives for including God as an explanatory apparatus in his account of generation are due to the limitations of his mechanical or corpuscular philosophy. The question remains, nonetheless, exactly what the ontological status is of any formative powers that he would include in his ideas of seminal principles. We saw that his early notions of seminal principles were largely informed by his reading of Sennert and Highmore. But if forms are eliminated from his ontology, it is not at all obvious how the seminal corpuscles will be able to act. In order to evaluate this question, we must move from Oxford to Cambridge. During the 1670s Boyle became engaged in a rather public controversy with the community of Platonists in Cambridge, specifically with the theologian Henry More. This controversy, which largely focuses on Boyle’s pneumatics, is crucial for understanding Boyle’s views on both generation and his natural philosophy more generally. And so, it is to this debate that we attend in chapter 3.

Chapter 3. Plastic Powers and Platonism: *Cambridge: 1659-1685*

3.1 Henry More and the Cambridge Platonists

3.1.1 *Background*

Two universities fueled intellectual life and discovery in seventeenth-century England. The first, which we examined in the last chapter, was Oxford. The second was Cambridge. Robert Willis, a contemporary of Boyle, provided a brief account of William Harvey's life in which he described Cambridge as, "a school of logic and divinity rather than of physic."[230] In contrast to Oxford, Cambridge was not burgeoning with experimental anatomy or vivisection but was rather a hotbed for mathematics and theology. That characteristic prevailed throughout the seventeenth century, led in part by the prolific theologian and philosopher Dr. Henry More.

Henry More was born in Grantham, Lincolnshire and went on to study at Eton, where he studied with the tutor Robert Gell.[231] Gell introduced him to, "the kind of mystical Greek theology that later came to dominate [his] own spiritual life."[232] His emphasis on Greek Platonism had a profound effect upon his own personal life, as he eventually came to reject his own strict Calvinist upbringing as well as the writings of Christian Scholastic authors.[233] Perhaps not coincidentally, Henry Moore's religiosity played a central role in his intellectual pursuits. It was through this religious crisis that More embraced a kind of

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230 See Willis's introduction in Harvey, *The Works of William Harvey*: p. xix.

231 At Lincolnshire, he attended the same grammar school at which Isaac Newton would later study. Similarly, More shared an analogous early education with Robert Boyle, as both attended Eton under the tutelage of John Harrison. Ward et al, *The Life of Henry More:* p. xiv

232 Ibid.

233 This rejection would ultimately result in More becoming estranged from his father, Alexander More, who served as alderman and mayor of Grantham. See More, MacKinnon, *The Philosophical Writings of Henry More*: p. x

Christian Platonism that emphasized the purification of the soul.[234] Once at Cambridge More, along with Ralph Cudworth, became a central figure to a group of scholars that would become known as the "Cambridge Platonists." Like Boyle and many of their contemporaries, they vehemently rejected Scholastic forms and took an active interest in the many scientific developments. They were, for example, among the first to read Descartes, with whom Henry More corresponded. Further, they were among the earliest fellows to have joined the Royal Society. [235]

Ultimately, however, the group was distinct in that they were theologians first and foremost, consequently devoting themselves to defending both God's existence and the immortality of the soul.[236] These Platonizing theologians committed to a kind of substance dualism that was informed not just by Plato but also by later Platonists like Plotinus and Ficino, as well as contemporary developments like those of Descartes. This world view can be best understood in terms of a Great Chain of Being in which the fundamental principle governing Nature is an immaterial soul or spirit. For Henry More, this role would be filled by his hylarchic principle, or Spirit of Nature.

3.1.2 *Immortality of the Soul*

As a dualist, Henry More's relationship to the mechanical philosophy is a complicated one. Alan Gabbey, for example, has argued that More had always been critical

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234 Crocker, *Henry More, 1164-1687: The Biography of a Cambridge Platonist*: Chapter 4

235 Michael Hunter has pointed out the large number of members who were not residents of London, and thus mostly absent from the society's meetings. Cudworth and More, along with Isaac Newton, Isaac Barrow among others, are listed as university dons at Cambridge whose occupation kept them from visiting London frequently. See Hunter, *The Royal Society and Its Fellows 1660-1700:* p. 115.

236 Hutton, "The Cambridge Platonists," pp. 308-309, in *Blackwell Companion to Early Modern Philosophy.*

of Descartes' metaphysics.[237] Regardless, Henry More grew increasingly intolerant of what he took to be the harsh materialism and mechanistic determinism expounded by Descartes, both of which he associated with atheism.[238] For More, natural phenomena spontaneously deviated from the mechanical laws of nature in such a way that only a spiritual agency could be responsible for them. In his later works, this spiritual agency was a universal Spirit of Nature, or *hylarachic* principle, which is defined by its power to animate and organize inert matter.[239] These ideas came together in print with More's 1659 *Immortality of the Soul.*

Immortality of the Soul was brought to Boyle's attention by Samuel Hartlib, who wrote to the young Aristocrat in April of 1659 stating that he, "saw an excellent book yesterday, coming piping hot out of the press from Cambridge, called, *The Immortality of the Soul, so far forth as is demonstrable from the Knowledge of Nature and the Light of Reason*. By Henry More, Fellow of Christ's College in Cambridge."[240]

On More's account, even the gravity of stone or earth and the levity of fire are not "meerly Mechanicall, but vitall or Magicall," and cannot thus be explained by "meer Matter" alone. [241] He later deduces from this premise that "if the pure Mechanick powers in Matter and Corporeal motion will not amount to so simple a Phaenomenon as the falling of a stone to the Earth, how shall we hope they will be the adequate cause of sundry sorts of Plants and other things"? [242] Thus, while he agrees with Descartes both on the rejection of substantial forms and on the belief that sensations result only from "Matter as are made by difference of

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237 Gabbey, "Philosophia Cartesiana Triumphata: Henry More (1646–1671)": pp. 171-250

238 Crocker, *Henry More, 1614-1687: The Biography of a Cambridge Platonist*: 145 ff.

239 Reid, *The Metaphysics of Henry More*: p. 329; In his earlier works and poems, in contrast, More appeals to a multitude particular seminal forms rather than a single, universal principle. For a more detailed account of how More's ideas change over time, see Ibid. pp. 317- 328.

240 Boyle et al, *The Correspondence of Robert Boyle*: v.1 p. 336

241 More, *Immortality of the Soul*: p. 275

242 Ibid. pp. 465- 466

Motion, Figure, Situation of parts, &c...," More nonetheless vigorously disagrees with the French philosopher on how that matter gets modified.

Vis-à-vis generation and corruption, More argues that "... it is not meer and pure mechanical motion that causes all these sensible Modifications in Matter, but that many times the immediate Director thereof is this *Spirit of Nature* (I speak of) one and the same every where."[243] He then compares the Spirit of Nature to a clear-minded judge who gives the same verdict before concluding that the Spirit of Nature is responsible not just for the fetuses of animals, but that "all Plants and Flowers of all sorts (in which we have no argument to prove there is any particular Souls) should be the effects of this *Universal Soule of the World."*[244]

Henry More defines this Universal Soul of the World, or Spirit of Nature, as an incorporeal substance that is "without Sense and Animadversion, pervading the whole Matter of the Universe, and exercising a plastical power therein... raising such Phaenomena in the World, by directing the parts of the Matter and their Motion, as cannot be resolved into meer Mechanical powers."*[245]* On More's view, that plastic, immaterial spirit is necessary not just for the complex organization of matter required by generation, but for *any* process or occurrence of nature.

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243 Ibid. p. 466

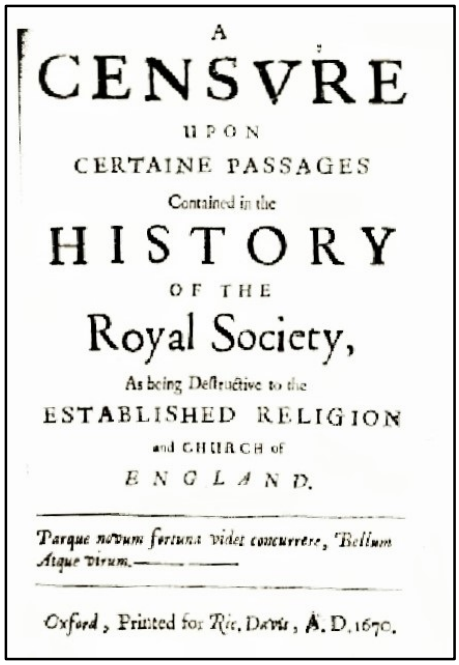
244 Ibid. p. 467

245 More, *Immortality of the Soul*: p. 450

3. 2 Controversy between Henry More and Robert Boyle

3.2.1 *Censure upon the Royal Society*

More's attempt to reduce everything to the Spirit of Nature, as well as his growing animosity towards Descartes, dominated his controversy with Robert Boyle. This controversy was ignited by Henry Stubbe's pamphlet, *A censure upon certain passages contained in the History of the Royal Society as being destructive of the established Religion and Church of England.*[246] In an attempt to tarnish the reputation of the society, Stubbe cited More's criticisms of Descartes as evidence that More had come to reject the philosophy of that society to which he himself belonged. [247]


A
CENSVRE
UPON
CERTAINE PASSAGES
Contained in the
HISTORY
OF THE
Royal Society,
As being Destructive to the
ESTABLISHED RELIGION
and CHURCH of
ENGLAND.
Parque novum fortuna videt concurrere, Bellum
Atque virum.
Oxford, Printed for Ric. Davis, A. D. 1670.

More responded by forcefully denying that his arguments against an atheistic, Cartesian world view applied to the experimental approach promulgated by the Royal Society. Instead he drew a sharp distinction between the two, citing Boyle's experiments on air.[248] Specifically, he drew upon Boyle's investigations with the air-pump outlined in Boyle's *Defence of the Doctrine Touching the Spring and Weight of the Air*, which led to what we know as Boyle's Law, i.e. the inverse relationship

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246 Stubbe actually composed the pamphlet in response to Bishop Sprat's *History of the Royal Society*, and in his ire went so far as to maintain a long correspondence with Boyle in an attempt to persuade him to leave the society. For more on this, see Ornstein, *The Role of Scientific Societies in the Seventeenth Century*: p. 132.

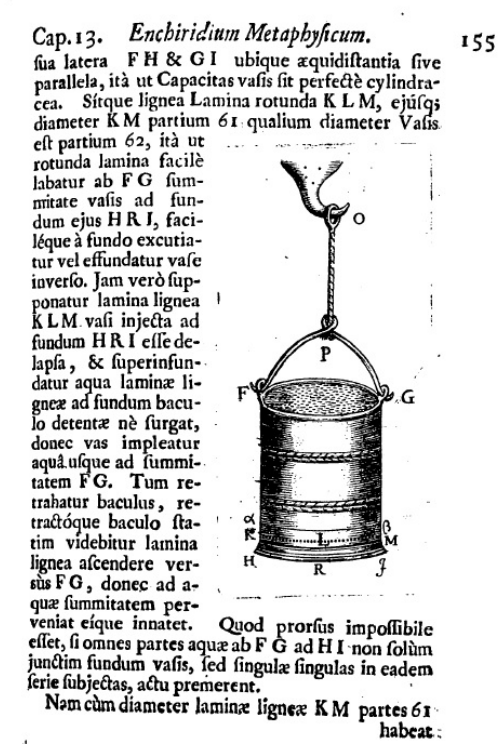
247 Greene, "Henry More and Robert Boyle on the Spirit of Nature": p. 470

248 Crocker, *Henry More, 1614-1687: The Biography of a Cambridge Platonist*: p. 153

between pressure and volume. This position More shortly thereafter articulated in his 1671 *Enchiridion Metaphysicum.*

3.2.2 *Enchiridion Metaphysicum*

The cover page alone expresses the confidence with which More wrote nothing short of a diatribe against the Mechanical Philosophy, as it proclaims itself to be an "illuminating and succinct dissertation of incorporeal things," and one in which the "vanity and falsehood" of explaining the many phenomena of the world in accordance with the laws of Cartesian Mechanical Philosophy "is discovered".[249] In Chapter 12 of the treatise, More uses the experimental results of Boyle's air-pump in his proofs of the immaterial, hylarchic spirit.[250]


Cap. 13. *Enchiridium Metaphyſicum.* 155

ſua latera F H & G I ubique æquidiſtantia ſive parallela, ità ut Capacitas vaſis ſit perfectè cylindracea. Sítque lignea Lamina rotunda K L M, ejúſq; diameter K M partium 61 qualium diameter Vaſis eſt partium 62, ità ut rotunda lamina facilè labatur ab F G ſummitate vaſis ad fundum ejus H R I, faciléque à fundo excutiatur vel effundatur vaſe inverſo. Jam verò ſupponatur lamina lignea K L M vaſi injecta ad fundum H R I eſſe delapſa, & ſuperinfundatur aqua laminæ ligneæ ad fundum baculo detentæ nè ſurgat, donec vas impleatur aquâ uſque ad ſummitatem F G. Tum retrahatur baculus, retractóque baculo ſtatim videbitur lamina lignea aſcendere verſùs F G, donec ad aquæ ſummitatem perveniat eíque innatet. Quod prorſus impoſſibile eſſet, ſi omnes partes aquæ ab F G ad H I non ſolùm junctim fundum vaſis, ſed ſingulæ ſingulas in eadem ſerie ſubjectas, actu premerent.

Nam cùm diameter laminæ ligneæ K M partes 61 habeat:

Despite the confidence communicated by the tract, More was clearly in over his head when tackling the complex details of Boyle's pneumatic experiments.

Dr. More could not understand how either gravity or pressure could have any force with only mechanical means. The pressure of liquids, for example, is contingent on depth. (Consider the pressure experienced by deep-sea divers, an example that Boyle himself later provides.[251]) But

249 "De Rebus Incorporeis Succincta & Luculenta Dissertatio... In qua quamplurima Mundi Phaenomena ad Leges Cartesii Mechanicas obiter expenduntur illiusque Philosophiae, & aliorum omnino omnium qui Mundana Phaenomen a in Causas pure Mechanicas solvi posse supponunt, Vanitas Falsitasque detegitur." More, *Enchiridion Metaphysicum*: Cover page

250 For an indepth discussion see Greene, "Henry More and Robert Boyle on the Spirit of Nature": p. 471

251 Boyle, et al. The Works of Robert Boyle: v. 7, p.

citing Boyle's experiments with water pressure, More complained of how ridiculous it would be to think that water could be capable of that much force.[252] Atmospheric pressure was similarly lost on him. More considers an experiment in which butter that had been placed within Boyle's famed air-pump was compressed flat. More simply refused to believe that air alone could have been responsible for the action.[253] His errors are frankly too numerous to list in their entirety. But underlying the whole of them was More's assumption that all matter is passive and thus incapable of any power.[254]

Upon discovering that Henry More had appropriated his experiments, Boyle was incensed. More wrote to Boyle in the winter of 1671 in an attempt to mollify his relations with the famed aristocrat. He begins the letter by stating how he was motivated by Christianity and questions what objection Boyle could have to sincere piety. He later concludes by emphasizing to Boyle that his own work came, "from one, that does very highly honour you and love you, and whatever displeasure you may conceive against him, is resolved, whether you will or not, to love you and honour you, and wish you all good possible…" [255]

It is the body of More's relatively short letter, however, that really gets to the heart of the issue. The English theologian writes

> … that the phænomena of the world cannot be solved merely mechanically, but that there is the necessity of the assistance of a substance distinct from matter, that is, of a spirit, or being incorporeal, as I must confess, I do conceive myself most firmly to have concluded from these experiments; for which, I ever hold the world and myself obliged to you: and though there be an infinite disparity betwixt your experience and experimenting and mine, yet I did presume, for those few I did consider, that I might thoroughly

252 More, *Enchiridion Metaphysicum*: pp. 154-156.
253 Ibid. pp. 142 ff.
254 Cf. Coudert, "Henry More and Witchcraft": pp. 123-124, in *Henry More Tercentary Studies*
255 More to Boyle, Dec. 4, 1671; Boyle et al, *The Correspondence of Robert Boyle:* v.4, pp. 233- 234

> understand them as far as concerned my purpose and make safe use of them…"[256]

In addition to the atheism that he associated with a Godless world of inert matter, Henry More also thought that no adequate account of nature could be given in terms of only inert matter acting mechanically. But Boyle saw More's application of his experiments to the latter's own plastic principle and unobservable immaterial spirit as a distortion of his own view and ultimately as an attack.[257] The pure intentions and deep affections expressed by More in his letter would not save him from a detailed rebuttal on the part of Boyle, who soon after published *Hydrostatical Discourse occasion'd by some Objections of Dr. Henry More* in 1672.

3.2.3 *Henry More, Robert Boyle, and the Hydrostatical Discourse*

That Boyle took the opportunity to compose a response to More is striking as doing so was out of character for him. Some background as to why he did so can be gleaned from the preface of *Hydrostatical Discourse*, in which Boyle explains his motivations for having composed such a response. Namely, that More's analysis made Boyle's claims seem irrational and absurd such that he worried that they "might pass for unanswerable" among those familiar with the intellectual authority of More and less knowledgeable about the details of hydrostatics. But while Boyle is quick to point out that he has composed only a defense, "save the two Chapters wherein [he] was particularly invaded," he is all the more eager to censure More on behalf of Descartes (who, as Boyle points out, was unable to defend himself):

> ... I dare not forbear owning my not being satisfied with that part of his Preface, which falls foul upon *Monsieur des Cartes* and his Philosophy. For

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256 Ibid.

257 Cf. Crocker, *Henry More, 1614-1687: The Biography of a Cambridge Platonist*: p. 161

> though I have often wish'd, that Learned Gentleman had ascrib'd to the Divine Author of Nature a more particular and immediate efficiency and guidance in contriving the parts of the Universal Matter into that great Engine we call the *World*; and though I am still of Opinion, that he might have ascrib'd more than he has to the Supreme Cause in the *first* Origine and Production of things Corporeal... and though not confining my self to any Sect, I do not profess my self to be of the Cartesian: yet I cannot but have too much value for so great a wit as the founder of it, and too good an opinion of his sincerity in asserting the existence of a Deity, to approve so severe a Censure as the Doctor is pleased to give of him. [258]

It seems to be the hostility More had taken in addressing the Mechanical Philosophy that is a main driving force in Boyle's reply. Further investigation, however, suggests a more complex response from Boyle.

In addition to expressing his defense of Descartes, Boyle offers profound insight as to his own worldview. We see here as he prepares a defense of his mechanical philosophy against an immaterial hylarchic principle that he does not consider himself to be a Cartesian and laments that Descartes had not ascribed to God "immediate efficiency and guidance in contriving the parts of the Universal Matter," especially in the first production and Creation. The nature and centrality of God is undoubtedly a key issue pressing Boyle to compose a response. More had not only used Boyle's own experiments against him, but he did so to make a claim about God that Boyle would have taken to be problematic both ontologically and theologically. At issue is the nature in which God interacts with his creations and the matter from which those creations are composed. John Henry touches on this point nicely when he says that,

> The strict dualism of Henry More, in which matter was necessarily inert and all activity had to be attributed to a spiritual or immaterial operator, was not

[258] Boyle et al., The Works of Robert Boyle: v. 7, p. 142, *Hydrostatical Discourse*

> accepted by Robert Boyle. Conversely, Boyle's belief that God could endow matter with 'essential modifications' which included motion and 'seminal rudiments or principles' was anathema to Henry More.[259]

These differences—of God and of matter— are what is ultimately at stake in this debate between the two Englishmen.

Boyle then continues to More's objections, the first of which is that had Boyle presented a mechanical explanation of his pneumatic experiments, then he would have been able to explain the mechanical cause of the gravitation of both the individual particles and of the atmosphere. To this Boyle answers that he had no intentions of writing an entire system of philosophy. Rather,

> having sufficiently proved, that the Air, we live in, is not devoid of weight, and is endowed with an Elastical Power or springiness, I endeavour'd by those two Principles to explain the *Phœnomena* exhibited in our Engine, and particularly that now under debate, without recourse to a *Fuga Vacui*, [the abhorrence of a vacuum] or the *Anima Mundi*, [World Soul] or any such unphysical Principle. [260]

Thus, placing an emphasis on experiment Boyle answers that his solution is without recourse to immaterial forces or principles.

Boyle spends most of the body of the *Discourse* on correcting Henry More's several assumptions about the former's pneumatic experiments dealing with the specific gravity of objects and fluids within the receiver and the atmospheric particles surrounding them, specifically how they relate to the gravitation and pressure of fluids. Near the end of the tract, he concludes with the main thrust of his response, one which echoes his earlier sentiments:

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259 Henry, "Henry More versus Robert Boyle: The Spirit of Nature and the Nature of Providence": p. 56 in *Henry More (1614-1687) Tercentary Studies*.

260 Boyle et al., The Works of Robert Boyle: v. 7, p. 148, *Hydrostatical Discourse*

> "I see no need we have to flye to [the *Doctors Hylarchical Principle*], since such Mechanical Affections of matter, as the Spring and Weight of the Air, the Gravity and Fluidity of the water and other Liquors, may suffice to produce and account for the Phænomena without recourse to an Incorporeal Creature..." [261]

His conclusion, however brief, communicates a good deal to the reader. First, Boyle does not bother to deny More's Hylarchical Spirit but rather the need to appeal to it for explanation of physical phenomena. Further, he includes the spring of the air, which he also describes as an "elastical power", and the weight of the air (a gravitational power) among the mechanical affections of matter. These powers are not, by any means, reducible to the so-called primary affections of matter such as size and shape. And yet they seem, nonetheless, to fit within his own conception of a mechanical property of matter.

3.2.4 *Newman-Chalmers Debate*

Boyle's response to More provides an important insight to Boyle's own conception of "mechanical". That Boyle vehemently rejected Henry More's differentiating his experimental results from his mechanical philosophy strongly reinforces the extent to which Boyle, himself, identifies the two as part of the same, indistinguishable program. This point was made recently by William Newman in response to Alan Chalmers. Newman's debate with Chalmers, which spans several years, centers largely on the question of whether Boyle's corpuscular theory of matter productively informed his chymical experiments.

Chalmers' answer to this question is an emphatic "no". He first defended this position in 1993 with "The Lack of Excellency of Boyle's Mechanical Philosophy," where he argues that, "far from there being an intimate and productive link between Boyle's mechanical philosophy and his science, his scientific successes were achieved *in spite*, rather

[261] Boyle, et al. The Works of Robert Boyle: v. 7, p. 183, *Hydrostatical Discourse*

than because, of his allegiance to that philosophy."[262] Chalmers goes on to argue that, "the case that Boyle makes for the mechanical philosophy can be seen to be very weak indeed."[263] At the crux of Chalmers' argument is Boyle's reliance in his chemistry on properties of matter (like plastic powers) which are not reducible to shape, size, and motion. Fueling Chalmers's criticism is an emergent view of science which he makes explicit in his 2009 book, *The Scientist's Atom and the Philosopher's Stone - How Science Succeeded and Philosophy Failed to Gain Knowledge of Atoms.* Thus, one of the central aims of Chalmers's reading of Boyle is to establish a demarcation between experiment and philosophy, which he sees as being a central aspect of the Scientific Revolution. He articulated this interpretation more recently in 2012, stating that

> …it was the experimental philosophy that constituted the beginnings of modern science and that it owed less to the mechanical philosophy than is typically supposed.
>
> Seventeenth-century scholars did not always maintain or show an appreciation of the distinction between the experimental philosophy and the mechanical philosophy. However, one participant in the scientific revolution at least, namely Robert Boyle, did explicitly identify and articulate a distinction between experimental learning and matter theory as articulated by mechanical philosophers (including himself.)[264]

Newman has argued in turn that Chalmers allows his own agenda of explaining the emergence of science as a discipline separate from philosophy to inform overtly his interpretation of a major figure like Boyle. "To Chalmers…" writes Newman, "the division between legitimate 'science' and accommodationist 'philosophy' is a fundamental article of faith. Philosophers may be satisfied with inference to the best explanation, but 'scientists

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262 Chalmers, "The Lack of Excellency of Boyle's Mechanical Philosophy": p. 541

263 Ibid. p. 541ff.

264 Chalmers, "Intermediate causes and explanations: The key to understanding the scientific revolution": p. 551

aspire to do better and infer the right explanation'." [265] Newman contends that the "dualist methodology" that Chalmers employs can allow for neither gradual intellectual development nor scientific re-orientation in history which allow for later fruitful developments. As such, he fails to do history properly.

I would like to focus on Chalmers's recent 2016 reply, "Viewing past science from the point of view of present science, thereby illuminating both: Philosophy versus experiment in the work of Robert Boyle," in which he reiterates the distinction between mechanism in a general sense, or "clockwork mechanism", and mechanism in a restricted sense, "ontological mechanism". Whereas Newman "appropriately points out in this context" the longstanding tradition of "clockwork mechanism," Chalmers claims that it is Boyle's commitment to the latter—the ontological thesis that the world is composed of "one catholic or universal matter common to all bodies"— that interferes with his experimental program. He further argues that "Boyle's own words, and many of them, leave us with no choice but to interpret Boyle's mechanical philosophy in the strict sense as involving a strict reductionist thesis."[266] But Boyle's ontological reductionism goes against his own experimental inquiry because the ultimate causes, i.e. mechanical affections of matter, "lay beyond what could be observed or accessed experimentally."[267] Instead, the investigator of nature must direct his efforts towards intermediate causes, which involve states of matter such as heat, cold, fluidity, and fermentation.

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265 Newman, "How not to integrate the history and philosophy of science" : p. 204

266 Chalmers, "Viewing past science from the point of view of present science, thereby illuminating both: Philosophy versus experiment in the work of Robert Boyle" p. 29

267 Ibid. p. 30

Thus, argues Chalmers, "the beginnings of experimental science in the seventeenth century were distinct and did not owe much to deliberations about the ultimate structure of the material world with which the mechanical philosophy in the strict sense was concerned."[268] I will show, however, that intermediate causes such as fermentation, plastic powers, and elasticity, were both understood and explained by Boyle in terms of his corpuscular philosophy, and that this philosophy adhered to ontological mechanism in a strict sense.

3.3 Ontology of Generation in the Seventeenth Century

3.3.1 *Mechanical Affections of Matter*

In dealing explicitly with Boyle's mechanical philosophy, Newman has criticized previous authors such as Chalmers for their "implicit reliance on Cartesianism in framing their definitions of the mechanical philosophy."[269] Newman goes on to argue that, "[t]he fact that Boyle does not attempt to reduce all phenomenal change to the level of the *prima naturalia* or initial particles does not mean that his chymical explanations are not mechanical, since the aggregate corpuscles are also endowed with mechanical affections having explanatory force."[270] But Chalmers' response highlights an important issue regarding the Mechanical Philosophy in the seventeenth century, one that lacks clarity. Namely, what does it mean for something to be a mechanical affection of matter? Furthermore, how exactly do the powers and principles described by Boyle fit within a mechanical ontology?

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268 Ibid. p. 34

269 Newman, *Atoms and Alchemy: Chymistry and the Experimental Origins of the Scientific Revolution*: p. 178

270 Ibid. p. 182

In his most recent paper Chalmers unrelentingly compared Boyle's account of matter with that of eighteenth-century chemist, Étienne François Geoffroy in order to understand why Boyle never manages to come up with the notion of *chemical compound.*[271] But it may have been more fruitful to compare his world view with that of Descartes and discover why Boyle never considers himself to be a Cartesian. As we saw at the beginning of his reply to Henry More, Boyle laments of Descartes that the French mathematician had not ascribed to God more immediate efficiency within nature and at Creation. [272] In his own ontology, Boyle does just this by ascribing to God the plastic powers of seminal corpuscles.

More generally, Boyle is far more comfortable than Descartes with presenting a world in which matter is endowed with powers. That Boyle is distinguishable from Descartes because of his inclusion of powers is hardly earth-shattering. This feature of his work has been a long-standing point of contention in the secondary literature.[273] But what is surprising is Boyle's appeal to these powers as mechanical affections. Mechanical affections for Boyle are often taken to be synonymous with he calls the primary or universal affections of catholic matter. Here, however, "mechanical affections" seem to correspond to intermediary corpuscular structures. Those properties or powers, moreover, are mechanical in virtue of,

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271 Chalmers, "Viewing past science from the point of view of present science, thereby illuminating both: Philosophy versus experiment in the work of Robert Boyle": pp. 33-35. Chalmers suggests that "One down to earth reason why Boyle was not in a position to anticipate Geoffroy lies in the fact that only a small portion of the data concerning the building up of chemical substances from and breaking them down into their components was available to Boyle." (Ibid. p. 34.) Ultimately, however, Chalmers argues that it was his matter theory and commitment to the Mechanical Philosophy (in a strict sense) that was holding Boyle back.

272 Boyle et al., *The Works of Robert Boyle*: v. 7, p. 142, *Hydrostatical Discourse*

273 See: Anstey, "Robert Boyle and the heuristic value of mechanism"; Chalmers, "Experiment Versus Mechanical Philosophy in the Work of Robert Boyle: A Reply to Anstey and Pyle"; Clericuzio, "A Redefinition of Boyle's Chemistry and Corpuscular Philosophy"; Pyle, A. "Boyle on Science and the Mechanical Philosophy: A Reply to Chalmers."

to use Boyle's own words, "their being grounded upon the Laws of the Mechanicks." [274] Yet Boyle's account of them as mechanical in this particular instance does not obviously fall into what is often described as "Clockwork mechanisms" or "Course of Nature" mechanisms because Boyle is discussing properties at the corpuscular level. What remains unclear, then, is precisely what the ontological status is of such so-called mechanical affections and powers of matter.

3.3.2. *Chymical Powers as Supervenient Properties*

One way of understanding the ontological status of the various chymical powers described by Boyle is in terms of supervenient properties. Some qualification is necessary because I am invoking a concept from present-day philosophy of mind that would not have been available to Boyle himself. But I nonetheless think that it could help to describe a specific aspect of Boyle's ontology, as he would have understood it, and to give us a means by which to parse some of the more confusing aspects of Boyle's program. 'Supervenience' denotes the ontological status of higher-level properties that are determined by and necessarily dependent upon lower-level base properties. Put another way, supervenience is a necessary but not sufficient condition for reducibility. This concept is usually employed to describe modes of being that are, much like Boyle's own theory of matter, hierarchically structured. It further differs from the notion of emergent properties in that the latter holds that higher-level properties necessarily lack reducibility.

[274] Boyle et al., *The Works of Robert Boyle*: v. 7, p. 148, *Hydrostatical Discourse*

In philosophy of mind, supervenience addresses the mind-body problem by holding that mental states supervene upon physical properties. The main appeal of supervenience, then, is that it promises ontological dependence without entailing reducibility. On this view, mental properties—while not existing independently of physical ones—can nonetheless supervene upon base properties even if they are not reducible to them.[275] Just as a proponent of supervenience does not postulate an ontologically separate, immaterial body when describing the non-reducibility of mental states, so too does Boyle not postulate immaterial or separate entities when discussing the powers of corpuscles. Thus, to say that powers on Boyle's account are supervenient properties is to say that they do *not* exist independently of base corpuscular structures, regardless of whether or not they are reducible to them.

Walter Ott recently argued that Boyle "sanitizies" powers, as it were, by treating them as relations and then reducing those relations to the relata or objects on which they supervene.[276] Fatherhood, for example, is a kind of relation that is easily reducible to the members of its relationship. We ascribe "fatherhood" to a person in virtue of his relation to some other existing body, i.e. his son or daughter, rather than assume it to be some real or intrinsic property. A powerful part of Ott's argument rests on a somewhat notorious passage of Boyle's from the *Origin and Forms of Qualities*, where Boyle compares the manner in which powers work to that of a lock and a key:

> We may consider then, that when Tubal-Cain, or whoever else were the Smith, that Invented Locks and Keyes, had made his first Lock... That was onely a Piece of Iron, contriv'd into such a Shape; and when afterwards he made a Key to that Lock, That also in it self Consider'd, was nothing but a Piece of Iron of such a Determinate Figure: but in Regard that these two Pieces of Iron might now be Applied to one another after a Certain manner...

275 Guttenplan, *A Companion to the Philosophy of Mind*: pp. 575-577

276 Ott, *Causation and Laws of Nature*: pp. 140 ff.

> the Lock and the Key did each of them now Obtain a new Capacity and it became a Main part of the Notion and Description of a Lock, that it was capable of being made to Lock or Unlock by that other Piece of Iron we call a Key, and it was Lookd upon as a Peculiar Faculty and Power in the Key, that it was Fitted to Open and Shut the Lock, and yet by these new Attributes there was not added any Real or Physical Entity, either to the Lock, or to the Key, each of them remaining indeed nothing, but the same Piece of Iron, just so Shap'd as it was before. [277]

The take-away from Boyle's analysis here, Ott claims, is that just as fatherhood is not a *real* quality but a relation, so too are powers merely relations to some other object. Hence, Boyle would claim, it a serious mistake on the part of Scholastics to assume that powers could be intrinsic or real properties. The reducibility of powers to relations "means that [Boyle's] ontology need including nothing more than Descartes himself was willing to countenance."[278]

Now, Ott is certainly right when he says that Boyle's main problem with his opponents is "their tendency to reify qualities." [279] But relations are only one mode of supervenience, and some of the powers to which Boyle appeals (such as the elastical power of air and the plastic power of seminal corpuscles) do not fit this scheme. Indeed, even on Ott's account, Boyle does sometimes say that "powers or dispositions are present even in the absence of the relevant relatum."[280] With the elastic power of air, it's not at all obvious what the other relatum would be.

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277 Boyle et al., *The Works of Robert Boyle*: pp. 309-310, *The Origin and Forms of Qualities*; Cf. Ott, *Causation and Laws of Nature*: p. 143

278 Ott, *Causation and Laws of Nature in Early Modern Philosophy*: p. 147

279 Ibid. p. 142

280 Ibid. p. 148

Peter Anstey has pointed out that Boyle sometimes makes claims about powers that suggest that they are a distinct ontological category from relations.[281] He further argues, following Boyle's lock and key analogy, that a critique of powers as real qualities does not necessarily entail his own reductionism about relations.[282] Anstey provides a strong case to be made both for and against the reduction of powers to relations before concluding that regarding the relational nature of sensible qualities that we have "we have uncovered two incompatible and irreconcilable aspects of [Boyle's] thought." [283]

The sharp analysis provided by both Anstey and Ott reflects a tendency of the secondary literature to consider Boyle's notion of powers within the context of relations in dialogue with other early modern thinkers such as Descartes, Suaréz, Locke, and Hume.[284] Boyle does have relevant things to say about relations. This narrative is no doubt helpful for understanding these figures, especially given the parallels between Boyle and Locke and the extent to which Locke is influenced by Boyle in his own writings. But consider that Boyle's theory of matter is largely informed by a long history of experimental chymistry via Starkey and Sennert, in which case that dialogue may not fully capture the idiosyncrasies of Boyle's ideas about matter, power, and causation. In that context, supervenience starts to match the kind of hierarchical notions of matter and composition described by Boyle.

Perhaps one way to think of Boyle's lock and key analogy is that with a God's-eye view, the specific mechanisms involved at the corpuscular level would be clear and readily explained in terms of the physical attributes of matter. But, as we shall see in the next chapter,

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281 Anstey, *The Philosophy of Robert Boyle*: pp. 87 ff.

282 Ibid. p. 98. Cf. Ott, *Causation and Laws of Nature in Early Modern Philosophy*

283 Anstey, *The Philosophy of Robert Boyle*: p. 107

284 See: O'toole, "Qualities and Powers in the Corpuscular Philosophy of Robert Boyle";

Boyle believes that our own epistemic nature is considerably limited. He consequently would rather focus on the mechanical effects. For him, it is enough that the powers supervene upon corpuscular clusters.

Chemical properties as supervenient powers in Boyle's ontology was recently discussed by Marina Paola Banchetti-Robino, who argues that Boyle anticipates contemporary accounts for the supervenience of chemical properties on subventient physical ones [285] It is important to point out that Banchetti-Robino's account of Boyle is problematic in certain respects, the least of which not being her description of Boyle as a "16th century chemist,"[286] and much of her discussion is within the context of emergent properties in quantum mechanics. She nonetheless introduces an important distinction within Boyle's philosophy that can help to shed light upon the Newman-Chalmers debate, Boyle's beliefs about generation, and his mechanical ontology more generally. Namely, she distinguishes between the commitment to a mechanical ontology, on the one hand, and the commitment to reductionism on the other. Boyle maintains the former all the while rejecting the latter. In doing so, Boyle appeals to an ontology that "embraces both a mechanistic conception of the lower ontological level and a non-reductionistic conception of the higher ontological level" and can moreover, "explain the chemical phenomena he encounters in his experimental work in a manner that is anti-reductionist and that accommodates the notions of emergence and supervenience of chemical properties" [287]

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285 Banchetti-Robino, "The Relevance of Boyle's Chemical Philosophy": pp. 240- 265 in *The Philosophy of Chemistry: Practices, Methodologies, Concepts.*

286 Ibid. p. 262

287 Banchetti-Robino, "The Relevance of Boyle's Chemical Philosophy": p. 262, in *The Philosophy of Chemistry: Practices, Methodologies, Concepts.*

The distinction between a mechanistic conception of matter, on the one hand, and a non-reductionist approach to experiment, on the other, is likely the very aspect in Boyle's writings that Chalmers was trying to differentiate. The problem with his characterization, however, is that it presupposes that Boyle's theory of matter is reductionistic in the first place, putting Boyle's ontological mechanism at odds with his own experimental approach. But Boyle's controversy with Henry More over his own hydrostatical experiments illustrates that while Descartes and other contemporaries may have had this sort of approach, such reductionism is not one that Boyle seems to have held.

If I am right that powers in Boyle's ontology act as supervenient properties, then his inclusion of them is still mechanical in a "strict", ontological sense because:

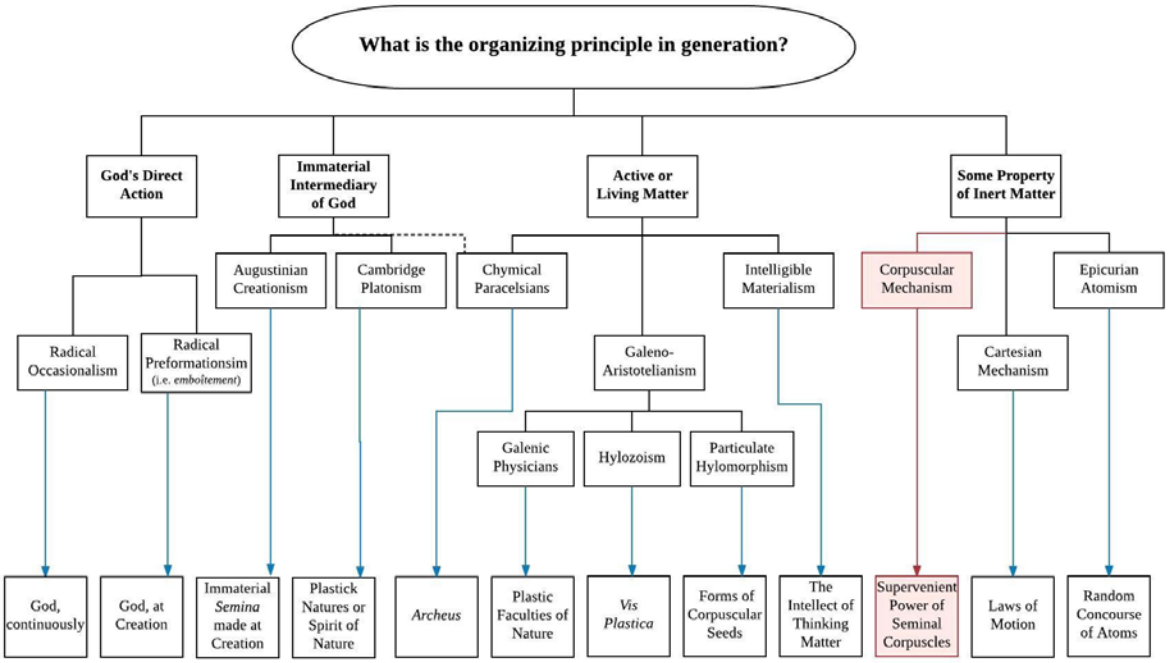
1. mechanical affections of matter are happening at the corpuscular level, and
2. Boyle is not positing the existence of anything other than inert matter. Even if powers are not obviously reducible to inert matter, they still do not exist as independent entities.

His refusal to posit powers as independently existing "real" entities, moreover, would become a large theme in his *Inquiry into the Notion of Nature.*

3.3.3 *Corpuscular Mechanism*

On the subject of generation, just as springiness and elasticity are mechanical affections of matter, so too can the power of seminal principles be understood this way. That is to say, there is room in Boyle's ontology for a supervenient plastic power of seminal corpuscles that could rightly be called mechanical (in a strict sense). In order to understand the ingenuity of Boyle's approach, it might be helpful first to survey how his contemporaries around the

1670s would have answered this one, gripping question: What is the force responsible for organizing matter in generation? For an overview, consider *Table 3.31*.[288]



The above table is organized (left to right) by the level of God's involvement in the cause and force of generation. It's worth noting, however, that explanations on both extremes—that is, ones that either rely solely upon God or eliminate him entirely—were treated by most seventeenth-century scholars as altogether untenable positions.

Boyle presents what I have labeled "Corpuscular Mechanism," which is mechanical at the level of corpuscular matter, i.e. ontological mechanism in a "strict" sense. It is not, however, reductionistic like its Cartesian cousin. It further leaves room for God to be active in the formation of life on Earth. For reasons discussed in the next chapter, Boyle is committed to nescience about the mode in which the power of seminal principles work.

[288] See Appendices for a comprehensive version of this chart.

There is, nonetheless, room in his ontology for the plastic power of seminal principles to act as supervenient properties of corpuscular matter.

The next several pages elaborate upon the various positions portrayed here so to provide a context for Boyle's *Free Inquiry into Notions Nature.* Boyle actually began composing *Free Inquiry Into Nature* in the 1660s around the same time as the *Origin and Forms of Qualities,* and both criticized the lack of intelligibility of Aristotelian forms. But he returned to it in 1680 after the publication of other philosophies that would ascribe agency to nature, namely the hylarchic or plastic spirit of the Cambridge Platonists and the neo-Aristotelian cosmologies of people like Francis Glisson.[289] What I hope to show is that Boyle is in the unique position that he must refute those who would appeal to immaterial causes or ascribe agency to nature while simultaneously carving a space for powers in a world made up entirely of inert matter.

3.4 Generation Through God's Direct Action

3.4.1 *Occasionalism*

Occasionalism, simply stated, is the view that created substances lack causal efficacy and cannot act as efficient causes. This means that God alone is the true cause of things on Earth. In the seventeenth century, most Occasionalists held that it was through God that the universe maintained its constancy, entailing God's re-creating of the world at each and every moment. In doing so, the passive and finite creations of God would be unable to contribute to the efficient cause or future states of other bodies.[290] A proponent of *Radical*

289 Hunter, *Boyle: Between God and Science*: p. 203

290 Nadler, "Malebranche on Causation": p. 129-130, in *The Cambridge Companion to Malebranche*; Ott, *Causation and Laws of nature in Early Modern Philosophy*: p. 65 ff.

Occasionalism, then, would simply allow the conversation to end there. If God re-creates the universe at every moment, then he would ultimately be responsible for bringing every substance into being each time he does so. Problem solved.

Except that no one (that I am aware of) actually held this view, and in the context of generation Radical Occasionalism was seen as a potential pitfall of Cartesian mechanism. If bodies have only the property of passive extension, then no active force or causal efficacy can come from them. In this case, God would have to be actively involved in *each* and *every instance of generation*. [291] The most prolific proponent among Boyle's contemporaries to promote Occasionalism was Catholic priest and French Cartesian, Nicolàs Malebranche. Like both Boyle and Descartes, Malebranche did not ascribe either immaterial powers or agency to nature. Instead, active causes in nature result from the constantcy of God's volition. But even Malebranche was against reducing the entirety of natural philosophy into a single theorm. Thus, even if God alone is the true, underlying cause of things he does not act arbitrarily. Instead, so-called laws of nature are the regularities or guiding principles of God's actions when re-creating the world.[292] And so, the task of the natural philosopher, to observe and account for regularities in nature, in practice never really changes.[293]

In the case of generation some secondary or occasional cause must still be present in nature. Karent Detlefson has pointed out that the problem of generation makes a striking case for Malebranche regarding his separation of secondary causes in nature, i.e. explanatory naturalism, from his metaphysical Occasionalism because of the "immense import of both

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291 Cf. Roe, *Matter, Life and Generation*: pp. 8-9.

292 Ott, *Causation and Laws of Nature in Early Modern Philosophy*

293 Nadler, "Malebranche on Causation" p. 131, in *The Cambridge Companion to Malebranche.*

the empirical and teleological in Malebranche's practice," the latter of which distinguishes him dramatically from Descartes. [294] With regard to the former, new empirical evidence by means of microscopy would come his way as well so that he would provide a radically different account of generation from that of Descartes' mechanical epigenesis.

3.4.2 *Pre-existence*

That fascinating, empirical insight came by way of Dutch physician, Jan Swammerdam. Swammerdam had performed a public vivisection of a silkworm caterpillar in 1665 for Thevenot's *académie* in Paris, where he revealed that the wings, antennae, and other parts of a grown butterfly were, though not fully formed, nonetheless present in this seemingly unrelated creature. He met Malebranche three years later while in Paris, and the French theologian was stunned by the implications of the discovery.[295] Their collaboration resulted in the doctrine of pre-existence, sometimes referred to as *emboîtement,* which is a radical version of preformation that states that each egg contains the pre-formed germs of future generations, similar to a set of Russian nesting dolls.[296] This view was articulated to its fullest extent in 1674 in Malebranche's *Recherche de la vérité.*

Even though God's direct action is the driving and organizing force of generation, it does so only during the original six days of Creation. All embryological development since then is merely an enlargement of parts and subsumed under growth, thus solving the problem

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294 Detlefsen, "Supernaturalism, Occasionalism, and Preformation in Malebranche": pp. 447-448.

295 See Pinto-Correia, *The Ovary of Eve: Egg and Sperm and Preformation*: pp. 20 ff. for a more detailed discussion.

296 Gasking, *Investigations into Generation: 1651- 1827*: pp. 43 ff.; Pyle, "Malebranche on Animal Generation," in *The Problem of Animal Generation in Early Modern Philosophy* pp. 194-214; Roger, *The Life Sciences in Eighteenth- Century French Thought*: p. 267

of generation and efficient cause. Boyle, however, never subscribes to pre-existence, in part because he does not share all of Malebranche's assuptions about causation. [297]

3.5 Immaterial Intermediary

3.5.1 *Platonism and Generation*

The Cambridge Platonists also rejected Occasionalism, or any view in which God was directly involved in generation after Creation for that matter. Henry More provided a strong argument against the Occasionalist (albeit not yet knowing of Malebranche) in *Immortality of the Soul*, stating that God could be immediately or directly responsible for the generation of things on account of miscarriages and monstrosities, as there is "no Matter so perverse and stubborn but his Omnipotency could tame; whence there would be no Defects nor Monstrosities in the generation of Animals."[298] But more generally there was the attitude that His constant involvement in sustaining the world directly was too laborious a task to be becoming of a Deity. This meant that while they shared the commitment to God's constant involvement in generation, they held that He did so only through an indirect medium.

Previously in Chapter 1, we examined the history of immaterial *semina*, or the *logoi spermatikoi*, as a causal agent of generation. In the seventeenth century this concept was unsurprisingly tied to the biblical story of Creation, following the Augustinian tradition. There certainly were those among Boyle's contemporaries who upheld the belief in

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297 Cf. Boyle et al, T*he Works of Robert Boyle*: v. 10 p. 448, *Inquiry into Notions of Nature*. Anstey, "Boyle on occasionalism: an unexamined source" and Ott, *Causation and Laws of Nature in Early Modern Philosophy*, Ch. 18: "Boyle and the Concurrentists" provide lengthier discussions on this topic.

298 More, *Immortality of the Soul*: p. 217. Cf. Reid, *The Metaphysics of Henry More*: p. 338.

Augustinian seminal reasons or principles. The French physician Claude Perrault, for example, had a notion of panspermia that is particularly close to Augustine's *logoi spermatikoi*.[299] On this account, the seminal reasons or principles act as the formal, final, and efficient causes combined.

Cudworth and More, however, presented an alternative intermediary responsible for generation that is likewise incorporeal or immaterial. Their incentive for such an intermediary, plastic natures or hylarchic spirit was the combat against atheism. Ralph Cudworth similarly became increasingly disenchanted with Descartes due in part to the latter's rejection of final causes in natural philosophy.[300] William Hunter has pointed out that the plastic natures as used described by the Cambridge Platonists is virtually interchangeable with the *logoi spermatikoi* or seminal reasons, suggesting that "Perhaps the need for the new name came from a desire to avoid direct dependence upon ideas associated with the Roman Catholic tradition or the pagan traditions of Neo-Platonism and Stoicism."[301] There may we well be something to this, especially given both their determinism to combat atheism and the tense religious and political climate then at Cambridge.

We've discussed in some detail Henry More's hylarchic Sprit of Nature. One important difference between this (in its later iterations) and the theory of seminal reasons is that the universal world soul or spirit bears more responsibility in the generation of living beings. Cudworth's theory of generation is somewhat more complicated.

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299 Roger, *The Life Sciences in Eighteenth-Century French Thought*: p. 294

300 Ott, *Causation and Laws of Nature in Early Modern Philosophy*: p. 135 ff.

301 Hunter, "The Seventeenth Century Doctrine of Plastic Nature": p. 200

3.5.2 *Ralph Cudworth and Plastic Natures*

Ralph Cudworth was among the more prominent of the Cambridge Platonists. He spent most of his life at Cambridge, where he was professor of Hebrew. Cudworth was especially dedicated to opposing atheism, which for him was promulgated by materialism, mechanism, and determinism-each of which he saw as problems in the Cartesian mechanical philosophy.[302] He thus denied that generation could happen mechanically, arguing instead that it was *Plastic Natures* that were the driving force of generation. This notion of an immaterial principle is what most modern readers associate with "plastic nature" or "plastic power" due to his popularization of the term with his 1678 *The True Intellectual System of the Universe. The True Intellectual System of the Universe,* an impressive tome of more than eight-hundred pages, is described by Cudworth on the title page as a refutation of atheism. Unsurprisingly then, he is careful to distinguish his plastic natures from those described by Stoic and atheistic philosophers of antiquity. [303] He describes the atheistic hylozoism of pre-Socratics, for example, as "an unshapen embryo of some dark and cloudy brains, that was never yet digested into an entire system, nor could be brought into any such tolerable form..."[304]

The plastic nature on Cudworth's view then is a tool by the hand of God, which he describes as "first principle and original of all things in the universe be thus supposed to be body or matter, devoid of all animality, sense, and consciousness, then it must of necessity be either perfectly dead and stupid, and without all manner of life..." [305] His account of

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302 Zagorin, "Cudworth and Hobbes on Is and Ought": p. 129, in *Philosophy, Science, and Religion in England 1640- 1700*.

303 Giglioni, "The Cosmoplastic System of the Universe: Ralph Cudworth on Stoic Naturalism": p. 9

304 Cudworth, *The True Intellectual System of the Universe:* p. 123

305 Ibid. p. 196

immaterial plastic natures is distinct in that they are understood in terms of both the universal world-soul and the immaterial active forces of individual living beings.[306] Whereas the former is like More's hylarchic principle, the latter likely has more in common with the *logicoi spermatikoi* of Neo-Platonists. Cudworth's ideas about generation consequently seem to bear more similarity to Dr. More's earlier works rather than the later view discussed in detail in this chapter.

3.6 Active and Thinking Matter

3.6.1 Galeno-Aristotelian Efficient Cause

All subsets of the Galeno-Aristotelian explanatory line of thought share in common the belief that the efficient cause is informed and directed by the form or faculties of the soul and thus acts accordingly. Although the efficient cause is often explained in terms of physical actions upon matter, as seen with Aristotle's description of heat as responsible for coagulation, it's the form and/or faculties that are responsible for explaining how the matter gets organized in the specific way that it does.

Some of Boyle's contemporaries would certainly have been at the forefront of his concerns while composing *Inquiry into the Notion of Nature*. Kenelm Digby, for example, is cited in Boyle's juvenile *Atomicall Philosophy* as "our deservedly famous Countryman S^{r} Kenelme Digby."[307] Digby, along with Nathaniel Highmore and William Harvey was an English Royalist whose investigations into generation were strongly influenced by Aristotle.[308] Like Sennert and Liceti before him, Digby provided a particulate account of

306 Smith, *Divine Machines: Leibniz and the Sciences of Life*: p. 128

307 Boyle et al., *The Works of Robert Boyle:* v. 13, p. 227, *Atomicall Philosophy*. Cf. Hunter, *Boyle: Between God and Science*: p. 108, and Newman, *Atoms and Alchemy:* p. 160.

308 Cobb, *Generation*: pp. 128-129

Aristotelian hylomorphism. On his view, the specific virtue of the seed is responsible for assisting in the embryo's gradual development.[309]

Another such target of Boyle when composing *Inquiry into the Notion of Nature* was the English physician Francis Glisson.[310] Glisson, unlike More and Cudworth, was an active attendant at meetings in the early days of the Royal Society. His work is unique in that he combines Harvey's account of the body and acceptance of Aristotle with the chymistry and *archaeus* of Van Helmont. The result was a hylozoistic theory of matter endowed with form, which ultimately removes the line between living and inorganic beings. His main philosophical work, *De Natura Energetica* (1672) expounds upon this unique theory of matter, which he defines as, "energetic substance endowed with life," which he calls the *vis plastica.* On this account, matter was not only living but "perceptive, endowed with appetites and aversions and, ultimately, capable of thought" [311]

3.6.2 Thinking Matter

Table 3.31 includes what I've labeled "Intelligible Materialism", which is the view that all things are made up of only matter (including minds) and that all matter is self-moving. In particular, I have in mind someone like Margaret Cavendish, who rejected the mechanical philosophy in favor of thinking matter.[312] Generation on this view is somewhat easy to explain since matter is not inert, but moves and divides itself accordingly. Cavendish and

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309 Roger, *The Life Sciences in Eighteenth-Century French Thought*: pp. 105- 107.

310 Hunter, *Boyle: Between God and Science*: p. 103

311 Henry, "The matter of souls: medical theory and theology": p. 91, in *The medical revolution of the seventeenth century*

312 For an in-depth discussion about how Cavendish's matter theory relates to sex, generation, and reproduction see James, Susan: "The Innovations of Margaret Cavendish": pp. 225-232; and Walters, *Margaret Cavendish: Gender, Science and Politics*: pp. 37- 99, Ch. 1. "Redefining Gender in Cavendish's Theory of Matter."

those who share her unique materialism, however, do not seem to be on Boyle's radar, so to speak. He consequently does not have a good response.

If powers are supervenient upon lower level corpuscular structures, then it is not at all clear why the power or disposition to think could not also be understood this way. The best analysis of Boyle on thinking matter is provided by Peter Anstey, who says of the English chymist that:

> Perhaps then, the most we can say is that Boyle was convinced of the immateriality of thinking substances by revelation, bolstered by natural reason, and that these two together sufficed to preclude a serious consideration of the empirical possibility of thinking matter, in spite of the fact that it is entirely consistent with his ontology. [313]

On the subject generation, the one advantage that the formative power of seminal corpuscles would have over the power of thinking matter is that the former plays a central role in Boyle's ideas about the biblical account of creation.

3.7 Free Inquiry into Notions of Nature

3.7.1 *The Ambiguity of 'Nature'*

Free Inquiry into the Notion of Nature is organized as a rebuke of those who personify nature in order to explain natural phenomena. Boyle begins the preface by inquiring why "many Learned Men" have "written of the *Works of Nature"* or principles of nature, etc. without ever having bothered to define, "call in *Question* or discuss" precisely what they take nature to be.[314] Consider, for example, such imprecise phrases as: "nature

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313 Anstey, "Boyle Against Thinking Matter": p. 497, in *Late Medieval and Early Modern Corpuscular Matter Theories*

314 Boyle, et al., *The Works of Robert Boyle*: v. 10, p. 439, *Inquiry Into the Notion of Nature*

abhors a vacuum"[315]; "Nature preserves itself; "Nature always does things by the most efficient means"; "Nature makes the Night succeed the Day"[316] and it becomes clear that 'nature' is being used to denote a large and unclear range of different powers, significations, and principles. Indeed, Boyle argues that term 'nature', as used among his contemporaries, is a vexed and ambiguous one that is often employed in misleading ways.

But Boyle's concern is not only that this account of nature leads to an "unsound and deceitful Foundation" of natural philosophy, but also that discussing nature in such a vulgar, unclear manner has had an undue influence on religion:

> ... many Atheists ascribe so much to Nature, that they think it needless to have Recourse to a Deity, for the giving an Account of the Phænomena of the Universe: And, on the other side, very many Theists seem to think the commonly Received Notion of Nature, little less, than necessary to the Proof of the Existence and Providence of God ...[317]

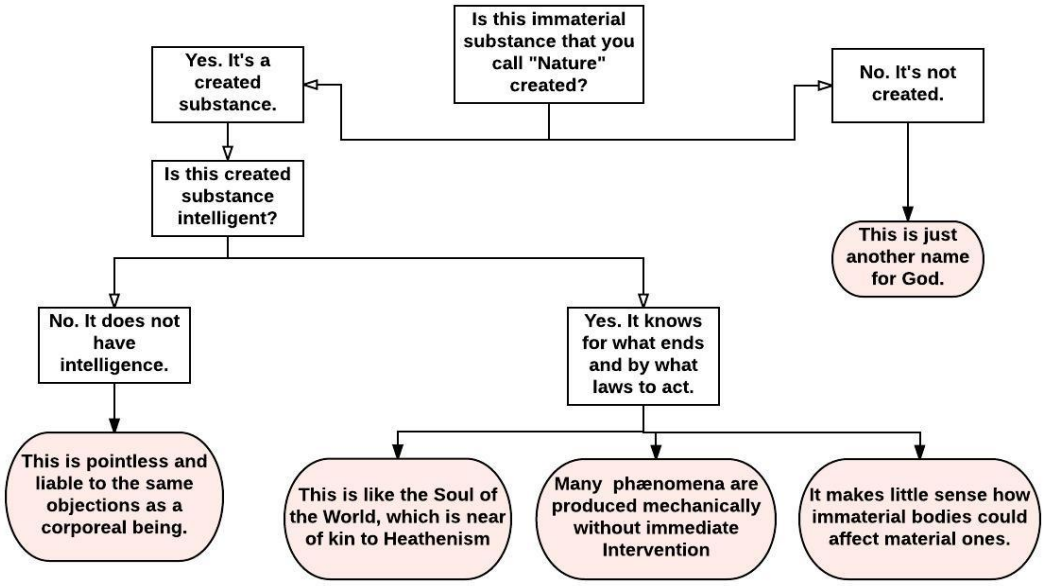
In this context he explains his motivations and intentions in writing the *Inquiry into the Notion of Nature*, which is "to keep the Glory of the Divine Author of Things from being usurp'd or intrench'd upon by His Creatures" and to make the creations of God more readily and thoroughly understood by the natural philosophers undertaking the study of them.[318] He consequently will reject philosophies that attribute agency to nature, postulate the existence of powers or eliminate God's influence from natural processes- including that of generation.

3.7.2 *Platonism*

315 Cf. Ibid. p. 462
316 Cf. Ibid. p. 453
317 Ibid. p. 439
318 Boyle, et al., *The Works of Robert Boyle*: v. 10, p. 442, *Inquiry into Notions of Nature*

Boyle's first rejoinder to a creative power like plastic natures is that it is not consistent with biblical account of creation described in *Genesis*. "And whereas Philosophers presume," he writes, "that [Nature], by her Plastick Power and Skill, forms Plants and Animals out of the Universal Matter; the Divine Historian ascribes the Formation of them to Gods immediate." He then quotes two separate passages from *Genesis,* in which God alone is responsible for bringing forth plants (grass, herb yielding seed, and fruit) and later animals.[319]

He later responds more directly to Neo-Platonists who would describe nature in terms of some immaterial spirit, such as the hylarchic principle or plastic nature, by first



asking of this immaterial substance whether it is created, and if that created substance be intelligent. As one can see with the flow chart below, Boyle quickly rules out notions of Nature that are neither created nor intelligent in order to deal with those views of his contemporaries.

[319] Ibid. p.459

Boyle never says to whom among his peers he is responding, but it becomes clear that he has Platonists like More and Cudworth in mind. For he goes on to say that if Nature is understood as an incorporeal substance endowed with understanding, then it

> ... performs such Functions as divers of the Antients ascribe to the Soul of the World; besides, that this *Hypothesis* is near of kin to Heathenism, I do not think, that they who shall with many *Grecian*, and other Philosophers, who preceded Christianism, suppose a kind of Soul of the Universe, will find this Principle sufficient to explicate the *Phœnomena* of It. [320]

In an effort to "compare the Macrocosm and Microcosm", Boyle lists several operations of the body that can be explained mechanically without recourse to the soul, such as digestion and respiration. While some natural philosophers may claim that an animal's soul is responsible for the formation of the fetus, Boyle points out that in the case of humans, as "exquisite an Engine as 'tis justly esteem'd, is form'd without the Intervention of the rational Soul..." as the fetus is not ensouled until six weeks. [321]

His response is a curious one: it does not seem to apply to a universal world soul but rather the individual rational soul. Boyle nonetheless goes on to provide a solid refutation of the neo-Platonic World soul or plastic natures by insisting that it makes little sense how an immaterial, created substance could "by a Physical Power or Action move a [Corporeal] Body..." [322]

3.7.3 *Active & Thinking Matter*

Early in *Inquiry into the Notion of Nature* Boyle suggests that 'Nature' was used by his contemporaries to mean one of eight different significations which, if replaced by more

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320 Boyle et al, *The Works of Robert* Boyle: v. 10, p. 553, *Inquiry into Notions of Nature*

321 Ibid.

322 Ibid. p. 554

precise terms, would help to eliminate ambiguity. One of these definitions addresses those ascribing agency and active powers to nature: "an Aggregate of the Powers belonging to a Body, especially a Living one."[323] The notion of nature—that is, of powers that belong to bodies—applies equally both to a Galenic conception of the body and Glisson's *vis plastica.* Boyle later goes on to explain precisely the problem with such a definition, which is that it picks out something that does not exist independently of matter. When speaking of digestion, for example, Boyle complains that people

> ... do not mean I know not what Entity, that is distinct from the Human Body... but, observing an actuating power and fitness in the Teeth, Tongue, Spittle, Fibres and Membranes of the Gullet and Stomach, together with the natural Heat, the Ferment...and some other Agents, by their Co-operation, to cook or dress the Aliments, and change them into Chyle; observing these things, I say, they thought it convenient... to express the *Complex* of those Causes... by the summary *Appellation* of *concocting Faculty*. [324]

Hence, Boyle says that faculties or powers of the body are not actual beings or notional entities, yet they're spoken of as if the tasks they complete were "perform'd by *real* Agents." [325] Here is where the supervenience of powers comes into play. Unlike the powers described by Glisson or Galenic physicians, Boyle's powers do not exist independently of matter as real entities. This difference between their views is subtle but important.

Boyle's argument against Scholastic forms of the Peripatetics is closely related. Referencing his essay on Salt Peter, he states matter-of-factly that he will "acknowledg no

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323 Boyle et al, *The Works of Robert Boyle*: v. 10, p. 456, *Inquiry into Notions of Nature*

324 Ibid. p. 463

325 Boyle et al, *The Works of Robert Boyle*: v. 10, p. 464, *Inquiry into Notions of Nature*

such Chymerical and Unintelligible Beings." [326] Criticizing the incomprehensibility of Scholastic forms, the English Aristocrat says that "if [the Form] be any thing positive, [it] should be an *Immaterial* Substance."[327] With the form as an immaterial substance, such an appeal would be privy to the same criticisms cited above. Boyle goes on to complain that obscure notions of nature as forms allows those who use them to feign knowledge or disguise their ignorance.

Boyle later argues that often the effect of so-called powers is in actuality "is produc'd by the Texture, Figure, and, in a word, Mechanical Disposition of the Agent..." As an example he refers again to his analogy of the lock and the key. The key, he explains, is said to have an "*aperitive Faculty"* that it can gain or lose through no change of its own, but by a change "in the Locks it is apply'd to, or in the Motion of the Hand that manages It." [328] We can see him trying to carve a space for the powers of inert matter within a mechanical ontology.

3.7.5 *Epicureans and Boyle*

Another criticism of the Peripatetic philosophy made by Boyle is that the Aristotelians hold the world to be eternal and as a "Work of Nature" despite its not having an architect. [329] Similarly, the Epicureans are unable to give an account of the first formation of the world, according to their own principles, because "...'twas by the Coalition, or Convention of these *Atoms*, that the World had its Beginning. So that, according to them, it

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326 Boyle et al, *The Works of Robert Boyle*: v. 10, p. 486, *Inquiry into Notions of Nature*

327 Ibid.

328 Ibid. p. 562

329 Boyle et al, *The Works of Robert Boyle*: v. 10, p. 468, *Inquiry into Notions of Nature*

was not *Nature*, but *Chance*, that Fram'd the World." [330] And yet, Boyle explains, both reason and revelation reveal that the world is not eternal, but had a first cause or formation.

It is within the context of the various alternatives that Boyle presents his own account of the "the First Formation of the World," which he is apt to describe as "probably" so to avoid being dogmatic about "so weighty, and so difficult" a topic. Here, he says that

> ... the Great and Wise Author of Things, did, when he first Form'd the universal and undistinguish'd matter, into the World, put its Parts into various Motions... by his Infinite Wisdom and Power, he did so guide and over-rule the Motions of these Parts, at the beginning of things, as that...they were *finally* dispos'd into that Beautiful and Orderly Frame, we call the *World*; among whose Parts some were so curiously contriv'd, as to be fit to become the Seeds, or Seminal Principles, of Plants and Animals.[331]

Here we see again Boyle's appeal to a seminal rudiment or principle resulting from Creation that is ultimately responsible for the generation of living beings. Boyle eventually concludes in this discussion that whatever happens in nature is "really done but by particular Bodies, acting on one another by *Local Motion*, Modifi'd by the other *Mechanical Affections* of the Agent, of the Patient, and of those other Bodies, that necessarily concur to the Effect, or the *Phænomenon* produc'd." [332] This line of reasoning, we shall see in the next chapter, echoes Boyle's own thoughts about mechanical explanation.

3.8 **Conclusion**

[330] Ibid.

[331] Boyle et al, *The Works of Robert Boyle*: v. 10, pp. 468-469, *Inquiry into the Notion of Nature*

[332] Ibid. p. 470

A necessary condition of a mechanical ontology is that the world be composed solely of inert particles of matter, but it need not be reductively so. The two major alternatives on this account were Epicurean atomism or Cartesian mechanism, neither of which Boyle found sufficient to account for the organization of complex bodies-especially given God's absence from these accounts. Thus, it is within this context that we can appreciate Boyle's constant protests that he cannot accept "that either these Cartesian laws of Motion, or the Epicurean casual Concourse of atoms, could bring meer Matter into so orderly and well contriv'd a Fabrick as this World." [333]

Boyle must then present an alternative account in which the organizing force in generation is some property of inert matter. In some ways, Boyle seems to be stuck between a rock and a hard place. He could even be accused of wanting to have his cake and eat it, too, so to speak. He bemoans that for Cartesians God is not more involved in nature on other mechanical accounts, and yet he rejects both God's direct involvement and the supposition of an immaterial intermediary. He rejects active matter and that powers are real entities, but he insists that some powers are mechanical affections.

I have argued that powers are best understood in Boyle's ontology as supervenient properties of inert matter, which means that they are determined by and entirely dependent upon lower levels of corpuscular structures. On this view, he does not posit powers as independently existing entities, but as non-reducible properties of matter. This account has the added advantage of explaining Boyle's tendency to treat his "corpuscular" philosophy as interchangeable with his "mechanical" one. Chalmers claims that experimental practice of

[333] Boyle et al, *The Works of Robert* Boyle: v. 5, p 353, *Origin of Forms and Qualities*

seventeenth century naturalists like Boyle focus on intermediary causes rather than the underlying causes related to catholic matter and the mechanical philosophy. But the intermediary states of matter and related causes, such as the elasticity of the air or fermentation, have an important part in the more general picture of Boyle's mechanical ontology. They are, furthermore, inseparable from it.

In his reply to Henry More, Boyle gives fascinating insight into what he holds a mechanical explanation to be, namely, that it has no recourse to an immaterial or incorporeal agent to explain the phenomena at hand. In the next chapter, we shall see the important role this line of reasoning plays in Boyle's own account of mechanical explanation and in his epistemic approach to the mechanical philosophy more generally. Further, we will examine the specific agents of generation as described by Boyle and how his views change over time.

Chapter 4. Mechanizing Principles, Powers, & Petrifying Spirits: *London 1668-1690*

4.1 Boyle's Changing Views

4.1.1 *Sceptical Chymist in London*

In 1668 Robert Boyle arrived with his belongings to Pall Mall, the house of his elder and doting sister, Lady Katherine Ranelagh.[334] Boyle would make the residence his permanent home, dwelling in the busy city of London for more than twenty years. In addition to the company of his highly esteemed sister, Boyle had at Pall Mall a laboratory where he could readily conduct experiments. London undoubtedly provided Boyle with a diverse and engaging atmosphere for experiment and natural philosophy. With frequent trade and a burgeoning population, London had become the intellectual place to be, *l'endroit rêvé*, filled with a lively atmosphere and abundance of scholars both residing in and travelling through the city.

Both Francis Glisson and Walter Needham, whom we encountered in previous chapters, had taken up residence in London as practicing physicians and members of the Royal College of Physicians. Robert Hooke, who had once been under Boyle's employ, was now charged with the task of reconstructing parts of London destroyed in the Great Fire of 1666. Hooke, nonetheless, made frequent visits to Pall Mall, where he discussed a range of topics. Several prominent figures passing through London, such as philosopher Gottfried Leibniz, also had the opportunity to meet with the English Aristocrat during his time in London. And finally, his close proximity to the Royal Court, combined with his Aristocracy,

334 Hunter, *Boyle Between God and Science:* p. 164

provided Boyle the opportunity to frequent the court of King Charles II.[335] Although, one source of irony, discussed by Michael Hunter, is that Boyle's participation in Royal Society meetings actually decreased significantly upon taking residence in London.[336] This fact seriously calls into question the extent to which Shapin and Schaffer present Boyle as a calculating mastermind, self-fashioning himself and the composition of the Royal Society as part of his strategy to promote his experimental philosophy. [337]

Shortly after his arrival to London, Boyle's work was violently interrupted in June of 1670 by the "paralytic distemper" he suffered, a seizure of some sort that sounds not unlike a stroke. This frightful event resulted in a "weak and languishing condition" on the part of Boyle that lasted for several months.[338] Upon his recovery, his religious devotion perhaps intensified by his illness, Boyle published two theological apologetics*: Excellency of Theology* and *Some Considerations about Reason and Religion.*[339] Appearing at roughly the same time was Boyle's "About the Excellency and Grounds of the Mechanical Philosophy" (which was appended to Excellency of Theology) and *Essay on Origine and Virtues of Gems*. A close inspection of these works will provide the reader with further insight as to Boyle's views on: the problem of generation as it pertains to plants, animals, and minerals; the forces of generation that Boyle allows in his ontology; and just how his views on these various topics were beginning to change.

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335 Hunter, *Boyle Between God and Science:* p. 168.

336 Hunter, *Boyle Between God and Science:* p. 169. See also, Hunter, *The Royal Society and Its Fellows*: p. 40.

337 Schaffer, Shapin, *Leviathan and the Air Pump.*

338 Hunter, *Between God and Science:* p. 174.

339 Ibid. pp. 175-176.

4.1.2 *Spontaneous Generation*

One of the more radical changes on the subject of generation in Boyle's own writings reflects a more general shift in the seventeenth century that was happening, namely that from the unequivocal acceptance of spontaneous generation to its denial. In truth, this shift had already begun at the turn of the century with figures such as of Fortunio Liceti and Daniel Sennert, who hold that so-called spontaneous generation is not actually spontaneous (that is, arising entirely from internal principles[340]), but is the result of seeds or seminal principles, which lay hidden within matter.[341] Putrefaction, then, does not produce living creatures but is merely the means by which latent seminal powers can take effect. But the assumption that decayed matter would produce insects through any means came into question during the seventeenth century, and by the end of the century it was an assumption that most would come to reject. This change was led, in part, by a debate between Jesuit naturalist, Athanasius Kircher, and Italian experimentalist, Francesco Redi.

A friend of Pierre Gassendi, Athanasius Kircher was both Jesuit priest and Professor of Mathematics at the *Collegio Romano*, where he became an internationally celebrated teacher and scholar. [342] Regarding the subject of generation, Kircher holds that seminal principles with some kind of formative power are required for plants and animals, fossils and

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340 See "spontaneous, adj." OED Online. September 2016. Oxford University Press. http://www.oed.com.proxyiub.uits.iu.edu

341 Hirai, *Medical Humanism and Natural Philosophy: Renaissance Debates on Matter, Life and the Soul*: p. 162.

342 Findlen, *Possessing Nature:* Ch.1, "A World of Wonders in One Closet Shut." See also: Hirai, "Mysteries of Living Corpuscles": p. 264, in *Early Modern Medicine and Natural Philosophy.*

crystals alike, but living beings can come only from matter that was once animated.[343]

Minerals, in contrast, are produced not by a plastic power properly called, but by "a saline power that is only 'akin' to a plastic one."[344] The most comprehensive account of Kircher's views on generation can be found within the volumes of his famed Encyclopedia, *Mundus Subterraneus*, where he also explains generation in terms of these invisible, analogical seeds. Just as spontaneous generation according to Daniel Sennert is caused by imperceptible seminal corpuscles—such as those of future worms or lower insects that found their way into putrefying matter—so too is this the case for Kircher. As with Sennert, moreover, Kircher describes these seminal corpuscles as hidden, emerging and vivifying by means of the ambient heat from a formerly living being. [345] According to Kircher, God endowed the world with *panspermia*, or the universal seeds of nature, at Creation.[346] The generative power of these invisible seeds, a seminal *spiritus*, was used by God to create life from chaotic matter and "play[ed] the role of the medium between the Creator and creatures." Thus, the issue of spontaneous generation is intricately connected to his views on Creation and the origin of all life.[347]

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343 Kircher, *Mundus Subterraneus:* Bk. 12, pp. 346-356. See also: Hirai, "Mysteries of Living Corpuscles": p. 265, in *Early Modern Medicine and Natural Philosophy*; and Smith, *Divine Machines: Leibniz and the Sciences of Life*: p. 224.

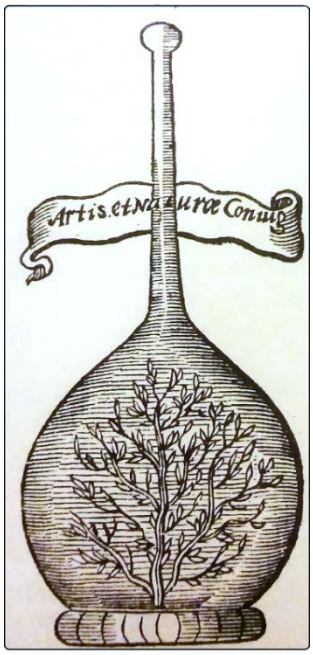
344 Chang, *Alchemy as Studies of Life and Matter*: p. 326

345 Cf. *Mundus Subterraneus*: Bk. 12, pp. 346 ff. and Sennert, *Hypomnemata Physica:* 380-382, Bk.5, ch.2.
See also: Hiro, "Kircher's Chymical Interpretation of the Creation and Spontaneous Generation": p. 85, in *Chymists and Chymistry*; Newman, *Atoms and Alchemy:* p.147; and Stolberg, *Particles of the Soul: The Medical and Lutheran Context of Daniel Sennert's Atomism*: pp. 181 ff.

346 Kircher, *Mundus Subterraneus*: Bk. 12, pp. 347.

347 Hiro, "Kircher's Chymical Interpretation of the Creation and Spontaneous Generation": p. 78-79, in *Chymists and Chymistry*. See also Roger, *The Life Sciences in Eighteenth-Century French Though*t: p. 266

In one experiment following his discussion on panspermia, Kircher describes the genesis of flies from their carcasses, which he does by gathering the fly corpses with honey soaked first in water and placed on a brass plate, which is then heated. When the fly-carcass



is exposed to the tepid heat of the ashes, the seminal material from the corpses produces microscopic worms, which eventually take shape, grow wings, and increase in size. [348] One of the more famous experiments involving regeneration and palingenesis, the "Vegetable Phoenix" is actually under the heading of distillation. Its fame may come from the fact that Kircher is said to have performed it for Queen Christina following her conversion to Catholicism.[349] The experiment conjures images of the mythical Phoenix, who rose to life again from its own ashes, as the Vegetable Phoenix was described as the burning of a plant, the resulting ashes of which produced a new, identical plant. Tragically, however, Kircher says that this experiment did not come to fruition in this particular case as he inadvertently left the phoenix container plant in the window sill, where it froze and broke on account of the winter February chill.[350]

In 1668, Francesco Redi (a courtier from the Royal Court of Ferdinando, Duke of Tuscany) published his findings from experimenting with insects, *Esperienze intorno all generazione degl'insetti* (Experiments on the generation of insects.) The treatise was later published in 1671 as *Experimenta circa generationem insectorum* (often referred to as *De*

348 Kircher, *Mundus Subterraneus*: Bk. 12, p. 381.

349 Mayer-Deutsch, "Quasi-Optical Palingenesis": p. 107, in *Athanasius Kircher: The Last Man Who Knew Everything.*

350 Kircher, *Mundus Subterraneus*: Bk. 12, p. 435; Cf. Solís, *La Ciencia de la Resurreccíon*: pp. 334-335

Insectis). Redi conducted a series of controlled experiments involving covered and uncovered substances that could putrefy, from raw meat and fish, milk and cheese, to fruits, such as pumpkin. What he discovered is that, when left out to rot, maggots and worms appeared only in the uncovered containers.[351] He describes the resulting worms as motionless days after their birth and "shrunk into eggs, differing only in size".[352] He then details his removing the "eggs" into a different container and watching their development. The larger "eggs" produced ordinary house flies, and from the smaller "there emerged, after twelve days, small flies resembling winged ants, which immediately after birth skipped about with such incredible sprightliness and vivacity so that they were the embodiment of perpetual motion."

He goes on to suggest that "the eggs producing the worms were laid by flies in the milk at milking time, when milk is left in the pails to gather, and is surrounded by swarms of flies." [353] His reference to eggs, rather than a seed or seminal principle, represents a similar sort of shift in the way in which seventeenth-century scholars began thinking about generation. As belief in spontaneous generations began to fade, adherence to ovism became increasingly more popular. [354] Redi's work became best known for his experimentation, through which he aimed to demonstrate that creatures such as maggots, previously believed to be the result of some kind of generative process from corrupt and putrid matter, actually develop from material laid by adult flies.

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351 Redi, *Experiments on the Generation of Insects*: pp. 74-76; Cf. Wilson, *The Invisible World*: p. 200

352 Redi, *Experiments on the Generation of Insects:* p. 74

353 Ibid. p. 75

354 Roger, *The Life Science in Eighteenth-Century French Thought*: p. 207

In doing so, he sought to refute Kircher's Doctrine of Palingenesis and supposed resuscitation of flies from their ashes. Indeed, a good deal of Redi's treatise could be seen as a direct response to Kircher.[355] He frequently names Kircher specifically, and on one such occasion describes the Jesuit, "though a man worthy of esteem" as erroneous in his claim that one could breed flies from putrefied fly corpses.[356] He goes on to explain:

> "The dead flies" says the good man, "should be besprinkled and soaked with honey-water and then placed on a copper-plate exposed to the tepid heat of ashes; afterwards very minute worms only visible through the microscope, will appear, which little by little grow wings on the back and assume the shape of very small flies, that slowly attain perfect size." I believe, however, that the aforesaid honey-water only serves to attract the living flies to breed in the corpses of their comrades and to drop their eggs therein; and I hold that it is of little use to make the experiment in a copper vessel heated by warm ashes, for without these accessories the worms would have bred in the dead bodies. I also frankly confess my inability to understand how these small worms, described by Kircher, could change into small flies without at first, for the space of some days, being converted into egg-like balls nor how those small flies could hatch out so small and then grow larger, as all flies, gnats, and mosquitoes and butterflies, as I have observed many times, on escaping from the chrysalis are of the same size that they keep through life.[357]

His detailed description of the insects that develop into "egg-like balls" is more aggressive than the text may initially seem, as it means that Kircher's own description of their life cycles, where they transform directly from worms into flies is flat-out wrong.

Kircher, however, was not Redi's only rival whose views on generation were addressed. Redi also addresses French philosopher Pierre Gassendi, who claims that cheese worms are the product of seed that was deposited on leaves and grass by flies and similar

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355 Cf. Bertoloni Meli, *Medicine, Mechanism, Disease*: pp. 180, 183; Cobb, *Generation*: pp. 85 ff; Wilson, *The Invisible World*: p. 193.

356 Redi, *The Generation of Insects*: p. 34

357 Ibid. pp. 34-35

creatures. Such worms make their way into cheese by way of milk, as animals such as cows and goats consume the seed unknowingly when eating grass. In response to this view, Redi says that, "with all due deference to this illustrious philosopher," he finds it implausible that "those deposits could retain their special powers after having passed through the complicated process of mastication in the mouth, and of digestion in the stomach, of the animals that swallowed them." [358]

Because of his credulity towards experiments and various accounts of them, Athanasius Kircher was viewed with considerable skepticism by members of the Royal Society. Francesco Redi's *De Insectis*, in contrast, was very well received once members of the Royal Society obtained it. But public denial of spontaneous generation did not begin with Redi's experiment on maggots, nor did his work fully put the issue to rest. We saw in Chapter 2, for example, that Hooke never appeals to the process of putrefaction as the formative agent responsible for the spontaneous generation of mushrooms, but explains their formation in terms of heat. In the following chapter, moreover, we will see how others such as Malpighi and Swammerdam contributed to these discussions, as well as those who publicly rejected Redi's findings. *De Insectis* is nonetheless an important episode among several in an ongoing shift in the ways that seventeenth-century scholars thought about "lower" insects, palingenesis, and the problem of generation more generally conceived. In many ways, it also represents a tipping point within this shift. Regarding the Royal Society, Peter Anstey communicates the effect of Redi's book when he explains that, "the publication of Oldenburg's review of [Redi's *De Insectis*] in the Philosophical Transactions marked a

[358] Redi, *Experiments on Generation of Insects:* p. 73

decisive turning point in views on spontaneous generation amongst members of Royal Society and their associates." [359]

Whereas Boyle's early notes on spontaneous generation assume generation from putrefaction of lower insects such as flies and worms, his later works are explicit in their rejection of this notion. He conducted a number of experiments with his air-pump in the late 1660s relating to spontaneous generation in hopes of understanding if or how seminal principles are affected in a vacuum.[360] Years later Boyle published an ambiguous allusion to generation from putrefaction in his *Memoirs for the Natural History of Human Blood* (1684), in which he describes himself hermetically sealing the bolt-head flask in which he had left blood so to keep it, "from being any way blown by Flies, or impregnated by Seminal Particles, that may be unsuspectedly convey'd to it by the Air." [361]

His tightly sealing the flask is reminiscent of Redi's own sealing of raw meat and other organic substances. Boyle's doing the same, however, was likely not inspired by Redi. The most striking indicator is his use of the phrase 'seminal rudiments' contra 'eggs'. The idea that seminal particles or rudiments could be responsible for generation from putrefaction was, in fact, addressed by Redi in his *De Insectis*, whence he repeated the experiments with substances covered in gauze. This set up allowed space for such rudiments to the rotted substances while simultaneously preventing adult flies to gain access. The results were the same.

The other fact to consider is the date at which Boyle conducted the many experiments described in *History of Human Blood;* they had actually been conducted several

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359 Anstey, *Boyle on Seminal Principles*: p. 618

360 See Boyle, et al. *The Works of Robert Boyle*: v. 6 pp. 256-258, v. 7 pp. 127 ff.; Cf. Anstey, *Boyle on Seminal Principles*: p. 617

361 Boyle, et al. *The Works of Robert Boyle*: v.10: p. 36, *The History of Blood*

years prior to his publication of the text. In that context, the seminal rudiments described here more closely resemble those rudiments described in his earlier notes on spontaneous generation. Whatever the case, Boyle explicitly rejected the notion that insects generate from putrefied matter later in life, as is evident from his *Christian Virtuoso*, published just before his death, where writes:

> I see not why it should be deny'd, that God's Providence may reach to his particular Works here below... that at the first Creation, or (if they dislike that term) Formation of things; the great Author of them must not only have extended his Care, to the grand System of the Universe in general, but allow'd it to descend so low, as to contrive all the Minute, and various Parts, (and even the most homely ones) not only of Greater and (reputedly) more perfect Animals, as Elephants, Whales, and Men; but such Small and Abject Ones, as Flies, Ants, Fleas, &c. Which being manifestly propagated by Eggs laid by the Female, cannot reasonably be thought the off-spring of Putrefaction. [362]

4.1.3 *Principles, Powers, and Petrifying Spirits*

In order to understand how Boyle's views on generation change over time, a brief examination of the agents of generation as described by Boyle—seminal principles, petrifick spirits, and plastic powers—would be helpful. Peter Anstey has provided the first comprehensive analysis of this topic with his 2002 paper, "Boyle on Seminal Principles". Anstey's paper categorizes Boyle's works on seminal principles by topic so that studying them in his corpus becomes feasible, and the amount of Boyle's work addressed by this piece is impressive. He also captures Boyle's diverse vocabulary, explaining that Boyle also uses the terms, " 'seminal contexture', 'seminal rudiments', 'seminal structures', 'seminal

[362] Boyle, et al. *The Works of Robert Boyle*: v. 11: p. 300, *The Christian Virtuoso;* Cf. Anstey, *Boyle on Seminal Principles*: p. 619.

properties', 'seminal endowments' and 'seminal virtues' as additional synonyms for 'seminal principles'." [363]

A plastic power is a molding agent that is responsible for organizing matter in generation. When Boyle uses the term 'plastick power', he seems to have one of two ideas in mind.[364] The first is the more general notion of a formative power. The source of that power could come from a number of agents, including the Galenic formative faculty, the soul or even on occasion the Neo-platonic world soul. It becomes clear from Boyle's writings, however, that the only agent which could have that kind of formative power for the purposes of generation within his own framework is a seed, or a seminal principle. Boyle more frequently uses the term in a restricted sense, which is the power of a seed to generate a body. In contrast to a seminal principle, a petrifick spirit is the agent described by Boyle as being responsible for the production of minerals. But his language remains confusing. Boyle tells us, for example, that the source of the petrifick spirit *could* be a seminal principle, which on his own view is most often associated with plastic powers. Further still, Boyle claims that the petrifick spirit is *almost like* a plastic power.

Based on Boyle's discussion of generation, Anstey argues for a threshold of complexity in the mind of Boyle beyond which a mechanical explanation is no longer sufficient. That there is such a threshold, Anstey claims, emphasizes Boyle's tension in accepting seminal principles as being, by nature, mechanical. His argument for this claim rests on the assumption that the petrifick spirit and the seminal principle have explanatory roles that appear to be interchangeable.[365] He further argues that Boyle's appeals to a seminal

363 Anstey, *Boyle on Seminal Principles*: p. 602.
364 For a list of Boyle's use of the term 'plastic', see appendix.
365 Anstey, *Boyle on Seminal Principles:* p. 622

or plastic power are made in order to explain those features of generation that are beyond the explanatory means of the corpuscular hypothesis. In short, Anstey presents Boyle as caught in a catch-22. On the one hand, if seeds operate mechanically, then Boyle has no reason to appeal to them as an explanatory agent in the first place. On the other, in admitting nescience, Boyle has to allow for the possibility of non-mechanical causes.[366]

I hope to show, however, that Boyle presents two very different kinds of processes for the production of minerals and that of living beings. Boyle's appeal to seminal principles and his so-called nescience about their nature, moreover, are rooted in deep theological commitment on his part rather than a tension within his mechanical philosophy. Boyle's fascination with *semina* seems isolated to his more juvenile works, and by the 1670s his notion of 'mechanical' becomes more restricted. Even so, he maintains a constant and consistent invocation of seminal principles so to keep a God's role in generation an active one. That role, moreover, is (to some extent, at least) beyond our capacity to understand.

4.2 Robert Boyle on Mineral Formation

4.2.1 *Boyle's Petrifick Spirit*

In a striking contrast to the generation of life, Boyle does not fear that the Godless production of minerals or metals will lend itself towards Atheism. Thus unlike earlier figures such as Anselm de Boodt, Boyle describes God's role in the generation of minerals a minimal one. Understanding Boyle's views on mineral formation requires unpacking of the agent he says is responsible for their production, namely a petrifick spirit. We first saw Boyle's petrifick spirit in his earlier notes on the generation of minerals.

366 Ibid. p. 628

In "Generation of Minerals", Boyle explains that although it results in coagulation, it does so "less like that of the Cicatricula of an Egg" and more like the coagulation of milk curds with rennet. Recall that in the case of the egg, the coagulation that takes place is from homogenous material. Milk contrarily consists of heterogeneous particles for Boyle, following his adaptation of Sennert.[367] Boyle goes on to describe how rennet is capable of coagulating milk into curds that endure a beating by mortar and pestle into "subtile powder."[368] He then goes on to describe just how the petrifick or "coagulating" spirit works, stating that

> ... besides the ways of working it may have unknown to mee, [our Petrific Spirit] may operate sometimes by Changing the Motion & Texture of the Fluid or Soft Body it pervades, and sometimes by excluding or destroying some subtill parts which before kept the Matter Soft or Fluid, and sometimes perhaps by both these ways together. [369]

Here we are presented with fascinating insight into Boyle's thoughts on the process of mineral formation, as it would make little sense for coagulation to occur via the excluding or destroying of the more subtle or corpuscular parts of completely homogenous material.

Thus, whereas a seminal principle organizes homogenous matter, I would argue that Boyle conceives of a petrifick spirit less as an organizing principle and more as an ingredient for coagulation of heterogeneous matter. Boyle would maintain this conception in later works, but his 1672 *Origin and Virtues of Gems*, we shall see, more emphatically emphasizes petrifiying virtue over a formative one.

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367 See Newman, *Atoms and Alchemy*: p. 165 ff.

368 Boyle et al, *The Works of Robert Boyle*: v. 13, p. 373, "The Generation of Minerals"

369 Ibid.

4.2.2 *Origin and Virtues of Gems*

Origin and Virtues of Gems was undoubtedly Boyle's most comprehensive publication to deal with the generation of minerals. This feature is not without irony as, unlike before, Boyle seems reticent even to use the term 'generation.' Instead, he systematically replaces 'generation' with 'origin'. He does so even to the point that he references his own unpublished work as the "my whole Discourse on the *Origine of Minerals*…"

Of course, Boyle's previous work on minerals never made it to the publisher. But his reticence is likely not without cause. Generation essentially involves production, and any production requires some kind of organizing principle that is over and above mere coagulation. His reservation, then, may have real implications for his understanding of the petrifick spirit, which acts as that force. This shift is consistent with Boyle's generally changing world view over time, which becomes increasingly more restrictive with what he considered mechanical.

He nonetheless continues to defend his thesis that minerals—and specifically gems—are formed originally by hardening a liquid. He additionally adds the second thesis that "many of the real Virtues of such Stones [i.e. gems] may be probably deriv'd from the *mixture* of *Metalline* and other Mineral substances..."[370] In arguing thus, he presents six arguments. A close examination of his arguments suggests that the heterogeneous matter, i.e. material accompanied by a gangue-like impurity, is a key factor in the way in which minerals are formed:

1. The transparency of gems suggest that they were once fluid.[371]

[370] Boyle, et al., The Works of Robert Boyle: v. 7 p. 12, *Origin and Virtues of Gems*

[371] Boyle et al, *The Works of Robert Boyle*: v. 7: p. 13, *Origin and Virtues of Gems*

2. Other minerals such as nitre and allom, the corpuscles of which, "being suffer'd to coagulate in liquors they swam in before, will convene into Christals of curious and determinate shapes…" It would be difficult to conceive of these shapes by some other means than being contiguous with a fluid.[372]

3. The internal texture of many gems imitates the coagulation of substances that Boyle observed to have once been fluid, and those kinds of coalitions which, "may constitute solid and considerably hard bodeys…"[373]

4. There are several examples, both from experiment and Boyle's own experience, where the colors of various gems seem "imparted to them, either by some colour'd Mineral Juice, or some tinging Mineral exhalation…" He spends several pages citing circumstantial evidence and experimental examples. In most of his examples, he describes the fluid of gems being colored by a mineral or mettaline tincture, which imparts a color to the gem. At one point, he even goes so far as to say that gems such as rubies and sapphires have been known to be colorless, suggesting that their color is derived from the mineral tincture itself. [374]

5. Solid gems "may include Heterogeneous matter".[375] As an example, he describes from experience a curious stone, presumably a geode, with a hard outer substance and "a Cavity wherein were coagulated very minute but polish'd and Chrystalline Stones, which seem'd to have their points inwards..." He gives other such examples of heterogeneous matter, such as hardened amber that includes a fly and Amethysts that seemed to include "hairs of a Brownish Colour." [376] Boyle later describes precisely how he conceives of petrification in that particular example, stating that

> … some (at least) of the Real Virtues of divers Gems may be derived from this [Petrifick Spirit], That whilst they were in a fluid form, (or at least not yet Hard'ned,) the Petresecent substance was mingled with some mineral solution or tincture, or with some other impregnated

[372] Ibid.
[373] Ibid. p.16
[374] Ibid. p. 22
[375] Ibid. p. 25
[376] Ibid. pp. 25-26

> liquor, and that these were afterwards Concoagulated, or united and hardened, into one Gem... [377]

6. Finally, his sixth argument he views as a subset of his third, namely that even transparent gems "have metalline or other extraneous Mineral Bodies mingled with them, *per minima*," which explains the uniformity of their color. From this feature he concludes that

> [I]t will be very agreeable to reason to suppose, that such a mixture was made, when the mingled Bodies were in a fluid form; since, besides that one may well ask, how else Metalline Corpuscles came to be convey'd into such compact and hard Bodies as Gems…[378]

The last three arguments (4, 5, and 6) each describe a process in which there is some external mineral body or tincture whose qualities are infused into the fluid. Whereas we are wont to think of these mineral inclusions as impurities, they play an important role in the production of gems and in giving them their shape, color, and other qualities. Argument 2 presents as similar kind of process as well, albeit in the converse. "Suffered to coagulate" in this context suggests that the corpuscles of mineral inclusions such as nitre are being acted upon, in this case by their interaction with the fluids or liquors in which they find themselves. Boyle goes on to explain that they will not convene into crystals with a determinate shape unless surrounded by fluid, which coagulations, as if in a mold.[379]

Thus, the collection of these arguments suggest that heterogeneous matter is necessary for the process of petrification and formation of gems and stones. The formation of gems and minerals, then, stands in stark contrast to generation, which for Boyle requires the organization of homogenous matter rather than the mere reaction of heterogeneous

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377 Ibid. p. 45
378 Ibid. p. 27
379 Ibid. p. 13

material. Heterogeneity as a requisite for mineral generation has significant implications for Boyle scholarship. For example, Peter Anstey claims that Boyle

> appears to restrict the operations of seeds for explaining the generation of growth of plants and animals and to account for the growth of minerals by something analogous to ferments. The liquid origin of minerals harmonises well with his account of creation… with the original homogenous matter of Genesis 1 being a water-like substance. But interestingly, in his discussion of mineralogy, Boyle nowhere uses this doctrine of creation as an argument for the liquid origin of minerals.[380]

That Boyle does so, Anstey claims is an, "interesting case of Boyle passing up cosmogonic considerations which could have bolstered his account of petrification and the formation of minerals." Anstey takes this as indicative of tension in Boyle, namely that minerals aren't really complicated enough to warrant a seminal principle. If the corpuscular interaction of heterogeneous are essential to the formation of minerals, however, then Boyle would have no reason to appeal either to seminal principles (which act upon homogenous matter) or to the original homogenous fluid of Genesis. The organizing of homogenous fluid is, in fact, a very different process than that described in *Origin and Virtues of Gems*.

Another telling feature of the Petrifick Spirit is that Boyle frequently describes it as supervening above the matter that is petrified.[381] For example, Boyle explains that he once

> found several empty Cavities of differing sizes and figures in the solid substance of the Stone, ... which seems to argue, that this compact and ponderous Body was made of a stony nature by the supervening of some Petrescent Liquor or Spirit, upon porous Earth or some other consistent substance. [382]

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380 Ibid. p. 623

381 See Boyle, et al. *The Works of Robert Boyle*: pp. 50, 55, 56, 68, 71.

382 Ibid. p. 5

His description of the petrification process, whereby the spirit pervades the porous substance that it coagulates and hardens bears similarities to Hooke's own theory of petrification in the *Micrographia*, with the exception that Hooke describes the porous substance as pervaded and filled with gravel, mud, or clay. Boyle conceives of this process with subtle fluids, the reaction of which causes petrification.

4.2.3 *Growth of Metals*

Shortly after the *Origin and Virtues of Gems,* Boyle published yet another text on the development of minerals, the *Growth of Metals,* in 1674. Here, when discussing possible causes of how the growth of gold and various metals occurs, Boyle writes (boldface mine)

> And even as to the Instances [of the growth of Gold and other metalls] that I have not mention'd, 'till several Observations have been made, to determin whether it be partly the contact or the operation of the Air, or some internal disposition, **analogous** to a Metalline Seed or Ferment, that causes this Metalline Increment, I dare not be positive…[383]

This kind of vacillating is typical of Boyle. Yet, note that when considering even the mere possibility of a metalline ferment as the cause of metallic growth, Boyle describes it as nothing more than analogical. Indeed, he makes a similar such analogy in his earlier "Generation of Minerals". Boyle's Petrifick Spirit is analogous to a ferment in the sense that it affects the corpuscles of the mineral liquors, causing them to coagulate and their texture to harden. But despite his misleading language, his Petrifick Spirit is an attempt to explain the change in the texture of minerals in terms of mechanical changes to their corpuscles, not animated ferments with formative powers. Boyle's writings on the process of petrification by means of coagulation and heterogeneity, had considerable influence upon his

[383] Boyle et al., *The Works of Robert Boyle:* v. 8, p.152, *The Growth of Metals*

contemporaries. In order to understand that influence, it might be helpful to begin with the circumstances surrounding the publication of *Origin and Virtues of Gems.*

4.3 Fossil Controversies

4.3.1 *Boyle, Fossils, and Gems*

When the Royal Society published Boyle's largest and most recognized essay on mineral formation, it had been rushed to the press. *Origin and Virtues of Gems*, printed in 1672, was but a fragment of a larger treatise of Boyle's on the subject of petrification. This state of affairs had been prompted by Oldenberg, whose panic was due to the recent printing of Nicolaus Steno's own *De solido intra solidum naturaliter contento dissertationis prodromus* (*Prodromus to a Dissertation Concerning Solids Naturally Contained within Solids*) in 1671.

Steno, born as Niels Stensen, was the Danish son of a Lutheran goldsmith who eventually became a famed anatomist and natural philosopher. A smith of many trades himself, Steno would later undergo a sort of religious crisis and convert from his devout Lutheran upbringing to Catholicism in 1667. He traveled extensively around Europe, residing in Copenhagen; Paris, where was a contributing member to the Thévenot *academie*; Leiden; Florence, where he would experiment with Redi on generation before eventually becoming a Catholic priest there; Denmark; Rome; and later in his life, the northern parts of Germany, Denmark, and Norway.[384]

[384] Cobb, *Generation*: p. 56 ff.; Koertge, *Complete dictionary of scientific biography*: p. 30

His remarkable skill at dissection secured his reputation among members of the Royal Society, evident from Oldenburg's correspondence in 1665, where he describes Steno as "a Dane living at Florence who is second to none as an anatomist…" [385]

A summon to Denmark, however, halted Steno's anatomical research in 1668, during which time he composed the extremely influential *Prodromus. Prodomus* communicates the idea that fossils are developed by the hardening of fluids derived from organic material. In order to make Steno's *Prodromus* available to a more general English audience, Oldenburg translated the treatise into English before *Origin and Virtues of Gems* had been printed. He did so, however, not without an informative preface to the reader. In his interpreter's preface, Oldenburg mentions "the Excellent Robert Boyle" within the first pages, explaining that Boyle, before having known of the *Prodromus*, "did upon occasion candidly declare" to him the following:

> First, That ... Transparent Gems or Precious Stones [were] once Liquid substances, and many of them, whilest they were either fluid, or at least soft, to have been imbued with Mineral Tinctures, that con-coagulated with them; whence he conceiveth, that divers of the real qualities and vertues of Gems... [386]

Further, Oldenburg explains, Boyle holds that these gems were Earth that had been, "impregnated with the more copious proportion of fine Metalline or other Mineral Juyces or Particles," which were then "reduced into the forme of Stones by the supervenience" of the Petrifick Spirit.[387] And indeed, like earthy substances, he claims that those of animals and plants could be, once lodged in the earth, "cased up by the supervenient Petrifick Agents that

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385 Oldenburg et al, *The Correspondence of Henry Oldenburg:* pp. 454-457

386 Steno, *The Prodromus to a Dissertation*: preface

387 Ibid.

pervaded" them. Here again, we see the Petrifick spirit described as "supervienient" resulting in coagulation.

Oldenburg goes on to give honorable mention to Hooke, who Oldenburg says "had intimated a good while ago" his having "ready some Discourses upon this very Argument [that minerals develop from fluids]", but had never finished them.[388] Though, one has to wonder if acquaintances of Hooke's, aware of his notoriously cantankerous personality, would have been apt to take such faint praise very seriously.

This same note to the reader was re-printed nearly verbatim in both the Latin and English editions of Boyle's *Origin and Virtues of Gems*, presented under the heading "The Publisher to the Reader". It begins by stating

> The Philosophy and Origin of Gems as well as theire Usefulness and Virtues will, I am perswaded be found, upon the attentive perusal of this *Essay* it self, so rationally and warily deliver'd therein, that there will need nothing to be said in the praise of the Composure thereof. I dare venture, notwithstanding the Noble Author's modesty, to present it to the most Critical taste, without hanging out a Bush to it.
>
> All I have to say in the publishing thereof, shall be the same, that was alledged by the English Interpreter of the Learned *Steno*'s Prodromus to an intended *Dissertation* of his, concerning Solids naturally contained within Solids, printed the last year by *Moses Pitt* in *Little Britain*; where in the *English* Preface occurr passages to this effect, *viz.* [389]

The author of this preface (presumably Oldenburg) then continues to re-print the same summary of Boyle's views on the petrification of minerals from fluid via the Petrifick Spirit, to which "many Fossils may owe their Origin, since he thinks, there may be

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388 Ibid.

389 Cf. Boyle, *Exercitatio*: A2; and Boyle et al, *The Works of Robert Boyle* v.7: p. 5

both *Metallescent* and *Minerallescent* Juices in the bowels of the Earth, and that sometimes they may there exist and operate under the same Spirits and Steams."[390] Oldenburg's English translation of Steno's dissertation was then included in a rare 1673 edition of Boyle's *Essay on Efluviams, subtilty, efficacy, and determiniate nature of efluviums*, so that Steno's account of fossils converged even more closely with Boyle's works on petrifaction and gems.

4.3.2 *Games of Nature and the Problem with Fossils*

Gems (such as crystals or diamonds) and fossils might strike us as odd bed fellows, but for Boyle and his contemporaries, the study of mineral generation was virtually inseparable from the topic of fossil formation. 'Fossil' was, in fact, adopted into English during the late sixteenth century from the Latin 'fossilia', which itself is derived from the verb 'fodere', meaning "to dig".[391] Thus fossils, as understood in the seventeenth century, included *any* object that had been retrieved from below the Earth's surface, from gemstones to minerals, metals to what we would now call fossils, and virtually any stony object dug from the Earth. [392]

The most problematic of these stony objects to explain were fossilized shells, which (unlike other fossils) had no living analogues. Even more strange was that the petrification of the area surrounding them, leaving behind a mere ghostly imprint of their existence. [393] Having no analogue among the living, they were frequently called *lapides sui generis*, or stones in a class unto themselves.

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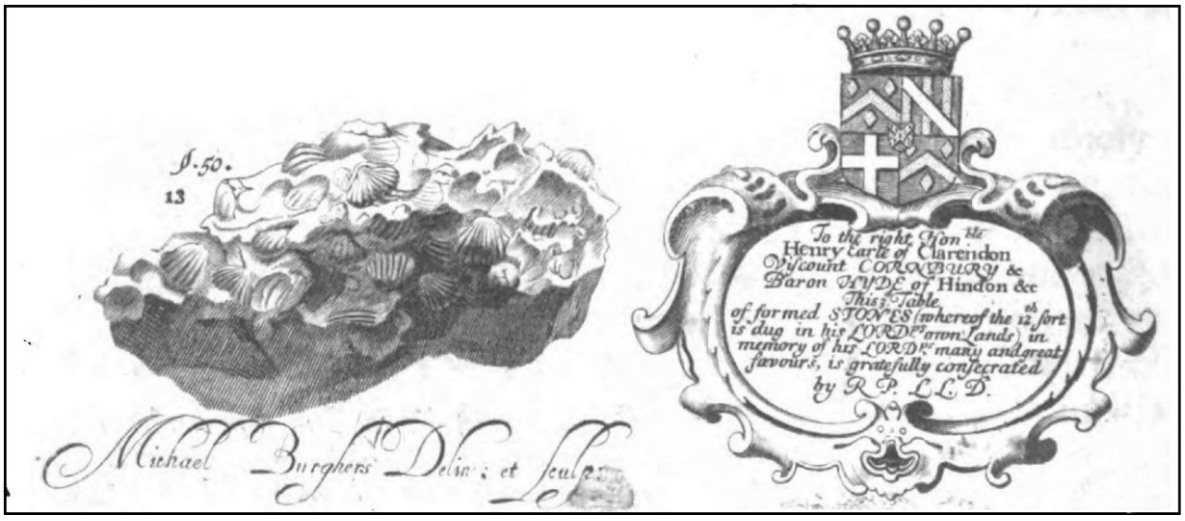
390 Ibid. p. 6

391 "fossil, n. and adj.". OED Online. September 2016. Oxford University Press. http://www.oed.com.proxyiub.uits.iu.edu

392 See Rossi, *The Dark Abyss of Time:* p. 6 ff.

393 Rapport, *When Geologists Were Historians*: p. 119



An English acquaintance of Boyle's, Robert Plot,[394] articulates the trouble with such stony shell-like formations in *Natural History of Oxfordshire*, first published 1677. He begins by asking whether these sorts of stony formations are

> *Lapides sui generis*, naturally produced by some extraordinary plastic virtue, latent in the Earth or Quarries where they are found? Or whether they owe their Form and Figuration to the Shells of the Fishes they represent, brought to the places where they are now found by a Deluge, Earth Quake, or some other means...? [395]

He ultimately concludes that they must be *sui generis*, as the argument that they were in fact shell fish at some point was presented with "more insuperable difficulties." [396]

Plot's position on the matter was basically one of three on the subject of fossil formation as understood near the end of the seventeenth century.[397] He shared this view with Martin Lister, who argued the following year in *Historiae animalium Angliae tres tractatus* that fossils are not, in fact, organic, but are *sui generis* rocks that are made by a

394 Plott actually wrote to Boyle with familiarity in 1674 about a curious salt spring with limestone. See Boyle, et al. *Correspondence of Robert Boyle*: v. 4, pp. 387-389

395 Plott, *Natural History of Oxfordshire*, as quoted by Rossi, *The Dark Abyss of Time*: p. 3

396 Ibid.

397 Cf. Rappaport, *When Geologists Were Historians*: p. 106 ff.

plastic virtue, or *vis plastica*, to bear an uncanny resemblance to the shells of living organisms. This sort of occurrence, they argue, is a *lusus naturae*, or sport of nature. The second view, conveyed primarily by Edward Lhwyd, states that "seeds" are lodged in the rocks or soil and had grown into mock shells. And finally, there was the view that fossil shells and similarly petrified items were unmistakably the remains of living and animals shellfish.

There is good reason to believe that Boyle not only held an affinity with the last view, but that he directly influenced two of its three main proponents: Nicolaus Steno and Robert Hooke.[398] One of the "insuperable difficulties" cited by Robert Plot for the organic theory of fossils was explaining just how the shell or stone had become stony or petrified in the first place. In describing the corpuscular process by which the Petrifick spirit produces minerals from fluid, Boyle provides an answer to this problem. In doing so, he plays a pivotal role in the seemingly exhausted topic of fossil formation as was understood in the decades surrounding 1700–a role that has yet to be fully explored.

4.3.3 *Boyle, Steno, Borch*

Boyle and Steno, whose work so closely echoed Boyle's own that both bear Oldenburg's introduction, present quite the conundrum for the historian. Put simply, if Boyle's treatise was published *after* Steno's own work—the impetus, even, for Oldenburg pushing Boyle's work to the press—then just how was Steno even aware of Boyle's own views of petrification in the first place? Unravelling one of the more perplexing episodes of

[398] The third contemporary of Boyle's to support this view was natural philosopher and polymath, Gottfried Leibniz. For a comprehensive discussion on Leibniz's account of fossil formation, see Rappaport, *When Geologists Were Historians*: 114 ff.; Rossi, *The Dark Abyss of Time*: Ch. 9; and Smith, *Divine Machines: Leibniz and the Sciences of Life*: 218- 231.

the seventeenth century, Toshiro Yamada has convincingly demonstrated that Steno likely learned of Boyle's ideas through his own mentor, Ole Borch. Ole Borch, who later became professor of philology, chymistry, and botany at the University of Copenhagen, met the young Steno as a student while at Our Lady's School of the City. Borch later travelled throughout Europe from 1660-1666 (where he arrived in several of the same cities as Steno) before his appointment as Dean at the University of Copenhagen.[399]

During his travels, Borch visited with Robert Boyle (among other English scholars) during his month-long stay in London. Yamada cites journal entries of Borch's, which provide a detailed description of their conversations, "almost all of which concern chemical operations" of mutual interest, such as salt of tartar as a solvent for flint, the Alkahest, mercury, and minerals like quicklime and rock crystal.[400] Borch later broaches on several of these topics in a letter to Boyle, dated March 1664, in which he described several of the experiments and discoveries taking place in Paris.[401] (Boyle almost certainly found meetings at the house of Abbé Bourdelot that focused on the rejection of ordinary Mercury as the "true universal alkahest of the ancients" to be especially of interest.) [402] Steno arrived in Paris and met with Borch later that same year in November, at which point "it would have been natural enough for them to discuss such topics related to Boyle." [403] Thus, we can see how Boyle's theories on mineral formation from fluids and petrification were transmitted to Steno before the latter's publication of the *Prodromus.*

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399 Yamada, "Hooke-Steno Relations Reconsidered: Reassessing the roles of Ole Borch and Robert Boyle": p. 112, in *The Revolution in Geology from the Renaissance to the Enlightenment*

400 Ibid. pp. 116-117

401 Ibid. p. 117; Cf. Boyle, et al., *The Correspondence of Robert Boyle*: v. 2: pp. 254-266.

402 Boyle, et al., *The Correspondence of Robert Boyle*: v. 2: p. 265

403 Yamada, "Hooke-Steno Relations Reconsidered: Reassessing the roles of Ole Borch and Robert Boyle": p. 117, in *The Revolution in Geology from the Renaissance to the Enlightenment*

Yet Yamada underestimates the significance of this influence due to his mis-characterization of the agents in generation discussed by Boyle. Yamada discusses the notion of a plastic power in regard to Boyle's writings on minerals, understandably describing his earlier writings as "ambiguous" because of "various phrases, for instance, plastic principles, Gorgonic Spirit, formative power, or diverse seminal principles."[404] He ultimately describes Boyle's attitude about a plastic power in his treatise on the generation of minerals as indicative of his presenting a "transition" stage from an organic or living to a mechanic view of Earth..."[405]

Boyle's own contemporaries would be apt to find his language confusing, especially that found in his unpublished notes, "On the Generation of Minerals." But however befuddled his unpublished, juvenile notes may be on the topic, there is good reason to think that he would have communicated something more comprehensible to Oldenburg, Borch, and Hooke in person years later. If so, we can trace an even stronger line of influence. Boyle's agent responsible for both the petrification and production, i.e. the Petrifick Spirit, was akin to a plastic power only in the sense that that it is an organizing principle capable of solidifying new bodies. Thus 'spirit' in this sense means something more akin to a subtle fluid than an immaterial force. That Boyle conceived of mineral formation early-on as something that originates from fluids is apparent not only from several passages in early texts, but also from the fact that his treatise "On the Generation of Minerals" was originally intended to be part of his writings on the nature of fluids. His more mature writings, moreover, as discussed earlier, make it apparent that this process derives from the

404 Yamada, *Hooke-Steno relations reconsidered: Reassessing the roles of Ole Borch and Robert Boyle*: p. 111

405 Ibid. p. 116

supervenient reaction of heterogeneous fluids. Taken in the context, several passages from the *Prodromus* bear striking resemblance to Boyle's own thoughts about the process of formation and petrification.

4.3.4 *Boyle, Hooke, and Petrification*

No episode involving Robert Hooke would be complete without a priority dispute, and Hooke's theory of fossils and petrification is no exception. In particular, Hooke accused Oldenburg of having communicated his ideas on fossils to Steno, thus allowing the Dane to have usurped his ideas. This claim, however, appears to be unsubstantiated. [406] Yamada's analysis of Boyle and Steno elucidates how Steno may have become unknowingly familiar with ideas on fossils shared by Hooke. The close proximity with which Boyle and Hooke worked together easily explains their influence upon each other, but it also makes it difficult to establish priority or to determine exactly who influenced whom and where. To some extent, tracing their interactions with each other on the topic may be impossible to do with certainty. Nevertheless, the most obvious place to start is Hooke's own *Micrographia* (1667), where he describes his microscopical observations of stony objects in Observation XVII, "Of Petrify'd Wood, and other Petrify'd Objects."[407]

In this section of *Micrographia*, Hooke explicitly denies the role of any plastic power latent in the Earth in the production of stony objects such as petrified wood, fossil shells or even crystals and diamonds.[408] In the case of fossilized shells, Hooke may well be

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406 Chapman, *England's Leonardo: Robert Hooke and the Seventeenth-Century Revolution*: p. 149; Hall, *Henry Oldenburg: Reshaping the Royal Society*: Ch. 9; Yamada, "Hooke-Steno Relations Reconsidered: Reassessing the roles of Ole Borch and Robert Boyle": p. 109, in *The Revolution in Geology from the Renaissance to the Enlightenment*

407 Hooke, *Micrographia*: pp. 107-112

408 Ibid. pp. 110-112

justified in being sour over issues to do with priority. *Micrographia* clearly communicates the idea that these stony shells are not generated by a plastic virtue but by, "the Shells of certain Shel-fishes, which, either by some Deluge, Inundation, Earthquake, or some such other means..." were filled with mud, clay or petrifying water. [409] This petrifying water is not at all like the petrifick spirit described by Boyle, but water that is "impregnated" with tiny, silty particles of earth and stone. [410] Most emphatically stressed by Hooke in his discussion of petrification as a process is the porosity of these various stony objects, as viewed with the microscope, which he thinks have been filled by some means with mud or clay, causing them to congeal over time.

Hooke's discussion of crystals in *Micrographia*, however, bears stronger resemblance to Boyle's own later formulation of his Petrifick Spirit. These observations are described in detail in Obsv. 13, *Of the Small Diamants, or Sparks in Flint.* Describing the regularity of crystals, Hooke writes that, "...as that form proceeded from a propiety of fluid bodies ... I could make probable, that all these regular Figures" have only three or four variations of "*Globular* particles" so that

> supposing such and such plain and obvious causes concurring the *coagulating particles* must necessarily compose a body of such a determinate regular Figure, and no other; and this with as much necessity and obviousness as a fluid body encompast with a *Heterogeneous* fluid must be protruded into a *Spherule* or *Globe*.[411]

We see here Hooke's description of crystal formation in terms of heterogeneous fluids. One possibility is that Boyle applied this idea, (one also discussed in their mutual earlier

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409 Ibid. p. 111

410 Ibid. p. 109

411 Ibid. p. 85; Cf. Yamada, "Hooke-Steno Relations Reconsidered: Reassessing the roles of Ole Borch and Robert Boyle": p. 120, in *The Revolution in Geology from the Renaissance to the Enlightenment*

experiments), to his idea of a corpuscular Petrifick spirit so to find a way to mechanize the agent.

4.3.5 *Fossils and Final Causes*

The controversy surrounding fossils eventually made its way into Boyle's discussion of final causes, where he cites the "most curiously shap'd kind of Stones," in a refutation of Epicureanism in which he argues that they are not the result of chance or without purpose. To support this claim Boyle argues that "some Learned Men" have made it apparent that these curious stones "were once really the Animals whose shapes they bear, or those Parts of Animals which they resemble; which Animal substances were afterwards turned into Stones, by the supervening of some Petrescent Matter, or Petrifying Cause."[412] His mentioning of supervenience of petrescent matter strongly suggest that the "Petrifying Cause" that Boyle has in mind is that of his Petrifick Spirit.

Yet he admits the possibility that they might be mineral in origin since he "will not be Dogmatical in this Point." In which case, Boyle claims that it is not implausible that a seminal principle might be responsible.[413] This argumentative strategy of Boyle's—that is, of assuming a premise of his opponent's view in order to make a rebuttal—is one that he commonly invokes. Ultimately, though, Boyle makes it clear that seminal principles are not responsible for mineral or inanimate objects on Earth, concluding that, "the *Inanimate* Bodies here below, that proceed not from Seminal Principles, have but a more parable Texture... as Earths, Liquors, Flints, [and] Pebbles..." [414] Nonetheless, his

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412 Boyle, et al. *The Works of Robert Boyle:* v. 11 p. 105, *A Disquisition about the Final Causes of Natural Things*

413 Ibid. p. 106

414 Ibid. p. 106

invocation of final causes and purpose provided by God for His creations brings into focus another important element influencing Boyle's natural theology and theory of generation, namely his Christianity.

4.4 Genesis and the Christian Virtuoso

4.4.1 *Robert Boyle on Creation*

The sincerity and intensity of Robert Boyle's Anglican faith has been recognized among both his contemporaries and our own. As we've seen, the problem of generation has a unique place in Boyle's natural philosophy because it is intricately connected to God's creation of the world via the biblical story of Genesis. Generation is consequently tied very closely to Boyle's theological commitments. These commitments play out on two levels: The first is ontological, and the second epistemological. On an ontological level, Boyle remains committed to seminal agents of generation, as he equates the alternative with atheism. Epistemologically, his theological voluntarism holds him to the view that our understanding of how God works those agents is ultimately limited.

Vis-a-vis his ontology, we saw in Chapter 2 that from his earliest writings, Boyle finds it too incredible to believe that particles of matter could organize themselves to create living beings without seminal principles ordered by God.[415] He would maintain that view throughout his life. In *Excellency of Mechanical Hypothesis* (1674) Boyle states that God not only gave motion to matter but also guided the various motions of its parts and established rules, or Laws of Nature. The world designed by God, moreover, is described as "furnished with the Seminal Principles and structure or Models of living Creatures." [416]

[415] Cf. Anstey, *Boyle on Seminal Principles*: pp. 605-608.

[416] Boyle et al, *The Works of Robert Boyle:* v. 3, p 104, *Excellency of Mechanical Hypothesis*

His later works echo these statements, as when he wrote in his *Inquiry into Nature* of God's creating the world from undifferentiated matter and his dividing it into portions of matter. Among the initial parts of matter Boyle includes those which, "were so curiously contriv'd, as to be fit to become the Seeds, or Seminal Principles, of Plants and Animals."[417] Thus from his writings we can surmise that throughout his life Boyle maintained a deep commitment to the existence of seminal principles so to avoid the atheism that he associated with Epicurean random concourse of atoms and to keep God's role in generation an active one following Creation.

What is interesting to note is that Boyle maintains this view in spite of the plethora of new discoveries concerning generation, which include anatomical revelations, eye-opening experiments, the realization that plants sexually reproduce, and the increasing popularity of ovism.[418] Peter Anstey touches on some of Boyle's underlying incentives when he writes that

> ... seminal faculties are appealed to [by Boyle] as higher-level explanations of natural phenomena. That is, Boyle first introduces seeds in 'A requisite digression' as higher level 'theoretical entities' which in turn require an explanation for their behavior. Boyle's claim is that they can only be satisfactorily explained by an appeal to God. This is an important step in Boyle's argument because we sometimes find him adducing the existence of phenomena that attest the presence of seminal principles as an argument for the existence of an intelligent force behind the construction of the universe. Thus seminal principles are an important premise in one of Boyle's arguments for design. [419]

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417 Boyle et al, *The Works of Robert Boyle:* v. 10, pp. 468-469

418 Boyle does list "The Historical Analysis of Eggs" as a possible research topic in his later medical writings. See Anstey, *Boyle on Seminal Principles*: p. 618 n. 63

419 Anstey, *Boyle on Seminal Principles*: pp. 605-606.

The centrality of seminal principles to Boyle's own argument from design helps to provide the context for his later *A Disquisition about the Final Causes of Natural Things*, where he laments that because of Cartesians and Epicureans people have "labour'd to Depreciate the Wisdom of God, and some of them presum'd to Censure the Contrivances of these living *Automata*, that (in their Protoplasts) were Originally His." [420] Seeds and their corresponding plastic powers are a constant on Earth and remain a necessary condition for the generation of any living being. This condition is closely tied to Boyle's appeal to final causes, which in the case of Creation are Universal ends, and display "the Creators immense Power and admirable Wisdom..."[421]

4.4.2 *Reason and Religion*

Robert Boyle produced a number of treatises in the late 1670s and 1680s relating to theology and the limits of reason. These works appear to be inspired by contemporary debates between Anglican churchmen about the essential reasonableness of Christianity, which non-conformists had come to question. Boyle took the position of Voluntarism, or the view that some of God's purposes in creation are beyond our capacity to understand.[422] Jan Wojick points to the relationship between Boyle's theological voluntarism and ideas of natural philosophy, citing a passage where Boyle states that

> The world itself was first made before the contemplator of it, man: whence we may learn, that the author of nature consulted not, in the production of things, with human capacities; but first made things in such a manner as he was pleased to think fit, and afterwards left human

[420] Boyle, et al. *The Works of Robert Boyle*: v. 11, p.145, *A Disquisition about the Final Causes of Natural Things*; Cf. Anstey, *Boyle on Seminal Principles*: 607

[421] Boyle, et al. The Works of Robert Boyle: v. 11, p.87, *A Disquisition about the Final Causes of Natural Things*

[422] Non-conformist views about the reasonableness of Christianity came about, in part, as a reaction to Calvinist ideas of Predestination. See Hunter, *Boyle: Between God and Science*, pp. 200 ff.

> understandings to speculate as well as they could upon those corporeal, as well as other things.[423]

Indeed, as she points out, previous scholars have "failed to recognize the extreme limits Boyle placed upon human reason." More recently, Sorana Corneanu has further analyzed *Reason and Religion* among Boyle's other theological treatises to show that Boyle's work is best understood within the framework of what Corneanu calls *cultura animi* or the cultivation of the soul, influential in seventeenth-century England. Reminiscent of Protestant pastoral care, *cultura animi* focuses on the alleviation of spiritual affliction by administering "spiritual physick".[424]

On this view, Boyle's rules of inquiry serve as guidelines for the Christian philosopher to develop "a practice of the regulation of assent invested with the role of a mind ordered discipline." That discipline is premised not only on the limits of intellect, but also on improving upon those limits by means of cultivating a practice of epistemic modesty and "flexible inquiry" on the part of the experimenter.[425] This sort of practice serves as a "Socratic Medicine" and plea for nescience, which can help to contextualize Boyle's writings on generation.

But first, it might be helpful to look at what sorts of things Boyle believes are beyond our capacity to understand. In *Discourse on Things Above Reason*, Boyle distinguishes between three different ways in which truths can be unknowable (though he admits that they

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423 Boyle, *Appendix to Christian Virtuoso*, as quoted by Wojick, *Robert Boyle and the Limits of Reason*: p. 196.

424 Corneanu, *Regimens of the Mind:* pp. 55 ff.

425 Corneanu, *Regimens of the Mind:* pp. 117, 127 ff.

are not exclusive.) These are Incomprehensible, Inexplicable, and Unsociable.[426] Incomprehensible truths are those, such as infinite space, eternity, and the boundless perfection of God, that are completely beyond our comprehension or capacity to imagine due to our finite nature. That is, we have no way of even grasping even *what* they are. [427] Inexplicable truths are ones, often discussed in geometry and natural philosophy, in which we know *that* they are true but "cannot conceive *how* they could be such." (Italics mine).[428] Genesis, Boyle says, is an example of the second of these unknowable truths. While we know that God created the heavens and Earth *ex nihilo*, we really aren't capable of knowing how one makes substance from nothing.[429] For further elucidation, consider another inexplicable truth to which Boyle compares Genesis, namely the Mind/Body problem:

> As, though divers learned men, especially Cartesians, and that upon a Philosophical account, assert, that God created the world;–yet how a substance could be made out of nothing (as they, and the generality of Christians confessedly hold) I fear we cannot conceive. And though all Philosophers, very few excepted, believe God to be the *Maker* of the World (out of pre-existent matter) yet how he could make it but by locally moving the parts of the Matter it was to consist of, and how an incorporeal substance can move a body, which it may pass through without resistance, is that which I fear will be found hardly explicable: For if it be said, that the Soul, being an immaterial substance, can never the less move the Limbs of the humane Body rightly dispos'd, I shall answer that it does not appear that the rational Soul doth give any motion to the parts of the Body, but only *guide* or *regulate* that which she finds in them already.[430]

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426 Boyle, et al. *The Works of Robert Boyle*: v. 9, p. 367, *Discourse on Things Above Reason.* Cf. Corneanu, *Regimens of the Mind*: p. 115 and Holden, *Boyle on Things Above Reason.*

427 Boyle, et al. *The Works of Robert Boyle*: v. 9, p. 367, *Discourse on Things Above Reason.*

428 Ibid. p. 368, 388. See also Boyle et al, *The Works of Robert Boyle*: v. 8, p. 264, *Reconcileableness of Reason and Religion;* and Holden, *Boyle on Things Above Reason*: p. 294

429 Boyle, et al. *The Works of Robert Boyle*: v. 9, p. 378, *Discourse on Things Above Reason.* Rhoda Rappaport touches on a similar point. Cf. Rappaport, *When Geologists Were Historians:* p. 47

430 Boyle, et al. *The Works of Robert Boyle*: v. 9, p. 378, *Discourse on Things Above Reason.*

In the above passage, Boyle appears to argue by analogy: Just as it appears to us that the soul could only guide or regulate previously existent motion of the body, rather than to produce, so too does it only appear to us that God could only make the Earth and its creatures from pre-existent matter. Ultimately Boyle would tell us that the perceptions that we have about the things above reason are neither clear nor proper. We can have no clear and distinct ideas of inexplicable truths, but "we can only know can only *perceive that they are above Reason*."[431] And finally, unsociable truths appear to us as contradictory due to our limited understanding. Divine foreknowledge, for example, seems *prima facie* irreconcilable with our free will.[432] Yet, the apparent contradiction lay merely in our incapacity to understand. Were we to have an unlimited intellect like God, it would no longer be apparent to us that these truths result in contradiction.

I would argue that the nature of plastic powers, the means by which God allows for living beings to replicate, belong to the first of these unknowable truths. We aren't really capable of comprehending what they are, and to some extent we likewise cannot fully conceive of how they work. But whatever their nature might be, we can limit our discussion of them to their effects upon matter as a physical agent. By adapting this kind of mitigated nescience and epistemic humility, we can further investigate creations of God to the best of our intellectual capacity.

4.4.2 *On the Resurrection*

Boyle addresses a topic closely related to generation with a relatively short addendum to *Reconcileableness of Reason and Religion*, namely resurrection. Related to the

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431 Ibid. p. 380

432 Boyle, et al. *The Works of Robert Boyle*: v. 9, p. 368, *Discourse on Things Above Reason.*

epistemic problems discussed earlier, Boyle's In "About the Possibility of the Resurrection," seeks to demonstrate that belief in resurrection of the body does not equate to belief in that which is impossible. The short answer, of course, is provided in Greek via the Gospel of Luke on the title page: "With God, nothing shall prove impossible." [433] Boyle does, nonetheless, spend several pages elaborating on its intelligibility, and he presents the work as a counter-argument to those who would argue for the *impossibility* of the resurrection. [434] The issue of resurrection shares interesting parallels to both redintegration and palingenesis. All three processes involve the scattered parts of a destroyed body that are later brought back together, thus reconstituting the subject's original configuration. Boyle unsurprisingly compares resurrection to each. At one point he even refers to the resurrection of a disseminated corpse—namely, one consumed by a cannibal—as a kind of "Redintegration." [435] This scenario Boyle takes to be a weighty objection because flesh of the body would then belong to two separate persons. To that objection Boyle presents three replies. The first and second state roughly the same idea: The human body is in a perpetual flux that begins with a very small bit of matter as an embryo and becomes an adult who is significantly larger. In a sort of Ship of Theseus example, Boyle explains that although the matter of that body has undoubtedly changed, "there is no determinate Bulk or Size that is necessary to make a humane Body pass for the same." [436]

Yet Boyle makes no invocation to the human body at all in his third response. Rather, he appeals to experiment, whereby he recognizes that a body can be "exceedingly disguised

433 Boyle, et al. *The Works of Robert Boyle:* v.8, p. 296 n.
434 Cf. Boyle, et al. *The Works of Robert Boyle:* v.8, p. 304, *Possibility of the Resurrection*
435 Ibid.
436 Ibid. p. 305

with those Mixtures" and yet retain its own nature. And unsurprisingly, he cites the redintegration of camphor[437] after providing a number of anecdotal examples:

> And if one can well appropriate the Precipitants to the Bodies they are to recover, very slight and unpromising Agents may perform great matters in a short time; as you may guess by the Experiment I lately promised you: Which is this, that if you take a piece of *Camphire*, and let it lie awhile upon *Oyl of Vitriol*, shaking them now and then, it will be so corroded by the Oyl, as to totally to disappear therein without retaining so much as its smell, or an manifest quality, whereby one may suspect there is *Camphire* in that Mixture; and yet, that a Vegetable substance, thus swallowed up, and changed by one of the most fretting and destroying substances that is yet knowing the world, should not only retain the essential qualities of its Nature, but be restorable to its obvious and sensible ones, in a minute, and that by so unpromising a *medium* as common water, you will readily grant, if you pour the dissolved *Camphire* into a large proportion of that liquor, to whose upper parts it will immediately emerge white, brittle, strong-scented, and inflameable *Camphire*, as before. [438]

From this experiment, he ultimately concludes that bodies are but a parcel of universal matter that is in no way unique to any particular individual. At the moment of resurrection, then, God could easily "exchange its last Mechanical Affections for those which it had" while it lived. [439]

Vis-à-vis palingenesis, Boyle cites Kircher's vegetable phoenix experiment as he explains that he won't presently entertain "the supposition of a Plastic Power in some part of the matter of a deceased Body," nor debate the validity of chymical experiments supporting it,

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437 For more Boyle's use of this experiment and its debt to Daniel Sennert, see Newman, *Atoms and Alchemy*: pp. 211-215.

438 Boyle, et al. *The Works of Robert Boyle:* v.8, pp. 307-308, *Possibility of the Resurrection*

439 Ibid. p. 308

> … by which *Kircherus*, a Polonian Physitian in *Quercetanus* and others, are affirmed to have by a gentle heat been able to reproduce in well-closed Vials the perfect Idea's of Plants destroyed by the fire: I will not, I say, in this place enter upon a Disquisition of any of these things, both because I want time to go thorow with it; and because though the Resuscitation supposing the matter of Fact, may give no small countenance to our Cause; yet I do not either absolutely need it, or perhaps fully acquiesce in all the Circumstances and Inferences that seem to belong to it." [440]

His reason for evading the topic, Boyle explains, is that "this Plastic Power, residing in any portion of the destroyed Body itself… will not perhaps be necessary to have recourse; since an External and Omnipotent Agent can without it perform all that I need contend for…"[441] And herein lay an essential difference between resurrection of a body following the Rapture and those other processes taken by Boyle to belong to the investigation of natural philosophy: One must not assume that Resurrection occurs "according to the common course of nature". It consequently need not be "possible to be effected by merely Physical Agents and means." [442] Boyle nevertheless attempts to demonstrate the plausibility of such a process in terms of the mechanical affections of matter because the essential part of resurrection ultimately belongs to the soul. [443] The human body, to which the soul should be re-joined, is simply some organization of universal matter, which God could easily do in accordance with the laws of nature.[444] That process can, moreover, be explained in terms of mechanical

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[440] Boyle, et al. *The Works of Robert Boyle:* v.8, p. 302, *Possibility of the Resurrection*.
Kircher, himself, actually saw the Vegetable Phoenix experiment as an analogical demonstration of biblical Resurrection. See Kircher, *Mundus Subterraneus*, Bk. 12: p.437; Mayer-Deutsch, "Quasi-Optical Palingenesis": p. 107, in *Athanasius Kircher: The Last Man Who Knew Everything.* Perhaps more surprising is that Redi set out to disprove Kircher's experiments largely on theological grounds, as holy mysteries of faith—such as Resurrection—are incomprehensible to men. See Wilson, *The Invisible World*: p. 200

[441] Boyle, et al. *The Works of Robert Boyle:* v.8, p. 303, *Possibility of the Resurrection*.

[442] Ibid. p. 299

[443] Ibid. pp. 310 ff.

[444] Ibid. p. 312

affections. And just what are said mechanical affections? Nothing more than "Gravity and Levity, Incorruption, Transparency and Opacity, Figure, Color" and other such qualities. [445] As with the last chapter, we see that the mechanical affections, for Boyle, are not synonymous with the reductionistic, "primary" qualities of matter.

Ultimately, Boyle's theological beliefs simultaneously commit him to stipulating the existence of seminal principles and admitting our inability to understand exactly how they work. Those commitments and their resulting tension, however, are not coming out of his mechanical philosophy. This epistemic approach of Boyle presents a large divergence with Descartes, a point illustrated by Corneanu, who writes that

> Boyle's position [on knowledge] is in stark contrast with a Cartesian rooting of philosophy in a number of foundational, infallibly true metaphysical principles from which subordinate truths can be deduced. For Boyle, the key concept is not "foundation" but growth, and the standard of truth cannot be firmly and definitively established through intuition but is a horizon of the process of the growth of philosophy.[446]

Taken in this context, we can begin to understand how the Socratic nescience, or epistemic humility, Boyle assumes can help to provide a context in which to understand his writings on generation. Though we may not be fully capable of understanding the nature of plastic powers or their manner of operation, we can still bear witness to their effects upon matter.

4.5 Boyle's Mechanical Account

4.5.1 *Agents of Generation*

The physical and corpuscular result of mixture, the Petrifick Spirit described by Boyle does not present the same problem for a mechanical program as would a plastic or generative

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445 Ibid.

446 Corneanu, *Regimens of the Mind*: p. 129

power. But are the formative powers of seminal principles—plastic powers—introduced in just those cases where Boyle lacked a mechanical explanation, or is Boyle providing a kind of mechanical explanation despite his appeal to agents like plastic powers? Put another way, could Boyle's account of seminal principles and their corresponding plastic powers be rightly called a mechanical explanation? Herein lies the heart of Anstey's two-horned dilemma. Anstey is absolutely right to claim that Boyle's seminal or plastic principles commit him to nescience about the nature of the agents responsible for generation. Boyle's voluntarism arguably commits him to it. But, the question at hand is whether that nescience precludes Boyle from providing for them a distinctly mechanical explanation. I would argue that it does not, insofar as the explanatory power of those agents comes from the structural or textural changes which those agents cause upon passive matter. Seeds can operate mechanically—as Boyle understands the term—regardless of the nature of their plastic powers. But in order to evaluate the explanatory power of plastic powers, we must first consider what Boyle takes to be a mechanical explanation.

4.5.2 *Boyle and Mechanical Explanations*

Boyle deals explicitly with what he takes to be a mechanical explanation in his 1674 treatise, *On the Excellency of the Mechanical Philosophy*. Boyle recognizes that there are different sects of Mechanical philosophers. Of other Mechanical philosophers, he complains, "that they think [the Mechanical Philosophy] pretends to have Principles so Universal and so Mathematical, that no other Physical Hypothesis can comport with [the Mechanical Philosophy], or be tolerated by it."[447] That kind of presumption Boyle inevitably describes

[447] Boyle, et al. *The Works of Robert Boyle*: v.8, p. 109, *Excellency of the Mechanical Philosophy*

as a mistake because mechanical principles are universal. They should, consequently, be inclusive and applicable to many explanations, rather than be exclusive and rejecting of certain explanations.[448] This claim is not insignificant either because it entails that on Boyle's view a mechanical explanation must be able to account for those things, like plastic powers, that would be otherwise incompatible with the ontological commitments of the mechanical philosophy.

Boyle elaborates upon his main complaint against those who would appeal to agents such as Harvey's plastic faculty or Cudworth's plastic natures. The problem with these explanations, Boyle says, is not that they would postulate an agent's existence. They simply fail to explain *how* these agents work. Naturalists aren't meant to explain what the agent *is* but rather what changes an agent makes and "after what manner, those changes are effected." These changes, according to Boyle, can inevitably be explained in terms of matter and motion:

> So that the *Mechanical* Philosopher being satisfied, that one part of Matter can act upon another but by vertue of Local Motion, or the effects and consequences of Local Motion, he considers, that *as*, if the propos'd Agent be not Intelligible and Physical, it can never Physically *explain* the *Phænomena*; *so*, if it be Intelligible and Physical, 'twill be reducible to *Matter*, and some or other of those onely Catholick affections of Matter, already often mentioned.[449]

Boyle presents a nearly identical point a decade later in his *A Free Enquiry Into the Vulgarly Received Notion of Nature* (1684). When he addresses Aristotelian Scholastics who use the Soul to explain processes such as concoction, generation, "plastick functions" and "I know not how many other Faculties, ascrib'd to Living Bodies..." his complaint is explicit. In order,

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448 Ibid.

449 Ibid.

"to explicate a *Phænomenon*," Boyle explains, "'tis not enough to ascribe it to one general Efficient, but we must intelligibly shew the particular *manner*, how that general Cause produces the propos'd Effect." He then goes on to chide those who take this view, writing that

> He must be a very dull Enquirer, who, demanding an Account of the *Phænomena* of a Watch, shall rest satisfied with being told, that 'tis *an Engine made by a Watch-Maker... as* he that knows the Structure and other Mechanical Affections of a Watch, will be able by Them to explicate the *Phænomena* of It, without supposing, that it has a Soul or Life to be the internal Principle of its Motions or Operations...[450]

Thus, the forces of generation to which Boyle appeals can satisfy the necessary and sufficient conditions he himself presents for mechanical explanation just in case their mode of operation is mechanical.

Here, it might be helpful to distinguish between a mechanical explanation and a mechanical ontology. Dennis Des Chene has recently provided an excellent discussion of this distinction, arguing that many seventeenth-century philosophers adopted mechanism as a mode of explanation without restricting themselves to a mechanistic ontology, especially when dealing with the science of life. As a point of example, he looks at Borelli and Perrault, who combined the "outright rejection" of Cartesian ontology "with a thoroughgoing commitment to mechanism, and thus to a non-restrictive mechanism." This position was held by "emphasizing a traditional division of labor" between the study of how active powers are transferred and determined (i.e. the study of mechanics), and the study of those powers or principles *per se*.[451] On this view, the mechanistic study of animals does *not* "preclude

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450 Boyle, et al. *The Works of Robert Boyle*: v. 10, p. 558, *A Free Enquiry Into the Received Notion of Nature*

451 Des Chene, *Mechanisms of Life: Borelli, Perrault, Régis*: p. 245-456

supposing them to have souls" but rather precludes the *appeal* to such occult qualities, formal faculties or the special powers of the soul as the method of explanation.[452]

Boyle, of course, does both: He provides a mechanistic (albeit not Cartesian) ontology as well as a mechanistic method of explanation. But his ontological assertions about the agents of generation are met with a degree of nescience and mitigated skepticism due largely to his own theological beliefs. His method of explanation can nonetheless be rightly called "mechanistic" independently of whatever problems his ontology might be said to encounter. A closer inspection of Boyle's seminal and plastic powers suggests that his appeal to them as causal agents follows this very method of explanation.

4.5.3 *Generation Explained*

We first saw Boyle appeal to this method of explanation when responding to William Harvey in the *Origin of Forms and Qualities*, that a plastic power within the *cicatricula* of an egg might actually be responsible for fashioning the embryonic development of a chick. To this complaint, Boyle answers that this objection does not invalidate his claim that the chick is a mechanically contrived engine. For, as he writes,

> let the Plastick Principle be what it will, yet still, being a Physical Agent, it must act after a Physical manner, and having no other matter to work upon but the White of the Egg, it can work up that Matter but as Physical Agents, and consequently can but divide the Matter into minute parts of several Sizes and shapes, and by Local Motion variously context them, according to the Exigency of the Animal produc'd, ... That which we are here to consider, is not what is the Agent or Efficient in these Productions, but what is done to the Matter to effect them.[453]

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452 Ibid. p. 255

453 Boyle et al, *The Works of Robert Boyle* v.5: p. 383-384

Note how Boyle ends this discussion by emphasizing how the explanatory power of the plastic principle comes from its physical effects upon matter. Boyle elaborates on that point, stating that,

> And when Man himself, who is undoubtedly an Intelligent Agent, is to frame a Building or an Engine, he may indeed by the help of Reason and Art, contrive his Materials curiously and skillfully, but still all he can do, is but to move, divide, transpose and context the several parts, into which he is able to reduce the Matter assign'd him.[454]

Boyle goes on to explain how the external heat of incubation puts the parts of the substance into motion so that, "the Formative Power (whatever that be) doth any more then guide these Motions, and thereby associate the fitted Particles of Matter after the manner requisite to constitute a Chick…" [455] In summary, throughout this response, Boyle places the explanatory focus upon the material effects and modes of operations.

Recall that in the *Origin of Forms and Qualities*, Boyle extended his reasoning of the chick's formation to that of the plant. In the same vein, he considers the claim that theory of the diverse qualities of a resulting plant are, "the productions of the Plastick Power residing in prolific Buds…" To this objection, Boyle replies that he, "shall return the same Answer that I did to the like Objection, when 'twas propos'd in the First Observation." [456] In other words, whatever formative agent might provide the formative, plastic power involved in generation, it still must act in a physical manner.

Likewise, we see Boyle take this approach to generation in *History of Fluidity*, where he criticizes those chymists who appeal to, "a certain secret internal principle, by some of

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454 Ibid. p. 384
455 Ibid. p. 384
456 Ibid. p. 389

them call'd a form[457], and by others a petrifying Spirit, lurking for the most part in some liquid vehicle," as being responsible for the formation of crystals. To that claim, he responds,

> I am very forward to grant, that (as I elsewhere intimate) it is a plastick Principle implanted by the most wise creator in certain parcels of matter, that does produce in such concretions as well the hard consistence as the determinate figure.
>
> We deny not then, that these effects depend most commonly upon an internal principle, but the difficulty consists in conceiving how that internal principle produces its effects, which these Writers not pretending to explicate intelligibly, we thought it not amiss briefly to survey some of the principal ways by which it seems that Nature makes bodies…[458]

Again, his primary complaint remains not about ontology, but the chymists' failure to explicate how such principles work. [459]

4.6 Conclusion

In the last decades of his life, Boyle spent his mature years in London more fully adapting the agents of generation (plastic powers, *semina*, and petrifick spirits) to his mechanical program. But Robert Boyle's writing had a habit that would frustrate the present-day reader[460]: Rather than eliminate the concepts that would go against his mechanical philosophy, he *redefines* them. Present-day readers are understandably confused, especially as his "Petrifick Spirit" evokes imagery from the likes of Anselm de Boodt. Some scholars,

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457 Though ultimately derived from Aristotle, 'form' had other meanings and implications attached with it, also. Those other associations included Neo-Platonized forms and transmutation.

458 Boyle et al, *The Works of Robert Boyle*: v. 7, p. 192, *Origin and Virtues of Gems*; Ibid. v.2, p.192, *Certain Physiological Essays.*

459 There is actually a larger problem with accusing Boyle of failing to provide an explanation as to the nature of seminal principles, and this is something which Anstey himself mentions. Two treatises devoted entirely Seminal Principles are no longer extant. It's quite plausible, if not likely, that he would have addressed such a matter with these, but it simply is not a fact which we can ascertain.

460 In truth, he had several.

moreover, have gone so far as to say that Boyle postulated the existence of a neo-Platonic, spiritual plastic power- similar to that of Cudworth, "[d]espite the fact that [Boyle] engaged in a controversy with Henry More regarding the Cambridge thinker's conceptualization of the Spirit of Nature..."[461] Further analysis, however, has demonstrated that Boyle's own conception of plastic powers were of an entirely different nature.

While such a mode of communication may be misleading to us moderns, the subtlety of his re-defining would not have been lost on his intended audience. In the previous chapter, we saw that Boyle's ontology is less than sparse. He appeals to springs, powers, and other such "mechanical affections" not frequently associated with a mechanical program by present scholars. That issue, however, is a separate one from that of explanation. Just as Boyle's theological commitments could be parsed, on the one hand, ontological; and on the other, epistemological, so too can his mechanical philosophy. For Boyle, the Christian Virtuoso is committed to a certain nescience regarding the ways in which God interacts with the world, and the problem of generation falls within that sphere. Take from that perspective, the nescience that Anstey astutely captures is the very epistemic virtue to which Boyle commits himself. That virtue, described in present-day literature as "epistemic humility"[462] and by Corneanu as "Socratic medicine"[463], necessitates the Christian Virtuoso to commit himself to nescience about the nature of things like plastic powers and to some extent, even the *modus operandi* of such agents. But regardless of their nature, their operations can be explained in terms of their effects. And those effects must necessarily be expressed in terms of the mechanical affections of matter. Boyle, accordingly, does just this. In many ways,

461 Flores, *Plastic intellectual breeze: the contribution of Ralph Cudworth*: pp. 141- 143.

462 See, for example, Cleeve: *Epistemic humility and causal structuralism.*

463 Corneanu, *Regimens of the Mind:*

this manner of explanation depends upon the traditional "division of labor" described by Des Chene. But Boyle's ingenuity is his shifting the investigation from essence of the agents in question to their mode of operation.

This chapter has delved into the influence of Boyle's Petrifick spirit upon theories of mineral and fossil formation. In the next chapter, we will see how Boyle's ideas on generation influenced the study of life and medicine. In doing so, we shall see how Italian anatomists appropriated not only his ideas on the forces of generation, but also his epistemic approach to mechanical explanation. For Boyle, one is able to provide a mechanical explanation just in case one can explain the effects of an agent in terms of its corpuscular effects upon matter. Essentially, Boyle allows for the possibility to black-box the agent, focusing on what it does rather than *what it is.* Boyle's motivations for this mode of explanation stem largely from his theological considerations about God, knowledge, and the limits of human reason. The anatomists discussed in the next chapter, however, have different motivations for adapting such a program.

Chapter 5. Boyle and the Anatomists: *Between Italy and the Royal Society 1669 -1704*

5.1 Marcello Malpighi and the Royal Society

5.1.1 *Dissertatio Epistolica de Bomboyce*[464]

Through the streets of London (many of which were still charred from the great fires that had torched them years prior) a modest-sized package travelled to Gresham College on a frosty February day in 1669. The parcel, delivered from Bologna, was met with delight by its English recipients and would prove to have a significant impact upon members of the Royal Society and seventeenth-century natural philosophy, more generally. Oldenburg presented it to other members at a Society meeting February 18th, and council members ordered its publication four days later.[465]

Their enthusiasm is, perhaps, not surprising since this particular treatise was actually composed at the behest of Oldenburg himself. He had been corresponding with its author, Marcello Malpighi, when he wrote to the Italian physician at the end of 1667 imploring the latter to investigate (among other the topics) the rather lucrative silkworm that had piqued the interest of the English gentlemen, including Boyle. The result, *Dissertatio epistolica de bombyce*, was nothing short of groundbreaking. Unlike previous texts devoted to microscopy and the study of insects, Malpighi focused on the *internal* anatomy of his subject. Accompanying the relatively short text were forty-eight remarkable drawings depicting that very thing, and the illustrative details stunned their English audience. The philosophical implications of Malpighi's experimental results were huge. Aristotelian natural history

464 *Epistolary Dissertation on the Silkworm*

465 Adelmann, *Marcello Malpighi and the Evolution of Embryology:* v. 1, p. 339

classifies insects such as the silkworm and other butterflies as bloodless, hence lacking internal organs or heterogeneous parts.[466]

Malpighi, however, demonstrated irrefutably that the internal structures of the silkworm were just as complex as those of mammals. Members of the Royal Society immediately recognized the significance of Malpighi's "incomparable History of the Silk-Worme" and agreed to publish the book (which had been dedicated to the Society) on February 22nd, 1669.[467] Marcello Malpighi was shortly thereafter elected honorary member of the Society on March 4th of that same year.[468]

5.1.2 *Malpighi, Swammerdam, and Preformationism*

Malpighi's detailed account of the internal anatomy of the silkworm had significant implications for the generation of the creature, particularly when it came to refuting Aristotle. Aristotle had claimed that caterpillar larvae were in reality worms that had spontaneously generated and are "not produced out of animals at all, but out of putrefying fluids." [469] On this view, the caterpillar-worm and resulting butterfly are understood as two completely different insects, each of which arise spontaneously from decay. The larva produces the chrysalis—which Aristotle viewed as a kind of "egg"— and the adult butterfly hatched from said egg was produced from the resulting rot.[470] Boyle's own early notes on spontaneous

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466 For Aristotle's discussion on this, see PA: Book II. Cf. Bertoloni Meli, *Mechanisms, Experiment, Disease*: 175; Cobb, *Generation:* p. 153.

467 This description is taken from John Evelyn's diary, where he describes the council meeting held to deliberate the publishing of the work. See *Adelmann, Marcello Malpighi and the Evolution of Embryology*, v. 1: p. 673.

468 O.S.

469 Aristotle, GA: 721 a: 5-10

470 Cobb, *Generation*: p. 133; Ogilvie, "Orders of Insects: Insect Species and Metamorphosis between Renaissance and Enlightenment": p. 326, in *The Life Sciences in Early Modern Philosophy*.

generation (discussed in earlier in Chapter 2) suggest this understanding of metamorphosis, specifically in his description of the silkworm "eggs." [471]

Malpighi's investigations of the silkworm, however, confirmed with unprecedented precision that both the anatomy of the creature and its generative process are considerably more sophisticated than previous thinkers had claimed. The internal organs of the silkworm meant that their generation from putrefied matter was simply implausible.[472] His delicate treatment of their anatomy, moreover, demonstrated the sheer complexity of their generative organs. From his investigations with the microscope, two things became clear: First, silkworms are the product of sexual generation in a manner that is not all that different from larger animals, such as birds. Second, the embryological process by which development takes place is likely through the growth of pre-formed parts.

With regards to the former, Malpighi maintained that the silkworm generates from eggs, produced by the female, that have been fecundated by male semen. In one impressive experiment, Malpighi attempted to fecundate virgin eggs himself, manually, by inseminating them with semen that he had extracted from the uterus and genitals of other silkworms. His attempt, however, fell short.[473] Nonetheless, his discoveries present a certain kind of uniformity in the sexual manner in which animals are produced. *De Bombyce* in conjunction with Redi's *Esperienze Intorno alla Generazione degl'Insetti* undoubtedly presented a serious challenge to the proponent of spontaneous generation. Few, however, were permitted to read both at the time of their publication. In England, members of the Royal Society were

471 Boyle et al, *The Works of Robert Boyle:* v.13: p. 286

472 See Bertoloni Meli, *Mechanism, Experiment, Disease*: 193

473 Cf. Bertoloni Meli, *Mechanism, Experiment, Disease:* 192-193; Cobb, *Generation*: 153-4

well familiar with Malpighi's work on the silkworm before having had the opportunity to read of Redi's own experiments on the spontaneous generation of insects. This much is evident from Oldenberg's correspondence. For example, he wrote to Hygens in July of 1669 that, "Mr. Malpighi's book [on the silkworm] is printed off… We have not yet seen Mr. Redi's book on the generation of insects, but Mr. Magalotti has promised to see that I receive a copy at the earliest convenient opportunity. Our book sellers are very lazy and careless in the business of selling scientific books…"[474]

As for the embryological development of the silkworm, Malpighi's findings strongly suggested preformationism, or the view that the embryo develops solely from an enlargement of its parts. Within the dissected caterpillar, he explains, "even before the cocoon is spun, the first vestiges of the wings are hidden beneath the second and third segments; in the head, the antenna can also be seen."[475] On this matter, his investigations would inspire several of his contemporaries to adopt an alternative account of animal generation, propelled by the philosophical problems surrounding it. Particularly delighted by Malpighi's discoveries and account was Jan Swammerdam.

Swammerdam had been conducting his own experiments upon the silkworm caterpillar as part of a lifelong interest in insects the result of which, *Historia Insectorum Generalis*, was printed that same year in 1669. Swammerdam's appreciation of *de Bomboyce* stemmed from the fact that its contents had confirmed his own findings. Namely, that the first vestiges of the wings and antennae are visible from within the caterpillar before it even

474 Oldenberg, et al. *Correspondence*, letter 1230 v.12: p. 94. The Latin translation of Redi's *Generazione degl'Insetti* was later published in Amsterdam in1671.

475 Cf. Cobb, *Generation:* p. 153

begins to spin its cocoon. Years earlier Swammerdam had performed a public vivisection of a silkworm caterpillar in 1665 for Thevenot's *academie* in Paris. There, he revealed that the wings, antennae, and other parts of a grown butterfly were, though not fully formed, nonetheless present in this seemingly unrelated creature. In doing so, he demonstrated that the caterpillar and resulting butterfly were actually one and the same. The pupa—once conceived as an egg of sorts—was simply a kind of intermediate stage. [476]

Despite its Latin title Swammerdam originally composed *Historia Insectorum Generalis* in Dutch, a factor that unfortunately limited the book's audience until its translation into French in 1682 and into Latin in 1685. Swammerdam himself, however, had remarkable influence upon the problem of generation– in part because of his chance meeting with Nicolàs Malebranche.Their collaboration resulted in the view *emboîtement*, discussed earlier in Chapter 3, which is a radical version of preformation that states that each egg contains the pre-formed germs of future generations.[477]

Secondary literature on Early Modern theories of animal generation tends to focus on the debate between epigenesis (i.e., the view that an embryo develops gradually and successively over time) and preformation. The general consensus is summarized nicely by Shirley Roe, who writes that

> In the late seventeenth and early eighteenth centuries, two rival schools of thought on the subject of generation existed. The preformationists believed that the embryo preexists in some form in either the maternal egg or the male spermatozoon. Most also thought that all embryos had been formed by God at the Creation and encased within one another to await their future

476 Cobb, *Generation*: pp. 140-144.

477 Gasking, *Investigations into Generation: 1651- 1827*: pp. 43 ff.; Roger, *The Life Sciences in Eighteenth- Century French Thought*: p. 267.

> appointed time of development. Epigenesists, on the other hand, argued that each embryo is newly produced through gradual development from unorganized material. Various explanations were proposed for how this gradual formation is accomplished, yet epigenesists were united in their opposition to preexistence.[478]

There is no doubt that the debate between preexistence and epigenesis begins at the end of the seventeenth-century, as she states here. But the conversation of preformation *versus* epigenesis that occurs in the early eighteenth century, whereby proponents of each view are united in their opposition to the other, has several features which are unique to that time period. By the early eighteenth century, most mechanists were committed to some kind of preformationism, for reasons described above. The problem of generation as understood throughout eighteenth century is additionally informed partly by theories of matter and of Vitalism unique to that time period.

Despite the difference of only a few decades, the terms of the debate surrounding preformation and epigenesis changed in important ways, and one must be careful not to project the terms of this slightly later debate into the past anachronistically. The second half of the seventeenth century could contrarily be characterized by a radical transition regarding the way that matter was understood. Although generation taken simply is the process by which matter is organized, the landscape of concepts pertaining to how generation takes place was considerably more varied. To understand that dynamic, consider that William Harvey's use of 'epigenesis' in *De Generatione Animalium,* was used in contrast not to preformation, but to *metamorphosis.*[479] Appeal to an epigenetic embryonic development was

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478 Roe, *Matter, Life, and Generation:* 1

479 Harvey, *On the Generation of Animals*: 335. Here, it is worth noting also that both epigenesis and metamorphosis on Harvey's account involve the origin of the germ in terms of an unorganized material.

not limited to those who invoked Aristotelian faculties. Descartes, for example, attempted to give a strictly mechanistic account of generation which similarly involved the gradual development of an embryo over time. Yet, despite that similarity, both Descartes and Harvey would, no doubt, consider their views to be diametrically opposed. They were hardly united.

Likewise, there was an even greater diversity in theories of preformation. Previous scholarship has discussed the subtle, yet important, differences to which I've alluded earlier between the theories of preformation, where the embryo is preformed before its development, and the more radical pre-existence, wherein all embryos were formed by God at Creation, existing before fecundation could even take place. Malpighi would become a strong proponent of the more mitigated theory of preformation, which pertains only to embryological development. As such, he would soon occupy a unique place in that, despite his adherence to preformation, he is still left with the problem of explaining just how generation takes place. His solution, as we shall see, would be inspired by none other than Robert Boyle.

5.1.3 *Treatises on the Chick*

Malpighi's analogy of the generation of the silkworm to that of bird eggs may very well have informed the next work of his to be published by the Royal Society. In 1671 he produced two treatises on the development of the chick, *De Formatione Pulli in Ovo* (*On the Formation of the Chick in the Egg*) and *Appendix repetitas Auctasque De Ovo Incubato Observationes Continens* (Repeated and additional Observations on the Incubated Egg), which were published by the Royal Society in 1673 and 1675 respectively. It is clear from Malpighi's introduction that his work is a direct response to William Harvey's writings about

the development of the chick pertaining to its earliest stages of life. Within the introduction, he writes

> [B]eing unable to detect the first origins, we are forced to await the manifestation of the parts as they successively come to view... But since, as Harvey says, "the first threads of Nature's weaving commonly lie hidden as in the depths of night"... and since, too, Nature's powers, being so variable... now delay the appearance of the fetus, you will therefore allow me, my learned colleagues, to share with you the rude beginnings of some observations stemming from the examination of incubated eggs.[480]

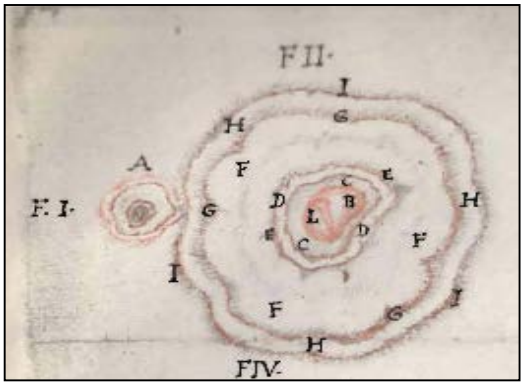
Like Harvey, Malpighi was not merely a natural philosopher, but also a physician. Both men emphasized empirical observation and the importance of seeing for oneself. Likewise, both drew from their experience as medical practitioners. Malpighi, however, differed methodologically from Harvey on two important points: He paid considerable attention to illustrations (which Harvey thought to be problematic), and his observations relied upon the use of a compound microscope.[481] The result was a detailed account of a microscopic world yet unseen to his English audience of that honorable society, surpassing even Hooke's *Micrographia.* Boyle would later speak highly of Malpighi's work on the chick-egg, appealing to it in the second part of his *Christian Virtuoso.* In Aphorism IX he writes of the *cicatricula* within the eggs of dunghill hens that, "… in this very small part of the egg, the curiosity of the excellent *Malpighi* has lately discovered a chick already formed, with all its essential parts; so that the incubation of the hen does little, or nothing more, than dissolve

480 Malpighi, *Pulli In Ovo.* Translated by Adelmann, *Marcello Malpighi and the Evolution of Embryology*: v. 2, p. 937

481 See Ruestow, *The Microscope in the Dutch Republic: The Shaping of Discovery*: p. 15

the humors of the egg, and procure that the parts of the chick…are displayed, and become first manifest and then conspicuous."[482]

As with *De Bombyce*, his work on the development of the chick egg was well received by the Royal Society largely in part because of his detailed drawings. In this case, his illustrations of those "rude beginnings" most accurately depicted development of the embryo during the first four days of incubation and did so with stunning detail. Take, for example, a



depiction of an egg which Malpighi believed (falsely) had not yet been incubated. The *cicatricula* (A) is shown here in its actual size (left), and to the right he has drawn it enlarged so that the reader can see its contents, a common scaling technique.

Looking then at the figure on the right, inside of the *cicatricula* is what Malpighi calls a *saccule* (B), which he describes that saccule as floating in a liquor of colliquament.[483] Inside of the saccule is the tiny, previously imperceptible fetus of the developing chick (L). Malpighi describes how he is able to see the chick when he puts the egg up against the sunlight because of the diaphanous texture. Of this experience, he writes

> I noticed the fetus enclosed as if in an amnion; and its head, with the first filament of the *carina*[484] appended to it, was clearly evident. Indeed, the loose and diaphanous texture of the amnion frequently permitted one to look through

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482 Boyle, et al. *Works of Robert Boyle*: v. 12, p. 446-447

483 Malpighi's beginning with the *cicatricula* he owes to Harvey. Cf. Harvey, *On the Generation of Animals*: 215

484 The *carina* he mentions here is the early formation of the chick's spine and part of what makes up the outermost boundaries of the chick. In other words, Malpighi describes a rudimentary outline of the parts of the chick.

> and see the enclosed animal...It is, therefore, proper to acknowledge that the first filaments of the chick must pre-exist in the egg and have a deeper origin, exactly as [the embryo] in the eggs of plants. [485]

Malpighi frequently compares the development of the chick to that of plants throughout his treatises. This frequent comparison likely has two pretexts. The first is the more obvious. As any gardener can testify, the bud of a plant contains, folded within itself, miniature leaves, petals, and already formed parts of the adult plant. Swammerdam points out a similar observation in *Historia.*[486] The second pretext is that Malpighi had been working intermittently on his own treatise on plants while composing both treatises on the chick, the material for which would eventually be published in two parts by the Royal Society as *Anatome plantarum* in 1675 and 1679. [487]

Malpighi continues the comparison between chick and plant embryos again after forty hours of incubation, stating that just as the leaves within the eggs of plants, so too are the first parts of the animal brought together within the *colliquament.* Further, they are "compounded of different vessels and congealed fermentative juices." From this observation, Malpighi concludes that

> it is consequently right and proper to surmise [what] we are considering the primeval and simultaneous production [of the parts] of animals. For we may surmise that the chick, together with the bounding saccules of almost all its parts, lies in the concealed in the egg floating in the colliquament, and that the nature of the latter results from the integration of the mingled nutritive and fermentative juices, through the joint action

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485 Malpighi, *Pulli in ovo.* Translated by Adelmann, *Marcello Malpighi and the Evolution of Embryology*: p. 945

486 Cf. Cobb, *Generation*: p. 235

487 Completion Malpighi's laborious research on plants was delayed in part due to Nehemiah Grew's on work on plants, which was composed roughly the same time. For more on this, see Adelmann, *Marcello Malpighi and the Evolution of Embryology:* v.1, pp. 371- 375 and Bertoloni Meli, *Mechanism, Experiment, Disease*: ch. 9.

> of which, when aroused, the blood is produced in successive steps and the parts formerly outlined erupt and swell out. [488]

Malpighi's discussion of the "simultaneous production of parts" puts him in stark contrast with other proponents of pre-existence like Malebranche or Swammerdam.[489] The latter assume that the rudimentary parts from which the embryo developed existed before fertilization. Development of the embryo before fertilization entails that the generation of the embryo is subsumed under growth, bypassing the problem of generation all together. For Malpighi, the embryo does not exist before fertilization. Its development begins *after* fertilization. Once the simultaneous production occurs, the embryo is preformed in the sense that it does not develop from a successive formation of its parts. All of the parts existing in a fully formed adult are already present, albeit concealed, in the newly produced embryo. Thus, Malpighi is committed to the unique view that while the development of an embryo may be subsumed under growth, its genesis most certainly is not.

It might be easy to confuse Malpighi's views with those of Harvey's metamorphosis. There are some similarities, as each consists of parts which form simultaneously and exist before the generation of the animal. It would be a mistake, however, to do so. First, Harvey's conception of metamorphosis is related to the spontaneous generation of insects, which Malpighi rejected.[490] More importantly, Malpighi does not deny that growth and gradual development occur within the egg. Where metamorphosis entails the breaking-up of homogenized material into different parts, Malpighi's view simply entails the enlargement

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488 I have changed the translation slightly. Cf. Adelmann, *Marcello Malpighi and the Evolution of Embryology,* v. II: 957, *Pulli in Ovo*

489 C.f. Bertoloni Meli, *Mechanism, Experiment, Disease:* 226; Roe, *Matter, Life and Generation:* 6; Roger, *The Life Sciences in Eighteenth-Century French Thought*: 259 *ff*

490 Harvey, *On the Generation of Animals*: 335

of parts that were produced simultaneously. But explaining just *how* those parts are produced is a difficult task. By appealing to fermentation, Malpighi is already leaning towards a chymical account.

Malpighi's comments in *De Ovo Incubato* support his previous claims. While observing the inside of the *cicatricula,* he notices that the first filaments are visible before incubation.[491] From these observations he surmises that

> This much is certainly clear: the first filaments of the *carina* are visible before incubation... Hence, I still cherish the conjecture that I have elsewhere advanced: perchance the juice, the vessels, and the heart pre-exist and gradually come to view, as we observe in the eggs of trees." [492]

Like his previous treatise, he continues to compare the embryo of the chick to that of the egg in plants. In the same passage, Malpighi also finds parts of the albumen in the yolk of the egg to be analogous to the leaflets of plant buds. From that parallel, Malpighi concludes that the umbilical vessels pre-exist in the *cicatricula.* At various stages Malpighi provides a chymical analysis by heating the substance of the chorion and amniotic fluids to see if they coagulate. (Often they do not, and their reaction is described in terms of bubbles.) [493]

With these two embryological treatises, Malpighi gives a largely descriptive account that centers on his effort to show that the first rudimentary parts of the embryo lie within the *cicatricula* before incubation and become visible only though motion. This means that the embryo develops from these structures by a mere growth of these parts. Nonetheless, those

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491 Malpighi's eggs were likely incubated by the summer heat in Italy.

492 Malpighi, *De ovo incubato*. Translated by Adelmann, *Marcello Malpighi and the Evolution of Embryology:* v. 2, p. 997.

493 See Adelmann, *Marcello Malpighi and the Evolution of Embryology*: pp. 1006 and 1009; Cf. Bertoloni Meli, *Mechanism, Experiment, Disease:* 231.

parts do not exist prior to fertilization, and the production of those rudimentary parts of the outermost boundaries is both philosophically and in practice a difficult thing to explain. Given that, one could imagine how a plastic power, or a molding and organizing force, which can mechanistically explain how the rudiments form from fluids, would be a helpful explanatory apparatus. Such an apparatus Malpighi gets from Robert Boyle.

5.2 Boyle, Malpighi, and the Problem of Plastic Powers

5.2.1 *Malpighi and Boyle*

Malpighi appropriated Boyle's notion of plastic powers in his own writings. This usage is part of a mechanical account of the generation of bodies from heterogeneous fluids. Moreover, and perhaps more importantly, it shows that Boyle's description of a plastic power was perceived as being mechanical by one of his own contemporaries similarly committed to the Mechanical philosophy. That appropriation, however, was based on the works of Boyle's that Malpighi had available to him. In short, Malpighi understands a plastic power to work like and be related to Boyle's petrifick spirit. Given Boyle's Latin works, that Boyle had such a concept in mind for the generation of animals in mind was a reasonable assumption on the part of Malpighi. Although Boyle does distinguish between the two forces of generation in his more juvenile notes on the *Generation of Minerals*, that treatise was never published in their lifetimes.

The essay in which Boyle is most explicit in print about the petrifick spirit remains his *Origin and Virtues of Gems.* This treatise in particular had an influence upon Malpighi. In a letter from Henry Oldenburg, dated 1672, Oldenburg explains that he is sending to Malpighi, along with the copper engravings for the illustrations of his embryological treatises

of the chick and their resulting figures, a Latin edition of Boyle's *Origin and Virtues of Gems* prior to its being published in Latin.[494] Boyle's essay later came out in 1673 as *Exercitatio de origine et viribus de gemmarum*, and that letter of Oldenburg's was published with Malpighi's first embryological treatise, *Pulli in Ovo.* That latter fact is of interest, too, because it means that any of Malpighi's contemporaries reading his earlier works on the chick would have known of his receiving and (presumably) reading Boyle's work.

The peak of the exchanges between Boyle and Malpighi happened after the death of Oldenburg primarily through Father Carlo Ronchi, a friend of Malpighi's who was serving as chaplain to the Queen of England (thus residing in London).[495] Malpighi was familiar with Boyle's *History of Blood*, which had been published in Latin as *Apparatus ad historiam naturalem sanguinis humani* and printed in Geneva in 1685. Filled with curiosity and un-answered questions about blood's constitution, Malpighi wrote to Ronchi in the beginning of 1686 expressing his deep admiration of Boyle and adding questions for Boyle about

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494 Oldenburg et al, *The Correspondence of Henry Oldenburg* v. 9: 229-230; Oldenburg refers to the work as, "Gemmarum Origine et Viribus Exercitatio" in his letter to Malpighi, despite the slightly different title given to the treatise in publication, " Exerciatio de Origine et Viribus de Gemmarum," published the following year, 1673, in London. Given Boyle's propensity for editing and altering his work, that fact could raise alarms as it entails that Malpighi might well have received a somewhat altered version of the treatise rather than the one which was published. However, it seems unlikely that Boyle would have altered the Latin version of this text. Also, Oldenburg translated many of the works coming from the Royal Society himself. Incidentally, there is yet another Latin of edition of Boyle's treatise published in 1673 from Hamburg, called, "Specimen de gemmarum origine et virtutibus". This translation seems to be unauthorized.

495 See Adelmann, *Marcello Malpighi and the Evolution of Embryology*: v.1, p. 500 for more on Carlo Ronchi. England's Queen in 1686, Mary of Modena, was an Italian born Catholic. Along with her husband, James II, she reigned over England just over three years. The Catholic faith of their son and heir, James Francis Edward, would later become a significant factor in the Glorious Revolution of 1688.

directions for making spirit of blood.[496] Accompanying this letter was a package of books and Porretta crystals.[497]

Boyle clearly received the message, as copy of the letter can be found within his papers.[498] He then responded through Ronchi shortly after expressing his gratitude for the Porretta crystals, his high regards for Malpighi, and his cheers for Malpighi's good health, along with Hooke and other members of the Royal Society.[499] He eventually prepared a vial containing *spirit of blood*, himself, and had it sent to Malpighi. [500] The sentiments described by Ronchi on behalf of Boyle were likely sincere, as evident from Boyle's subsequent request for Malpighi to host his nephew. [501]

Malpighi sent a second package to Boyle including more crystals later that year, but it seems to have been lost—a fact lamented not only by Boyle and Malpighi, but by other scholars from within their respective communities.[502] There was considerable interest among the rest of the community of Italian anatomists in Malpighi's correspondence with Boyle, and they wrote frequently to him inquiring about it. Most noteworthy for our purposes

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496 February 6th 1686, NS; January 26th, OS.

497 Malpighi et al, *The Correspondence of Marcello Malpighi:* 1135; As late as 1911, Porretta, located near Bologna, was noted for having "remarkably hallowed crystals." Chisholm, *The Encyclopedia Britannica: A Dictionary of Arts, Sciences, Literature and General Information*: 433

498 Boyle Letters, n. 10

499 Malpighi et al, *The Correspondence of Marcello Malpighi*: v. 3, pp. 1156-1161. Cf. Adelmann, *Marcello Malpighi and the Evolution of Embryology*: v.1, p. 498.

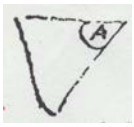
500 Ibid. That Boyle highly regarded Malpighi's work on blood is evident from his own History of Blood in the section, "Of the Relation between Spirit of Humane Blood and the Air". Here, he almost certainly refers to Malpighi's work as the "Experiments of an Italian Virtuoso." Boyle, et al. *Works of Robert* v. 12, p. 62 n.

501 Malpighi et al, *The Correspondence of Marcello Malpighi*: v. 3, p. 1258.

502 Ibid. p. 1250, p. 1258. Cf. Adelmann, *Marcello Malpighi and the Evolution of Embryology*: p. 501.

was Malpighi's correspondence with Lorenzo Bellini, Chair of Anatomy at the University of Pisa and himself deeply committed to a mechanical program.[503]

A letter from Malpighi to Bellini, who was also interested in the generation of minerals, articulates the relevance of the crystals sent to Boyle. In the letter, Malpighi explains that one particular crystal confirms Boyle's opinion that minerals originate from



fluid material: The crystal had an air bubble (A) that would move around as though the internal contents of the gem "had not entirely solidified."[504] Thus, the materiality of their correspondence, which in this case includes mineral samples that validate Boyle's own theory of generation, communicates to the present-day reader just how Boyle's account of a mineral generation and resulting coagulation can help to explain Malpighi's own writings that describe the work of a plastic power.

5.2.2 *Malpighi's Plastic Powers*

Malpighi's first and most noted reference to plastic powers is found in his epistle to Lyon physician, Jacob Spon. Malpighi sent a copy of the letter, dated November 1681, to the Royal Society in August of 1683. It was subsequently published in 1684. In the epistle, Malpighi describes the fecundation of several animals such as butterflies and a cow, as well as the fecundation of plants. More likely tha not, Malpighi had Boyle specifically in mind when writing to Spon.

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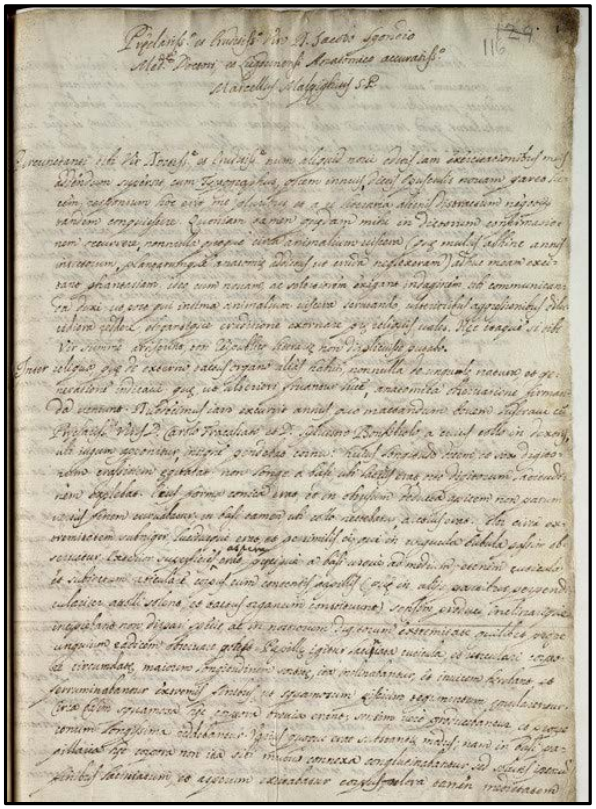
503 Koertge, *Complete dictionary of scientific biography*: p. 592; Roger, *The Life Sciences in Eighteenth Century French Thought*: p. 284

504 Malpighi et al, *The Correspondence of Marcello Malpighi*: v. 3, p. 1212

Accompanying the Royal Society's copy of the epistle was a letter to Dr. Francis Aston in which he explained that he had already sent a copy of the epistle to the "Illustrious Robert Boyle".[505] In fact, a copy of the epistle to Spon is still present in the archive of Boyle's manuscripts and papers.[506]



In the epistle, Malpighi makes only three references to plastic powers, the first of which is in passing.[507] The latter two references are in a later passage. He begins by describing that in butterflies, a sticky ichor drips from a structure attached at the end ovary through the vagina. Malpighi writes (boldface mine),

> By this ichor the semen of the male and also another humor emitted by a lateral chamber are received and maintained, and by all three of them eggs passing through the vagina are moistened and fecundated; and thus that **plastic power** is preserved for many days and communicated to eggs emerging at subsequent times. This, we may infer, is also true of the hen, where the energy of the semen received in a single mating is preserved to no small degree, with the result that eggs are fecundated even for some time thereafter. And since in the hen's egg Nature does not scatter and sprinkle the semen of the cock or another menstruum fecundated by the semen upon the cicatricula alone, in which the rudiments of the parts lie concealed, but also moistens with **plastic force** the entire egg (that is to say, the aliment in the form of

505 Malpighi, et al. *The Correspondence of Marcello Malpighi:* 910-911; Aston replaced Oldenburg as the Royal Society's secretary after the latter's death in 1677.

506 BP 17, fol. 116v-125r. See http://www.bbk.ac.uk/boyle/boyle_papers/bp17_docs/bp17_115v-116r.htm

507 The first mention of plastic virtues can be found in the very first sentence of the second half of the epistle to Spon. Malpighi refers to it in passing in the context of the uterus, which he calls the "workshop" or "office" of the plastic virtue. "…plasticae virtutis officinam contemplemur exarando ea…" (Malpighi, *Praeclarissimo Et Eruditissimo Viro D. Jacobo Sponio*: p. 630)

> albumen and yolk), so that the whole is fecundated, and residue, too, the uterus is analogous to the hen's egg, because it is swollen with humor and surrounds the ovule, it is therefore probable that the uterus and the humors it contains are also fecundated.[508]

That Malpighi had in mind something like a Galenic faculty is unlikely given his more general mechanical program. Such a reading would be an awkward one, too. This part of Malpighi's discussion is immediately preceded by a description of fluid particles in motion in which he explains that the male semen is able to fecundate eggs by mixing with an ichor from the vagina. In other words, fecundation results in the mixing of a female fluid with that of the male semen, which acts something like a ferment. This process, which Malpighi describes entirely in terms of particles of matter and motion, bears a lot of similarity to Boyle's own discussion of mineral formation. Malpighi concludes from his observations that the outermost boundaries of the chick are concealed within the *cicatricula* prior to incubation. Those first rudiments become visible only though motion and are formed separately from fluid.

Malpighi's *Vita,* from his *Opera Posthuma,* explains more explicitly just how those rudiments become visible through motion. He concludes from several observations on incubated eggs that the fecundated egg contains the rudimentary parts.[509] Those rudimentary parts, Malpighi explains, are nothing more than a collection of fluid confined by a membrane. After incubation, the fluid becomes thinner as the solid parts are dissolved into furrows so that the humors flow and are confined to the *cicatricula*. Within the *cicatricula*, in the same manner described in his embryological treatises, the parts swell and grow making the first

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508 Malpighi, *Praeclarissimo Et Eruditissimo Viro D. Jacobo Sponi.* Translated by Adelmann, *Marcello Malpighi and the Evolution of Embryology*: v.2, pp. 861-2

509 Malpighi presents the same view as in his embryological treatises, but here he is more explicit.

filaments visible. That happens, he explains, when the outermost parts are constructed, giving rise to cavities which are then filled by fluid, causing the early formation of the spine to emerge.[510]

In the context of his account of the initial simultaneous development of the outer-most parts, Malpighi once again refers to these plastic powers, stating that

> [Nature] begins to form the rudiments of the parts to be delineated… by means of whose pores, as by so many glandular sieves, she separates the infenced fluid from the fluid in which it is immersed; and the fluid thus confined is pervaded by the plastic spirit and organized, when unsuitable substances have been transpired and its parts have been properly adapted.[511]

Here, too, Malpighi appeals to the example of butterflies, whose wings and antennae are first sketched out in their outer parts, and then filled with fluid. In this sense, the passage echoes his earlier work in *de Bombyce*. The formation of the wings and antennae, however, differ dramatically from Swammerdam's own account or that of any staunch proponent of pre-existence. That's because the parts of the butterfly, though developed by the growth of parts, are produced from the described fluid. That fluid is essential for understanding Malpighi's appropriation of Boyle's plastic power or spirit. Each instance where Malpighi describes the function of a plastic power involves the coagulation and organization of fluid.

Recall how in *Pulli in Ovo* Malpighi describes the saccule as floating in fluid or liquor of *colliquament.* The fluid which fills out the cavities formed by the outer parts later

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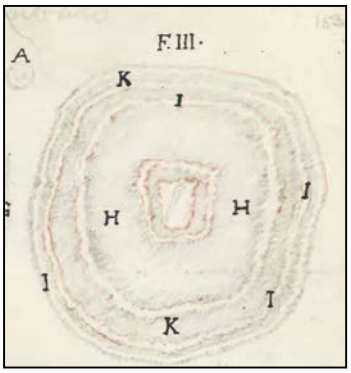
510 Malpighi, *Opera Posthuma, Vita*. Translated in Adelmann, *Marcello Malpighi and the Evolution of Embryology* v. 2: 866

511 Ibid. p. 866. Malpighi's account echoes Boyle's own description of the operations of parts and fluids in the body according to the principles of the mechanical philosophy as described in the "Usefulness of Natural Philosophy". Cf. Boyle, et al. *Works of Robert Boyle*, v. 3 pp. 466-467, "Usefulness of Natural Philosophy".

solidifies, and the parts are drawn out from their saccules. The rudimentary parts of the spine are then formed similarly. Here, the manner in which he describes the organization and hardening of the fluid from the saccules to create the rudimentary parts of the chick by the plastic power is strikingly similar to the manner in which Boyle describes the production of complex crystal formations in that both processes involve organized formation by the coagulation of fluids as the result of a mixture.

Another passage from Malpighi's posthumous work confirms that he wrote on plastic powers within the context of Boyle's work on minerals. In this particular essay, Malpighi is describing how fecundation of fruit occurs, notably those cases in which multiples occur. To explain, Malpighi appeals to juices and the power of the *colliquament*. In the case of subventaneous (that is, unfertilized) eggs Malpighi explains that the eggs only contain matter that is simply the accumulation of particles, because, "the plastic virtue misses by chance". Malpighi compares the fruit to flowers, stating that multiples arise from an abundance of mixed juice, and of floating particles. Given Malpighi's frequent comparison of the generation of the chick egg to that of plants, the long analysis and comparison of another plant to fruit is to be expected. More surprising, however, is the next comparison he makes, namely to stones.

"Similar phenomena," he writes, "also occur not infrequently in the concretion of stones." For an example, he looks at jet, which forms a kind of "egg" from fluid materials in which diverse tinctures and particles are present due to the different gravities of the particles. That process causes a kind of resistance which creates layers, like those of onions. The onion described in this passage is reminicient of the layering displayed in his sketches from the embryological treatises. Indeed, Malpighi goes on to compare the stones to his observations



in the incubated egg, which he discusses in *De Ovo Incubato*. Although he does not reference the treatise here, it might be helpful to look at one of the drawings from his manuscript in order to have an idea of the imagery Malpighi has in mind. Here, the center circle is the cicatricula, which contains the chick's rudiments, i.e. *carina*. He explains that the concentric circles of the stone exhibit a similar appearance (*speciem*) to the incubated egg, in which the many circles form around the *carina* from fermentation and get larger.[512]

As with previous works, Malpighi continues to analyze their growth in terms of the concretion of juices and the movement of fluid particles. He then mentions Boyle by name, stating that stones and gems are thought to derive their origins from fluids by "the most learned Boyle and Steno":

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512 Malpighi, *Opera Posthuma*: p. 90; "In lapidum quoq; concretione non rarò consimilia succedunt phænomena. Constat enim in gagate ovum ex fluida materia fieri, in qua cum adsint diversæ tincturæ, & particulæ fossilium et mineralium ex varietate gravitatis earundem, & resistentia ambientis fit ovum multiplicibus distinctum fluoribus, in quibus succedunt tandem concretione, quasi tot involucra sese contingentia ceparum instar manifestantur; quin immo & speciem simile exhibent, qualem in incubato ovo intuemur, in quo ex fermentatione circuli circa carinam velut aggeres cum interfluentibus liquoribus dilatantur, & multiplicantur."

> Succedunt autem in prima gagatis productione tot ova, non quia lapides ab ovo viventium more ortum necessariò trahant, sed materiæ necessitate. Constat namque ex his, quæ à Doctissimis D.D. *Boyle*, & *Stenone*, habentur lapides & **gemmas** suam originem à **fluidis** trahere. Et quoniam primum fluidum salibus, & particulis fossilium, & **mineralium** ad minima **solutis impregnatum** turget, ideo intestino suscitato motu exagitatur, & ambientis pondere premitur, unde à centro extrusæ graviores medio **fluido** aequali vi circulum efformant, cui aliæ succedentes consimili compressione extrusæ alium addunt, quod pariter repetitur secundum copiam primi **fluidi**, & ejusdem heterogeneitatem. [513]

What is more striking than Malpighi's explicit mention of Boyle is the extent to which Malpighi's language is parallel to that of Boyle's own in the passage of the *Exercitatio De Origine Et Viribus De Gemmarum* (*The Origin of Gems and Virtues),* in which Boyle explains specifically how he thinks that the petrific spirit acts upon matter:

> Atque ut hactenus dicta in rem meam vertam, existimem, quasdam (saltem) ex veris **Gemmarum** quarundam Viribus posse ex eo derivari, Quod dum **fluidam** illae formam obtinebant (vel saltem necdum durantae errant) substantia Petrifica **Minerali** cuidam **Solutioni tincturaeve**, vel alii cuidam **liquori impraegnato**, comixta, haeque postmodum substantiae coagulatae, vel unitae durataeve fuerint in unam **Gemmam**… [514]

That Malpighi's vocabulary mirrors Boyle's is striking given that Malpighi references such phenomena as impregnated liquors and stones all within a discussion of the fecundation of fruit. Outside of the context of Boyle's own works, such references would be simply odd and misplaced.

Furthermore, there are references in the passage which link it to other parts of the *Origin of Gems and Virtues*. For example, that Malpighi mentions both Steno and fossils is

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513 Ibid. p. 91

514 Boyle, *Exerciatio De Origine Et Viribus De Gemmarum*: p. 86; C.f. also, Boyle et al, *The Works of Robert Boyle* v.7: p. 45

not unrelated. Both the Latin and English editions of Boyle's *Origin and Virtues of Gems* include a preface from the editor which quotes Steno's summation of Boyle's argument for the formation of gems from fluid via the petrifick spirit.[515] This three-page long quotation comes from the former's *Prodomus*, in which Steno describes the formation of fossils.[516]

Further still, Malpighi mentions in the passage coagulation and heterogeneity. As discussed in the previous chapter, both coagulation and heterogeneous fluids are key themes for Boyle's treatise. Near the end of this discussion, Malpighi states that the generation of eggs requires an abundance of heterogeneous fluid, explaining the effects of the heterogeneity of matter in terms of fluids, volatile particles and motion. Thus, Malpighi's plastic power is not at all a principle resulting from something like a faculty; rather, it is, in his own terms, part of a distinctly mechanical account of the generation of bodies from heterogeneous fluids which is consistent with the observations made in his embryological treatises published several years earlier.

5.2.3 *Boyle, Malpighi, and Mechanisms*

The idea that fecundation occurs as the result of a mixture is by no means a new one. Indeed, even on the Galenic view the embryo is a result of a mixing of seeds which produces a formative faculty, or plastic and molding power. That power organizes the matter's constitution.[517] What distinguishes Malpighi's plastic powers from those of his medical predecessors is the manner and process by which he conceives that formative agent to work. For Malpighi, as for Boyle, the plastic agent is a distinctively physical one. And like Boyle,

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515 Cf. Boyle, *Exercitatio*: A2- A4; and Boyle et al, *The Works of Robert Boyle* v.7: 5-7

516 Steno, *Prodromus*; Boyle's work was published in 1672, Steno's in 1671.

517 Roger, *The Life Sciences in Eighteenth-Century French Thought*: p. 51

Malpighi is interested in explaining the effects of a plastic power in terms of matter and motion (in this case, the particle accretion of fluids).

Malpighi's discussion of plastic powers has not elicited quite the same response as has Boyle's, but it is nonetheless not without some controversy. In the monumental work, *Marcello Malpighi and the Evolution of Embryology,* Howard Adelmann writes that the plastic virtue is essentially, "a combination of the formal and efficient causes of Aristotle and the plastic or formative faculty of Galen."[518] This reading of Malpighi is problematic because Malpighi's career is marked by his attempt to explain anatomy in terms of the parts of a machine and with explanations totally devoid of reliance on the soul. Adelman's influence can be seen more recently in Catherine Wilson's 1995 book, *The Invisible World,* where she criticizes Malpighi as "thoroughly opportunistic and philosophically inconsistent in his explanatory apparatus, employing now the terms of Cartesian mechanism, which would explain growth as the process of fluid and particle accretion, now the language of plastic powers and unfolding, as each seemed suitable." [519]

Domenico Bertoloni Meli has recently argued contra Wilson that Malpighi likely borrowed the expression "plastic virtue" from Boyle. He bases that argument on Malpighi's claim that any agent—even something like a soul—must act physically upon matter as a machine, regardless of its nature. Here, Malpighi presents a philosophical stance virtually identical to that taken by Boyle in the *Origin of Forms and Qualities.* [520] This claim may well be one with which Wilson would be willing to concede, as she describes the same passage from Malpighi's *Riposta* later in her book

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518 Adelmann, *Marcello Malpighi and the Evolution of Embryology* v. 2: p. 866, n. 12

519 Wilson, *Invisible World:* p. 128

520 Bertoloni Meli, *Mechanism, Experiment, Disease:* p. 232-3

> Borrowing a figure ostensibly of Robert Boyle's, Malpighi argues that if the soul acts on the body in growth, sensation, and motion, it is "forced to act in conformity with the machine on which it is acting, just as a clock or a mill is moved in the same way by a pendulum of lead or stone, or by some animal, or man; indeed if an angel moved it, he would produce the same motion with changes of position as the animals or other agents do." [521]

Yet Malpighi makes no references to a plastic power until after Boyle published *Origin and Virtues of Gems,* despite the fact that *Origin of Forms and Qualities* was in print several years before Malpighi's treatises on the chick. This fact, along with their dialogue on minerals, suggests that Boyle and Malpighi not only shared a similar philosophical treatment of plastic powers, but also had in mind the same specific, corpuscular processes when describing agents involved in generation. The take-away is that Malpighi's appeal to plastic powers as an "explanatory apparatus" is nothing other than a means of describing generation as "the process of fluid and particle accretion."

Both Adelmann and Wilson have been misled by the term 'plastic' (and its Latin cognates) because of the extent to which it is so heavily associated with the faculties of generation. Boyle is markedly helpful to understanding Malpighi because he removes the concept of a plastic power from that traditional world view. Malpighi's plastic power is thus part of a mechanical account of the generation and consistent with the observations made in his embryological treatises published several years earlier, and he relies specifically upon Boyle for the missing explanatory agent in his account. For Malpighi, as for Boyle, that agent is recognized as mechanical because it is understood as a physical agent that acts on matter through motion.

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[521] Wilson, *The Invisible World:* p. 235. Wilson is still wrong to say, as Bertoloni Meli points out, that Malpighi was philosophically inconsistent or opportunistic.

5.3 Filippo Buonanni and the Issue of Spontaneous Generation

5.3.1 *Ricreazione and the Generation of Mollusks*

Among the books gifted to Boyle and the Royal Society by Malpighi was a copy of *Ricreazione dell'occhio e della mente nell' osservatione della chiocciole,* published in 1681.[522] *Ricreazione* was famed because of its detailed observations of seashells and mollusks. The work's importance lay in its very detailed illustrations and categorization. Its author, Filippo Buonanni, was a student of Athanasius Kircher and fellow Jesuit who spent his entire life in Rome. He was one of the most learned Jesuit priests of the second half of the seventeenth century. He taught mathematics at the Collegium Romanum, and he would later become curator of the Kircherian museum.[523]

Ricreazione is devoted to explaining the generation of various kinds of mollusks. Being the good Aristotelian he is, he describes them in terms of spontaneous generation. The subject of spontaneous generation comes up early in the text with the subject of snails, "Whether snails are generated by propagation of a species, or rather are born spontaneously from themselves." [524] Buonanni begins the chapter by explaining that Aristotle flatly denies the propagation of the species in Testaceous animals, claiming instead that they are born spontaneously from putrefied matter. [525] Testaceous animals, according to Aristotle, are animals such as barnacles, mollusks, sponges, and shellfish whose correlative parts are like

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522 Malpighi et al, *The Correspondence of Marcello Malpighi*: 906 n.3; Boyle letters, M-P no. 10 CALS

523 Koertge, *Complete dictionary of scientific biography*: p. 592

524 "Quaeritur an Cochleae propagatione Specierum generentur, aut potius sponte ex se nascantur." Buonanni, *Ricreazione*: p. 22

525 "Propagationem specierum in Testaceis negauit Aristoteles; eaque, sicuti Insecta, e massis putrefactis sponte nasci affirmauit." Buonanni, *Ricreazione*: p. 22

plants, causing them to lack the sensation and properties of motion shared by most other animals. Their generation is always spontaneous, though in some cases this happens in the form of "shoots." [526]

Buonanni continues by citing Aristotle's metaphysics, where Aristotle has a term for creatures of this kind: *spontaneous*. Spontaneously generated animals, Buonanni explains, are those living beings whose "matter is able to be moved even by itself in just the same way that the seed usually moves it in the generation of other animals…" [527] He addresses Redi's experiments specifically in the following chapter, stating that he may well find Redi's assertions that spontaneous generation never happens ridiculous. Redi, who re-affirmed consistently in his observations of insects that ordinary flies and gnats do not generate from either plants nor from the putrefied meat, but carry seed. Buonanni even goes so far as to say that by what means Redi tested his experiment, he does not know. [528]

As Chapter 4 explains, Redi saw himself as refuting Kircher's Doctrine of Palingenesis when he proved that maggots were not produced from putrefied matter, and indeed Redi speaks frequently of Father Kircher in his treatise on insect generation. Because Buonnani was both a devoted student of Kircher and a self-identified Aristotelian, it is not at all surprising that he would speak disparagingly of Redi's experiments.

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526 Aristotle, GA: 761 a: 15 - 763 b: 15

527 "…materia potest se ipsa moueri eo motu, quo semen mouet in generatione aliorum Animalium, qui motus dicitur spontaneus," Buonanni, *Ricreazione*: p. 23. Cf. Aristotle, Met. 1034b: 1-5

528 Irridebit sortasse mihi haec asserenti D. Redi, qui in observationibus Insectorum constanter affirmat: nullam accidere generationem spontaneam, sed omnes , quae videnentur in corporibus anima destitutis , accidere, ait ipse , ita tamen ut muscae ordinariae, & culices, semen antea suum eo deportarint, quo deficiente, ut alias dixi, neque ex herbis, neque ex carnibus putrefactis, vel qualicunque alia re, actu non vivente, quidquam nascetur. At quo nam pacto experimentum a me pluries factum oppugnaret, nescio. Illud subijciam." Buonanni, *Ricreazione*: p. 35

5.3.2 *Response to Ricreazione*

Due to its insistence on spontaneous generation, the book was not well received.[529] To say that living creatures would generate spontaneously after both Malpighi and Redi had published their experiments was an inexcusable transgression. For their part, Malpighi and Bellini frequently make disparaging references to Buonanni in their private correspondence. (Buonanni, sadly, did not reciprocate these sentiments but rather held Malpighi in high esteem, wishing to smooth matters over with him.[530]

Redi eventually responded to Buonanni in 1684 with *Osservazioni intorno agli animali viventi che si trovano negli animali viventi* (*Observations of living animals that are found in living animals*). The Latin edition, *Observationi intorno agli animali viventi negli altri animali viventi,* came out later that same year. As its title suggests, *Osservazioni* deals primarily with the generation of parasitic worms, and Redi provides within the treatise a continued defense of his claim that all animals originate from eggs.[531]

The following spring in 1685, Bolognese naturalist Giovanni Battista Trionfetti published a treatise that appears at least inspired by Buonanni. [532] *Observationes de ortu, ac vegetatione plantarum,* was the result of Trionfetti's experience and trials as an herbalist. [533] Like Buonanni, he challenged Redi's claims that all life comes from eggs, as well as his

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529 See, for example, Malpighi, et al, *The Correspondence of Marcello Malpighi*: p. 895, p. 931, p.1061, and p. 1176.

530 See Malpighi, et al, *The Correspondence of Marcello Malpighi*: p. 182 n. 9

531 Cf. Redi, *Osservazioni intorno agli animali viventi che si trovano negli animali* viventi: pp. 57-60. For more on Redi's ovism see Roger, *The Life Sciences in Eighteenth-Century French Thought*: p.207

532 Malpighi, for one, was convinced that Trionfetti had composed the book at Buonanni's insistence, as becomes apparent in his personal correspondence. See Adelmann, *Marcello Malpighi and the Evolution of* Embryology: v. 1, p. 495.

533 Cf. Bertoloni Meli, *Medicine, Mechanism, Disease*: p. 255

unwavering rejection of spontaneous generation. *Observationes de ortu* focuses on the origin and generation of plants.

Trionifetti argues that plants do not come from seeds or eggs, but from the center leaves or foliage (at medijs folijs). Part of his argument rests on the observation that not all plants have the same parts, and some do not have juices. Thus, the active particles (actiuiorum particularum) would have to be within a close vicinity of the eggs, or the "plastic parts" (plasticarum partium) in order for plants to originate from eggs. What we observe, however, is that these parts of plants are often covered by shells (as in nuts) or very thick membranes that would prevent the so-called plastic parts from contact with any active particles. [534] He goes on to provide an experiment that aims to prove that plants do not actually come from seeds. Namely, he claims to have broken up and burnt the stems of spurges and, after burying them, witnessed plants arise from the buried ashes.[535] In this sense, the experiment described by Trionfetti bears remarkable similarity to Kircher's own claims of palingenesis, and indeed goes right in the face of Malpighi's own claims of preformationism. Buonanni, unsurprisingly, had high praise for the book.

Buonanni ultimately replied years later in 1691 at Rome with *Observationes circa viventia, quae in rebus non viventibus reperuntur.*[536] *Observationes circa viventia* defended his earlier claims about the generation of mollusks and attempted to prove that, contra Redi, spontaneous generation could happen without the use of seeds. A notable feature of the book's reception is that it was criticized on methodological grounds just as much for its

534 See Trionifetti, *Observationes de ortu et generatione plantarum*: pp. 55 ff.
535 Adelman, *Marcello Malpighi and the Evolution of Embryology*: v.1 p. 495
536 Cf. Fazzari, *Redi, Buonanni e la contraversia sulla generazione spontanea*: pp. 99 ff.

content. Malpighi, for example, complained in a letter to Count Luigi Marsili that Buonanni's text

> …corrupts the true method of philosophizing a posteriori, rendering everything uncertain and every possible extravagance as credible. It maltreats Redi and other Moderns on some matters, notably on galls, touches me [i.e, Malpighi], for Buonanni think that their flies are produced spontaneously and not from eggs deposited in them; and he proves all this, not by a series of observations of his own, but by the conjectures and assertions of others. [537]

Buonanni's admiration to Aristotle and aversion to experiment, however unfair the objection, would understandably be viewed unfavorably by Boyle.

5.3.3 *Boyle, Malpighi, and Buonanni*

Malpighi's correspondence with Boyle through Fr. Carlo Ronchi strongly suggests that Boyle, upon hearing of Buonanni and Trionfetti, resolutely sided with Malpighi on the subject of generation. Malpighi wrote to Ronchi so to communicate with Boyle, anxious to know whether the latter had received the Portetta crystals sent by Malpighi. In gifting to Boyle a copy of *Ricreazione* Malpighi also provided an account of Trionfetti's subsequent treatise, eager to know of Boyle's thoughts and response. [538] (As with other letters written by the Bolognese physician, Malpighi suggests to Ronchi—and, by proxy, Boyle—that Trionfetti composed the book at Buonanni's instigation.) [539] Fr. Ronchi's response to Malpighi is described at end by Adelmann:

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[537] See Adelmann, *Marcello Malpighi and the Evolution of Embryology*, v. 1: p. 636.

[538] Adelman, *Marcello Malpighi and the Evolution of Embryology*: v.1 p. 498

[539] Adelman, *Marcello Malpighi and the Evolution of Embryology*: v.1 p. 498; *Bertoloni Meli, Mechanism, Experiment, Disease:* p. 255

> Boyle, Father Ronchi also reported, was no little astounded at the simplicity of those who had usurped and distorted Malpighi's doctrines to lend credit to a paradox no longer current regarding the generation of molluscs found on mountains and to extend it to the generation of plants. He had assured Father Ronchi that the mode of propagation of plants described as new by Trionfetti was a very old story in England; it had never occurred to him that it was desirable or possible to convey that idea that such propagation or generation is effected *ex putri*, and still less could this be true of the generation of testacea. [540]

Boyle's response undoubtedly provided the vindication Malpighi may have hoped for.

Although it was ultimately his rejection of Malpighi's and Redi's experiments that made him the subject of derision by Boyle, Malpighi, and their friends, Buonanni's devotion to Aristotle placed his ideas squarely in a different contrast class, as Buonanni ultimately retains the very substantial forms and soul that they seek to eliminate from mechanical explanations. This brief historical episode helps to demonstrate the diversity with which the problem of generation was addressed: Even after Redi's work, spontaneous generation was still an ongoing debate.

One key feature coming out of Buonanni's approach to nature, as observed by Bertoloni Meli, is his rejection of the uniformity of nature shared by Malpighi and other anatomists. That is, Buonanni was quick to point out that just because an experiment focused on one species, its conclusions could not, and should not, generalize to the results to others. This philosophical attitude of nature was shared by another Italian anatomist, Galenist physician Giovanni Sbaraglia.

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[540] Adelman, *Marcello Malpighi and the Evolution of Embryology*: v.1 p. 499

5.4 Giovanni Sbaraglia and the Galenists

5.4.1 *The Galenic Opposition to Mechanistic Anatomy*

One of Malpighi's most ardent adversaries was actually a student of Trionfetti, fellow Bolognese physician and anatomist Giovanni Sbaraglia. Sbaraglia's own practice of medicine was, in many ways, committed to a Galenic approach and understanding of the body. In order to understand this perspective more deeply, it might be fruitful to look briefly at what sort of explanation Galen seeks to give.

Although Galen does at times appeal to the structure of an organ to explain the manner in which it functions (the effects of which could certainly be explained mechanically) an understanding of that structure is not sufficient because the faculties ultimately responsible for those processes of living organisms are unique to the living soul. The relationship between the body and soul, according to Galen, is explained nicely by Mark Schiefsky:

> Like Aristotle, Galen identifies the body as the 'instrument' (organon) of the soul, the tool that enables it to carry out its characteristic activities. The body and its parts are for the sake of the soul, in the sense that they are adapted to the performance of the organism's activities. If one is to understand why an organism has the parts it does, it is necessary to have knowledge of its characteristic activities, as expressed in the 'character and faculties' of its soul.[541]

The influence that Galen's method of investigation and conception of the living body had upon Sbaraglia is readily apparent in his own 1697 *De recentiorium medicorum studio,* where he criticizes modern anatomists in failing for achieve anything new for the practice of

[541] Schiefsky, *Galen's teleology and functional explanation:* p. 8

medicine. Specifically, he complains of the moderns that while their anatomical investigations have proven previous theories about the function of certain organs wrong, they've yet to explain the actual *purpose* of those organs.[542] He later continues by stating that

> Pleurisy, asthma, and peripneumonia are not benefited any more by present-day practice than they were by the ancient, and if the chemists have contributed anything new, the schools do not enjoy this advantage from more thorough anatomical investigation…What should be studied is not the composition of the parts but the features and causes of diseases that are common and universal. Even when corrosive juices appear in definite places, it is the fluid that should be considered, not the finest structure, which generally requires to be repaired, whatever it may be, and if a particular remedy is required, use, experience, and analogy will suggest it; it will not be deduced from the finest components of the parts. [543]

Thus, his criticism of modern anatomists, like Malpighi, is two-fold: On the one hand, knowledge of the structure and parts will not bring forward any new knowledge of bodily processes, as it cannot explain the causes. And on the other, investigations of anatomy per se does not contribute to the actual practice of medicine, which considers the nature and health of the patient as a whole.

5.4.2 *De vivipara generatione scepsis*

Distinctive to the Galenic view of generation is its absolute and unwavering commitment that each parent produces semen that is responsible for shaping the matter of an embryo via the faculties. Sbaraglia's views about generation thus adhered to this commitment, which put him at odds against Harvey's pervading doctrine of "Ex Ovo

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542 Adelmann, *Marcello Malpighi and the Evolution of Embryology*: v. 1, p. 560

543 Sbaraglia, *De recentiorium medicorum studio*, as translated in Adelmann, *Marcello Malpighi and the Evolution of Embryology*: v. 1, p. 561

Omnia." That antagonism towards the ovist doctrine is readily apparent in his own treatise on generation, *De vivipara generatione scepsis*, published 1696 in Vienna.

Early in its dedication to Holy Roman Emperor, Leopold I Sbaraglia is explicit about his desire to progress against the more common idea of the moderns– viviparous animals generating from eggs. The very first chapter begins, in fact, with his criticizing the notion that all life must derive from a single structure. [544]

One of the more interesting chapters in Sbaraglia's text addresses experiments that had been performed previously by Nicolaus Steno during the latter's stay in Florence. Steno had dissected a viviparous dogfish shark years earlier in 1667 with the aid of his close friend, Francesco Redi. During his investigations of the dogfish, he noted similarities between the generative organs of the dogfish and that of the oviparous sting-ray that he had dissected several years earlier. His observations led him to the conclusion that, "the testicles of women are analogous to the ovary, whatever the manner the eggs themselves, or the matter that they contain, pass from the testicles to the uterus."[545] Thus, from this discovery he surmised that that the egg was not produced by the uterus, as postulated by Harvey, but came instead from those so-called female testicles, which he rightly identified as ovaries.[546]

But the role of the female testicles, i.e. the ovaries, posed a serious difficulty for those who would claim that all life (even the so-called viviparous animals) come from eggs. Especially problematic was the shape of the Fallopian tubes, which are positioned roughly an inch away from the ovary when at rest. This gap was first observe by Fallopius himself,

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544 Sbaraglia, *De vivipara generatione scepsis*: p. 1

545 Steno as quoted from Cobb, *Generation*: p. 99.

546 Roger, *The Life Sciences in Eighteenth-Century French Thought*: p. 207; Bertoloni Meli, *Mechanism, Experiment, Disease*: pp. 209, 217

who summarily concluded that the tubes could not serve as a passage way for the seed. The gap posed a similar problem for the ovists, who thus needed to explain exactly how the egg would travel from the ovary and to the womb. Nicolaus Steno's famed experiments on the dogfish shark resolved this issue, as his dissection demonstrated that the eggs had traveled from the ovary and into the womb of the shark despite the gap.[547]

Sbaraglia criticizes Steno's experiment on the grounds that the latter never explains just how it is the egg can travel from within the horn of the ovaries or to the uterus. Further, Steno is unwilling to stipulate for clarity's sake when dissecting the dog-fish shark whether the transmitted material is contained in the uterus, from within the (female) testis, or the egg itself. [548] Sbaraglia ultimately denies that this movement can occur, thus rejecting the significance of Steno's discoveries.[549]

5.4.3 *Modus Mechanicus*

Although Malpighi and Sbaraglia vehemently disagreed about function of the so-called female testicles and the nature of the egg, a more contentious point between them rests in their very methodological approach. Recall from earlier in this chapter that Malpighi's *Riposta* to Giovanni Sbaraglia maintains that the mode of operation of the soul is mechanical in virtue of its having to act in conformity with the machine. That is, regardless of whether a clock, for example, is moved by a man, a pendulum, or even an angel, the parts of the machine will be forced to act on matter in terms of motion. This feature of the soul, then,

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547 Roger, *The Life Sciences in Eighteenth-Century French Thought*: p. 221

548 Dubitant etiam ovorum Patroni in oviparis, quomodo ova in cornibus, aut in utero augeantur. Stenon noluit definire ut in dissecto pisce ex canum genere patet, an in uterum ex testibus an ovis contenta materia transmittatur, quo dubio evitavit difficultatem; Sbaraglia, *De Vivipara:* p.141-142

549 Ibid. pp. 142 ff.

makes its actions mechanical even if it is the soul that is ultimately the agent responsible. This philosophical stance, as we have seen, is one that Malpighi shared with his highly esteemed English colleague, Robert Boyle.

Malpighi elaborates his *Riposta* to Sbaraglia, stating that there are, "many ways in which these mechanics [i.e. mechanical operations] are disturbed, and the physician need not cure the faculties of the operating soul but must remove the impediments and what is disturbing the movements of the part. If this is so," he continues, "it is clear that medicine can be founded upon *a priori* reasoning, that is, upon the knowledge of causes and the mechanical means by which Nature operates both in health and disease; and if we proceed with the knowledge of medicines gained from experiment and mechanics, cure can be effected." [550]

Sbaraglia replied in turn with a rather harsh criticism to this argument, frequently referring to Malpighi as his antagonist (*antagonista*) and adversary (*adversarius*). His response is an important one for understanding the episode, too, because it offers the modern reader a unique perspective from a contemporary of both Boyle and Malpighi who, in many ways, defends a distinctly Galenic conception of the body. In his point-by-point rebuttal of Malpighi (where he frequently quotes his adversary verbatim), Sbaraglia never once denies that his opponent has presented a mechanical argument of medicine and the body. Nay, he laments the very fact of it, because such a mechanical explanation is neither sufficient nor helpful in the actual practice of medicine.

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[550] Malpighi, *Riposta,* as translated by Adelmann, *Marcello Malpighi and the Evolution of Embryology:* v. 1, p. 571.

His main complaint is the *modus mechanicus*, i.e. the mechanical mode, of explanation of Malpighi's account.[551] In other words, the explanation is insufficient and methodologically problematic because it cannot provide an account for the nature of the individual. For Galen, parts of the body exist for the sake of the soul, which is guided by its various faculties. Because the mechanical operations that natures uses for things like motion, sensation, respiration, etc. are hidden and varied, one cannot admit Malpighi's conclusion *a priori.*[552] The method of investigation should consequently begin with the nature of the patient rather than the structure of the parts.

Malpighi, however, attempts to demonstrate that the operation of the soul is not bound by the *faculties*, but by *motion*. Rather than begin with the nature of the patient and those processes most closely associated with the *telos* of the body, he employs an utterly backwards approach that begins with the structure of the parts and ends merely with a description of its effects. From Sbaraglia's perspective—that is, one informed by a traditionally Galenic understanding of the body—the kind of explanation posited by Boyle and Malpighi is considered to be a distinctly mechanical one. Both Boyle and Malpighi bracket off whatever agent is not immediately available to them in experiment, describing its effects in terms of matter and motion. In doing so, they shift the conversation from ontology to mode of operation. And it is that mechanical explanation that makes Malpighi's account totally unacceptable to the likes of a Galenist such as Sbaraglia.

Further, Sbaraglia denies the very mechanical principle that Malpighi advocates: that the soul or angel must act in conformity with the machine that it is acting upon. For an

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551 Cf. Bertoloni Meli, *Mechanism, Experiment, Disease:* p. 324.

552 Sbaraglia, *Oculorum et Mentis:* p. 252

angel, unlike a brute animal, is immaterial and not bound to place. But in order to act upon the machine, which is physical, it would have to move from one extreme to the other, with no intermediary. As such, both the manner in which it operates and its effects—the motion it produces—would not be the same. "Hence," Sbaraglia writes, "the entire text of the antagonist is struck down when it says [of a machine that it] must necessarily act in conformity, just as a clock or a mill is moved in the same way by a pendulum of lead or stone, or by some animal, or man; and even if an angel had moved it, he would produce the same motion with changes of position as the animals or other agents do." [553] Ultimately, he thinks that Malpighi is simply wrong to say that the soul could act in a way that is mechanical, "because when the soul uses the machine, its operation is one of life, and not mechanical."[554]

5.4.4 *Entelechia seu Anima Sensitiva Brutorum*

Sbaraglia's steadfast opposition to mechanistic anatomy is once again apparent in his posthumous *Entelechia seu Anima Sensitiva Brutorum* (On the Entelechy or Sensitive Soul of Animals). Published several years after Sbaraglia's death, the treatise is described as a "Demonstration" against Cartesians and mechanistic anatomy. The work is rich in content, a good deal of which is sadly beyond the scope of this chapter. We can, nonetheless, glean

553 "Ac si brutum esset aqualiter in loco, ac Angelus, qui non est in loco ad modum quantitatis continuae per commuensurationem ad locum, sed per operationem, quae non dependet a loco, sed illum sibi subiicit; unde nisi pracederet aliquod decretum, esset inaequalis motio, & juxta hoc principium Angelus transit ab uno extremo ad aliud sine medio; quare universus hic textus Antagonistae est configendus, dum ait; necessario agere ad instar horologii, vel molendini aqualiter moti a plumbeo pendulo, vel saxo, vel a bruto, aut ab homine, immo si ab Angelo moveretur, eadem sequeretur motio situum variation, ut efficient bruta." Sbaraglia, *Oculorum et Mentis:* 253.

554 "… quia quando anima utitur corpore, & est principium motivum machinae, operatio est vitalis, adeoque non mechanica" Sbaraglia, *Oculorum et Mentis:* p. 252

further insight regarding Sbaraglia's views on mechanistic anatomy from a few key passages within *Entelechia's* preface.

The first of these relevant passages comes from a discussion of mechanists such as Gassendi, Galileo, and Descartes (or even ancients such as Democritus or Leucippus) Sbaraglia says that, "a serious error seems to appear when the mechanists explain all the forces of nature through motion, shape, and other mechanical affections of particulate matter." [555] Not only does he take for granted the "other mechanical affections" of matter, but he is quick to include Boyle among those who err, on the basis of the *Physico-Chymical Essay*, in which Boyle discusses his experiments on the redinigration of Nitre, and again in the experimental section of the *Origin and Forms of Qualities*, where Boyle rejects the Scholastic substantial form.[556]

Another insightful passage from Sbaraglia comes from his considering the possibility of a mechanical generation of plants, which he says cannot be produced by only mechanical pieces (*fractura*). Thus, while he can freely admit that the generation of plants requires both seed for their propagation and some agent that uses organs as mechanical instruments, he criticizes his adversary (almost certainly Malpighi) for holding that generation properly happens without force, when he himself admits a force—an agent that *seems like* a plastic or architectonic faculty.[557] Worth noting, though, is that even as Sbaraglia addresses some of the ontological tension surrounding Malpighi's own accounts

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555 "… cum omnem naturae vim per motum, figram, & ceteras particularum mechanicas affectiones Corporum explicent, in hoc gravi errore versari videntur;" Sbaraglia, *Entelechia*: pp. 2-3

556 Ibid. p. 3

557 Quod unum quidem cum ità sit, ut a sola fractura mechanica produci nequeat: propterea fateri mihi liberè posse videor, Plantarum generationem, atque illarum semen propagationi necessarium, opus esse illius naturae: agentis, quae tanquam instrumentis utitur mechanicis Organis ad agendum. Sbaraglia, *Entelechia*: pp. 10-11

of generation, he still does not deny that the explanation provided by Malpighi is a mechanical one. It is, rather, mentioned in the very introduction of dissertation against mechanistic anatomy. His dissatisfaction with Malpighi's account of generation rests mainly with its rejection of any kind of faculty or formal cause.

And so we can see from the preface alone how generation plays a key role in Sbaraglia's dissertation against mechanistic anatomy, and that an attempt to explain generation in terms of the mode of operation without appealing the natural faculties is ultimately for him an unsatisfactory account.

5.5 Conclusion

The second half of the seventeenth century saw a plethora of discoveries and controversies regarding the nature of animal generation, many of which occurred from within the community of Italian anatomists, like Malpighi, who were dedicated to and influenced by the new and prevailing mechanical philosophy. Because of his inclusion and status within the Royal Society, Malpighi's correspondence serves as a link between members of the Royal Society in England and the community of other Italian anatomists with whom he corresponded. Many of the other anatomists wrote to Marcello Malpighi inquiring specifically about Robert Boyle. As a consequence, Malpighi's correspondence proves to be informative about Boyle's reception by other anatomists, like Bellini. This community of scholars, while receptive to Boyle, was somewhat removed from him due to due limitations imposed not just by geography, but by religion and language as well. Nonetheless, this chapter demonstrates how Boyle's mechanical program and ideas about plastic powers

directly influenced Malpighi's own works on the subject of generation, and indeed Boyle's influence vis-à-vis animal generation has been significantly under-appreciated.

Looking at Boyle's reception by the community of Italian scholars, anatomists, and naturalists further speaks to present-day literature concerning both Boyle and the Scientific Revolution. Alan Chalmers, for example, has consistently argued against any productive link between Boyle's mechanical philosophy and his science, stating instead that Boyle's success as a scientist was "*in spite*, rather than because, of his allegiance to that [mechanical] philosophy."[558] He goes to argue that, "the case that Boyle makes for the mechanical philosophy can be seen to be very weak indeed." [559] At the crux of Chalmers' argument is Boyle's reliance in his chemistry on properties of matter (like plastic powers) which are not reducible to shape, size, and motion.

Boyle's interaction with and influence upon Malpighi, however, are one example where Boyle's allegiance to the Mechanical Philosophy provided the direct means for his scientific success. That is to say, it was in virtue of its mechanical operations that Malpighi adapted Boyle's notion of a plastic power—an organizing and coagulating force—within his own anatomic writings and research. Other prominent figures within the community of Italian anatomists shared in their high esteem of Boyle largely because of his mechanical approach to matters of chymistry and experiment.

But *is* Boyle's account of plastic powers and generation mechanical? I would say that it is. More importantly, so did his contemporaries. In stipulating that the plastic power must

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558 Chalmers, *The Lack of Excellency of Boyle's Mechanical Philosophy:* 541. C.f. Chalmers' 2009 book, *The Scientist's Atom and the Philosopher's Stone.*

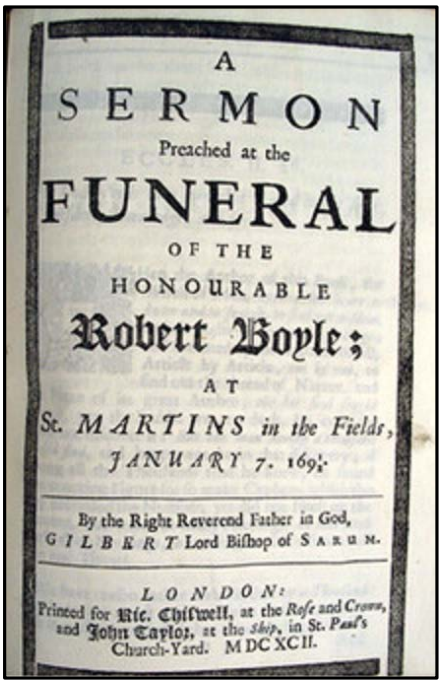
559 Ibid.

act physically upon matter, Boyle allows for the possibility of a mechanical plastic power. Malpighi seized upon that possibility. Because the micro-anatomists dealt with a variety of causes not yet known to them, Boyle's nescience about ontology and emphasis on mode of operation would make him an attractive alternative to Descartes. Their reception of Boyle, moreover, goes deeper than that of brilliant minds apt to make the same mistakes as one another. Malpighi and his allies were not simply confused in their conceptions of generation at the corpuscular level. Their lack of confusion becomes apparent when we expand the analysis of generation to include those like Buonanni and Sbaraglia who explicitly reject the Mechanical Philosophy of Boyle, Malpighi, Bellini, and their peers.

Triangulating between (1) Boyle, (2) Sbaraglia, Buonanni, and those committed to a Galeno-Aristotelian conception of the body, and (3) Malpighi and his supporters allows us to disentangle ideas of mechanical and even non-mechanical explanation regarding experimental investigations in the seventeenth century. Anatomy is a uniquely complex subject matter, and explaining even the most basic functions was no easy task. To provide a coherent account of animal generation (or even that of plants), then, would become the philosophical challenge of the century. Natural philosophers like Malpighi who were experienced in both anatomy and the practice of medicine were consequently willing to black-box those agents not yet discovered in their anatomical investigations with the understanding that such agents must necessarily act mechanically. This sort of approach became a common application of the Mechanical Philosophy, and the admitted nescience involved made the explanation no less a mechanical one. For the present-day reader to say otherwise is to commit the mortal sin of anachronism.

Conclusion. ***Boyle's Seminal Ideas***

Robert Boyle died in the middle of the night between December 30th and December 31st in 1691. His death was the result of a stroke, and news of it reverberated throughout the scientific communities of Britain and Europe. In Italy, Malpighi had learned of Boyle's death from his good friend, Silvestro Bonfigiuloli in February, 1692.[560] Later in August of that same year, Malpighi wrote to Count Luigi Ferdinando Marsili lamenting that he had no news from the Royal Society since Boyle's death. In the same letter, he also complained that Buonanni had recently published yet another book, *Observationes circa viventia, quae in rebus non viventibus reperuntur*, which attempted to prove spontaneous generation without seeds.[561]


A
SERMON
Preached at the
FUNERAL
OF THE
HONOURABLE
Robert Boyle;
AT
St. MARTINS in the Fields,
JANUARY 7. 169½.
By the Right Reverend Father in God,
GILBERT Lord Bishop of SARUM.
LONDON:
Printed for Ric. Chiswell, at the Rose and Crown,
and John Taylor, at the Ship, in St. Paul's
Church-Yard. MDCXCII.

My research shows that Boyle's works on generation had a profound impact upon the community of Italian anatomists in virtue of his mechanical approach. Prominent micro-anatomists such as Malpighi and Bellini accepted his notion of a plastic power in order to explain their experiments within their own anatomical writings and research. Their enthusiasm for Boyle was, moreover, because of his mechanical approach to matters of chymistry and experiment. And yet, even those who vehemently rejected a mechanists'

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560 Adelmann, *Marcello Malpighi and the Evolution of Embryology*: v. 1, p. 630. English cleric and Royal Society fellow Thomas Gale had actually written to Malpighi earlier with news of Boyle's passing, along with copies of Boyle's *Medicina hydrostatic* and *Experimenta & observationes physicae*, but Malpighi unfortunately never received the message. See Ibid. p. 629.

561 Ibid. p. 636; Cf. Ch. 5, pp. 194-195 above.

ontology, such as Giovanni Sbaraglia or G.B. Trionifetti, also rejected Boyle's account in virtue of its mechanical nature.

The consequences of Boyle's reception are not limited to Boyle scholarship, but rather have serious implications for what it meant in the seventeenth century to provide a mechanical explanation. A considerable amount of the secondary literature on Early Modern natural philosophy emphasizes the distinction between (1) a general clock-work mechanical view of the universe and (2) a more restricted ontological view of inert, particulate matter that works mechanically. That distinction is undeniably an important one for understanding works from the early modern period. But Boyle's corpuscular philosophy is somewhat unique in making this distinction blurry because the clock-work mechanisms function at the corpuscular level. In order to understand the intricacies of his project, I have argued instead that we separate the issue of mechanical ontology from that of a mechanical explanation.

Boyle's ontology, while not necessarily reductive, is nonetheless mechanical in a strict sense because the chymical powers to which he appeals are determined by and entirely dependent upon lower levels of corpuscular structures. That position put Boyle in sharp contrast with Galenists, Scholastics, and Neo-Platonists. But it likewise distinguishes him from other mechanists, a claim that Boyle frequently makes about himself. On the other hand, for Boyle and for many of his contemporaries a mechanical explanation is one which can explain phenomena, including the many processes of complex living beings, in terms of the physical interactions of bodies without an appeal to immaterial causes such as the faculties of the soul. A close examination of how Boyle treats the problem of generation throughout his life provides important insight about his mechanical program and theology,

contemporary views about the necessary conditions for mechanical explanation, and the centrality of the life sciences and of geology to the Scientific Revolution.

Generation played a huge role in Boyle's understanding of natural philosophy. Generation helped to serve as the context by which Boyle was introduced both the chymistry and anatomy, and it remained at the forefront of his concerns as he experimented with chymistry, pneumatics, minerals, anatomy, transmutation, and plants. He addresses the problem of generation in more than twenty treatises spanning roughly forty years. Boyle's understanding of the forces of generation, moreover, would remain closely tied to his ideas about God and the biblical account of Creation throughout his life. Given the magnitude by which the problem of generation informed Boyle's research and experimental program, that his views on generation have not receive more attention in the secondary literature is really quite surprising.

Examined within the context of his contemporaries, Boyle's treatment of plastic powers, seminal principles, and petrifick spirits helps to elucidate ideas about generation and about the mechanical philosophy more generally. What makes the seventeenth-century a fascinating and magnetic area of study simultaneously makes it complicated and requires careful scrutiny. That feature is that the seventeenth-century is a time of great transition. As a consequence of that intellectual transition, terms such as 'elasticity', 'gravity' and 'plastic powers' are in a constant flux. Boyle provides just one example of how a concept of a plastic power changed from one associated with immaterial forces and faculties to one which is contextualized within the mechanical philosophy. Even among his contemporaries there was a vast array of concepts associated with this formative force.

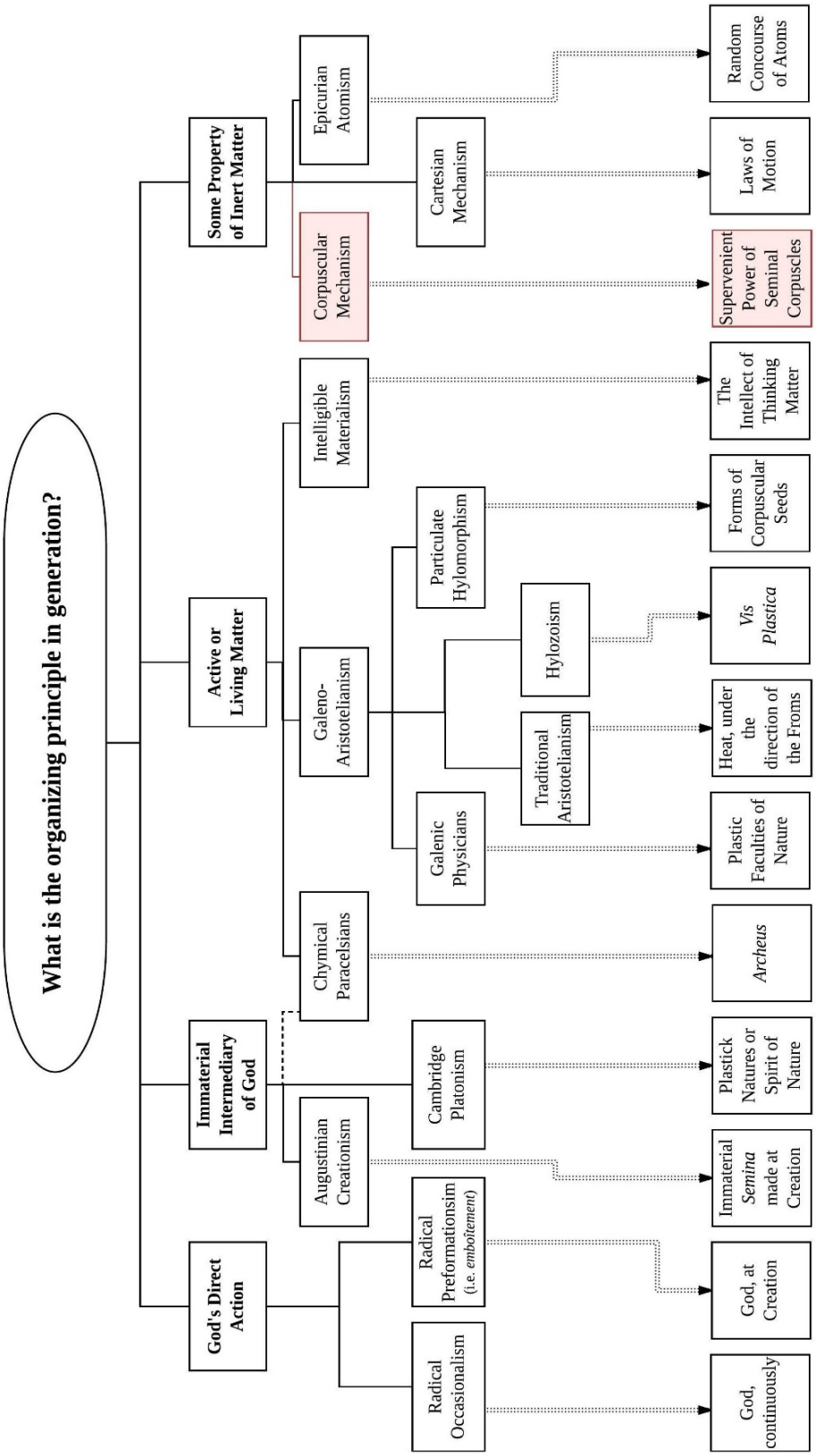
That several of his contemporaries accepted the mechanical nature of Boyle's account and of his ontology suggests that the "mechanical philosophy" was considerably more varied and nuanced than present historians recognize. A large part of the problematic historiography is due to the use of Descartes as the yard-stick for mechanical. But Boyle had strong epistemic and theological reasons for rejecting aspects of Descartes strictly reduction ontology. And those dealing with the complexities of anatomy were similarly more willing to black-box the agents as it were and accept in turn a sort of promissory note for a mechanical account. That contemporaries readily accept these terms suggests the strong need to re-evaluate present narratives about the histories of science, anatomy, and philosophy.

Finally, and most importantly, this episode illustrates the significance of the life sciences and of geological investigations to the "Scientific Revolution" of the seventeenth century. Though the past thirty years has seen progress slowly made towards establishing research that examines the role of medicine and anatomy in the "Scientific Revolution", it is only until very recently that historians have begun to investigate this long, neglected aspect. The subject of generation, and especially Boyle's own treatment of it, suggests that more work on this matter needs to be done. Similarly, the investigations of geological studies in the early modern period has been somewhat neglected, and I hope to have shown the significance it had among many of the natural philosophers discussed in this dissertation.

Generation is unique in that it accounts for the production of animal, mineral, and vegetable alike. Yet, research on the problem of generation often separates treats these topics as independent of one another. The abundant literature on animal generation, moreover, strongly emphasizes important debates between preformation and epigenesis. But my research on Boyle and his reception shows that the question of embryonic development

addresses only one of many important aspects in the problem of generation, and the question of how matter is organized and by what forces was central to thinkers of the seventeenth century. The question of what agent is responsible for organizing matter during generation was what Boyle attempted to solve in presenting his own account of the plastic power of seminal corpuscles and of petrifick spirits. In doing so Boyle managed to mechanize generation, and his seminal ideas on that topic helped to define seventeenth-century science.

Appendices


What is the organizing principle in generation?
God's Direct Action
Immaterial Intermediary of God
Active or Living Matter
Some Property of Inert Matter
Radical Occasionalism
Radical Preformationsim (i.e. emboîtement)
Augustinian Creationism
Cambridge Platonism
Chymical Paracelsians
Galeno-Aristotelianism
Intelligible Materialism
Epicurian Atomism
Corpuscular Mechanism
Cartesian Mechanism
Galenic Physicians
Traditional Aristotelianism
Hylozoism
Particulate Hylomorphism
God, continuously
God, at Creation
Immaterial Semina made at Creation
Plastick Natures or Spirit of Nature
Archeus
Plastic Faculties of Nature
Heat, under the direction of the Froms
Vis Plasticca
Forms of Corpuscular Seeds
The Intellect of Thinking Matter
Supervenient Power of Seminal Corpuscles
Laws of Motion
Random Concourse of Atoms

	Reference to 'Plastick'			Explaining:			In the Context of:					
	Title	Year Pub	Page Reference	Minerals	Animals	Plants	Seminal Principles	Power of the Soul	World Soul	Chymists	God	Other
1	History of Fluidity	1661	v. 2, p. 192	x								
2	Sceptical Chymist	1661	v. 2, p. 258	x	x	x	x			x		Formative Power
3	Sceptical Chymist	1661	v.2, p. 276		x	x	x					
4	Sceptical Chymist	1661	v.2, p. 348	x						x		
5	Sceptical Chymist	1661	v.2, p.351	x		x	x					
6	Usefulnesse of Natural Philosophy	1663	v. 3, p. 225								x	Living engines
7	Origin of Forms and Qualities	1666	v. 5, p. 362-3	x			x					Seminal form; denies
8	Origin of Forms and Qualities	1666	v. 5, p. 383-4		x			x				Contra Harvey
9	Origin of Forms and Qualities	1666	v. 5, 389			x						Plant buds
10	Origin of Forms and Qualities	1666	v. 5, p. 433	x			x					Transmutation
11	Origin of Forms and Qualities	1666	v. 5, p. 436				x					Transmutation
12	Usefulnesse of Experimental Natural Philosophy, 2nd Tome	1671	v. 6, p. 498									Manual skill, plastic art; plaster
13	Origin and Virtues of Gems	1672	v. 7, 28-29	x	x	x	x					
14	Origin and Virtues of Gems	1672	v. 7, p. 30	x								Plastic form
15	Excellency of Mechanical Hypothesis	1674	v. 8, p. 108						x			
16	Considerations About the Possibility of the Resurrection	1675	v. 8, p. 302									Deceased matter
17	Considerations About the Possibility of the Resurrection	1675	v. 8, p. 303			x						Ashes and plants
18	About the Mechanical Production of Tasts	1675	v. 8, p. 371			x		x				Tastes of plants
19	High Veneration to God	1684	v. 10, p. 172		x						x	Semen Animatum and preformation
20	Notion of Nature	1685	v. 10, p. 459		x	x			x			
21	Notion of Nature	1685	v. 10, p. 467								x	
22	Notion of Nature	1685	v. 10, p. 500		x							Aristotelian account of monsters; denied
23	Notion of Nature	1685	v. 10, p. 533		x							Aristotelian account of monsters; denied
24	Notion of Nature	1685	v. 10, p. 558		x	x		x				Peripatetics
25	Christian Virtuoso	1744	v. 12, p. 446		x							Eggs
26	Fragments of Boyle's Essay on Spontaneous Generation	2000	v. 13, p. 286									Eggs and silkworms
27	Generation of Minerals	2000	v. 13, p. 373-6	x			x					Petrifick Spirit

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Rossi, Paolo. *The dark abyss of time: the history of the earth & the history of nations from Hooke to Vico*. Chicago: University of Chicago Press, 1984.

Rudwick, M. J. S. *The Meaning of Fossils: Episodes in the History of Paleontology*. Chicago: University of Chicago Press, 1985.

Ruestow, Edward G. *The microscope in the Dutch Republic: the shaping of discovery.* Cambridge: Cambridge University Press, 1996.

Sargent, Rose-Mary. *The Diffident Naturalist : Robert Boyle and the Philosophy of Experiment*. Chicago: University of Chicago Press, 1995.

Schiefsky, Mark J. "Galen's teleology and functional explanation," in *Oxford studies in ancient philosophy*. Edited by D. N. Sedley. Oxford, GB: Oxford University Press, 2007.

Shackelford, Jole. “Seeds with A Mechanical Purpose. Severinus’ *Semina* and Seventeenth Century Matter Theory,” in *Reading the Book of Nature: The Otherside of the Scientific Revolution*. Edited by Debus, Allen and Walton, Michael T., 1996.

Shapin, Steven, and Simon Schaffer. *Leviathan and the Air-pump: Hobbes, Boyle, and the Experimental Life*. Princeton, N.J: Princeton University Press, 2011.

Smith, Justin E. H. *Divine Machines: Leibniz and the Sciences of Life*. Princeton: Princeton University Press, 2011.

Solís, Carlos. "La ciencia de la resurrección." *Asclepio* 64, no. 2 (2012): 311-52.

Stolberg, M. "Particles of the Soul: The Medical and Lutheran Context of Daniel Sennert’s Atomism." *Med Secoli* 15, no. 2 (2003): 177-204.

Walters, Lisa. *Margaret Cavendish: Gender, Science and Politics*. Cambridge: Cambridge University Press, 2014.

Walton, Michael T. “Genesis and Chemistry in the 16th Century,” in *Reading the Book of Nature: The Other Side of the Scientific Revolution*. Edited by Debus, Allen and Walton, Michael T., 1996.

Webster , Charles and John Dury. *Samuel Hartlib and the advancement of learning*. London: Cambridge U.P., 1970.

Wilson, Catherine. *The Invisible World : Early Modern Philosophy and the Invention of the Microscope*. Princeton, N.J.: Princeton University Press, 1997.

Wojcik, Jan W. *Robert Boyle and the limits of reason*. New York: Cambridge University Press, 1997.

Yamanda, Toshihiro. “Hooke-Steno Relations Reconsidered: Reassessing the Roles of Ole Borch and Robert Boyle.” In *The Revolution in Geology from the Renaissance to the Enlightenment*. Edited by Rosenberg, Gary D . Boulder, CO: Geological Society of America, 2009.

ASHLEY J. INGLEHART
CURRICULUM VITAE

Areas of Specialization: Early Modern Philosophy, Science, & Medicine; History and Philosophy of Biology; Medical Humanities
Areas of Competence: Mediaeval Philosophy; Philosophy of Science; Renaissance and Early Modern Studies

EDUCATION

Ph.D. Indiana Univ., Bloomington (IUB), 2017:
History and Philosophy of Science and Medicine, with minor in Renaissance Studies.

Seminal Ideas: The Forces of Generation for Robert Boyle and His Contemporaries
Committee: William R. Newman (chair)
Domenico Bertoloni Meli
Jutta Schickore
Robert Schneider (History, IUB)
Justin E.H. Smith (Université Paris, Diderot)

M.A. Virginia Polytechnic Institute and State Univ. (VT), 2008: Philosophy.
B.A. Virginia Commonwealth Univ. (VCU), 2006: Philosophy.

RESEARCH

Publications

"Boyle, Malpighi, and the Problem of Plastic Powers". In P. Distelzweig, B. Goldberg, and E. Ragland (Eds.) *Medicine and Early Modern Natural Philosophy*, v. 14 of the series *History, Philosophy and Theory of the Life Sciences.* Netherlands, Springer Jan. 2016. pp 295-321

"Filippo Buonanni and the Kircher Museum". In G. Rosenberg (Ed.) *Museums at the Forefront of the History and Philosophy of Geology: History Made, History in the Making.* GSA Books, Forthcoming 2017.

Works in Progress

- "Robert Boyle on Ferments and Fermentation"
- "The Powers That Be: Mechanical Ontology in the Seventeenth Century"
- "Harvey and Boyle on the Problem of Generation"

Invited Talks

"Boyle, Malpighi, and the Problem of Plastic Powers"
Workshop on Early Modern Medicine and Natural Philosophy. University of Pittsburgh. May 27, 2011

Refereed Conferences

"Filippo Buonanni and the Kircher Museum"
Panel: *Museums at the Forefront.* Topical session organized by the GSA History and Philosophy of Geology Division and the History of Earth Sciences Society. Annual Conf. for the Geological Society of America. Denver, CO. Sept. 25, 2016.

"Walter Needham's *Disquisitio Anatomica de Formato Fœtu*"
- Biennial Meeting for the International Society for the History, Philosophy, and Social Studies of Biology (ISHPSSB). Montréal, CA. July 8, 2015
- Midwest Junto for the History of Science. Madison, WI. April 18, 2015

"Robert Boyle on *Semina,* Transmutation, and the Generation of Life"
Panel: *Transmutation, Digestion and Imagination*. Sponsored by Society for the History of Alchemy and Chemistry. Annual Meeting for the Renaissance Society of America (RSA). Berlin, Germany. Mar. 28, 2015

"The 'Sceptical Chymist' as Geologist? Robert Boyle on Mineral Formation"
Panel: *The Great Ideas in Geology*. Topical session organized by the GSA History and Philosophy of Geology Division and the History of Earth Sciences Society. Annual Conf. for the Geological Society of America. Vancouver, CA. Oct. 20, 2014

"Robert Boyle on Ferments and Fermentation"
- Annual Conf. for the History of Science Society. Chicago, IL. Nov. 8, 2014
- Biennial Conf. for History of Philosophy of Science (HOPOS) Ghent, BE. July 3, 2014

"Anselm de Boodt's *Gemmarum et Lapidium Historia*"
Panel: *Great Books in Geology*. Topical session organized by the GSA History and Philosophy of Geology Division and the History of Earth Sciences Society. Annual Conf. for the Geological Society of America. Denver, CO. Oct. 27, 2013

"Picturing the Great Pox in Renaissance Europe: On the Representation of Disease"
Panel: *Medicine, 1300 – 1700: Studies Historical, Philosophical, Literary.* 3rd Annual Western Michigan University Medical Humanities Conf. Western Michigan University. Kalamazoo, MI. Sept. 26, 2013

"Imitation and Authority in Vesalius and Curtius: A Dispute"
Newberry Institute Annual Renaissance Studies Multidisciplinary Graduate Conf. Chicago, IL. Jan. 25, 2013

"Robert Boyle on Principles, Powers, and Petrifaction"
Annual Conf. for the British Society for the History of Science. Exeter, UK. July 17, 2011

Conference Commentaries and Departmental Events

Commentary on "The Funny Thing About Syphilis: The Sexual Economy of a Jest in Twelfth Night". Casey Caldwell (Northwestern University) IUB History and Philosophy of Science & Medicine Graduate Conf. Bloomington, IN. March 11, 2016

"Daniel Sennert, Nathaniel Highmore, and the Problem of Animal Generation"
Renaissance Studies End-of-Year Roundtable and Reception. Indiana University, Bloomington, IN. Dec. 11, 2015

"Malpighi, Galen, and the Egg"
Workshop on the History of Biology: In Honor of Fred Churchill. Indiana University, Bloomington, IN. Dec. 8, 2012

Commentary on "No Pairing Problem". Andrew Bailey (Notre Dame) Virginia Tech Graduate Philosophy Conf. Blacksburg, VA. Nov., 2007

Commentary on "The Minimalist Theory of Goodness and Moral Twin Earth". Douglas Edwards (University of St. Andrews) Virginia Tech Graduate Philosophy Conf. Blacksburg, VA. Nov., 2006

AWARDS

Fellowships and Honors

2014–2015 IUB College of Arts and Sciences Dissertation Research Fellowship
2014–2015 GSA History and Philosophy of Geology Division Student Award
2013–2014 Mikal Lynn Sousa Fellowship
2009–2010 IUB College of Arts and Sciences, HPS First Year Fellowship
2006, April Winner of the President's Award and selected for publication of 2006 Conf. Proceedings in *Oneonta Philosophy Studies*

Travel Grants and Awards

2015, April Richard S. Westfall Fellowship for Graduate Research: Montréal, CA
2015, March RSA Student Travel Award: Berlin, DE
2015, Feb. College of Arts & Humanities Institute Grad. Fellowship: Berlin, DE
2015, Jan. HOPOS Travel Grant: 10th Biennial Meeting of HOPOS. Ghent, BE
2014, Nov. NSF Travel Grant: Annual Conf. for the History of Science Society
2013, Nov. NSF Travel Grant: Annual Conf. for the History of Science Society
2013, Aug. Richard S. Westfall Fellowship for Graduate Research: Huntington Library. San Marino, CA.
2013, Mar. Newberry Renaissance Consortium: Newberry Library. Chicago, IL.
2011, July Butler-Eyles Travel Grant for the British Society for the History of Science: Exeter, UK.

TEACHING

As lead instructor

Indiana University. Bloomington, IN

HPSC X102: Science Revolutions: Plato to NATO (Fall 2015)
HPSC X100: The Science of Sex: From Ancient Attitudes to Victorian Secrets† (Spring 2014, Fall 2013, Spring 2013, Fall 2012)
HPSC X100: Eggs, Seeds, and Embryos: The Problem of Generation† (Spring 2012, Fall 2011)

† Denotes a class that I designed and proposed to the faculty.

† Denotes a hybrid class with an online component.

Ivy Tech Community College. Bloomington, IN
PHIL 220: Philosophy of Religion (Spring 2016[i], Fall 2015)
PHIL 101: Introduction to Philosophy (Spring 2016[‡])

John Tyler Community College. Chester, VA
PHIL 211: History of Western Philosophy (Spring 2009, Fall 2008)
PHIL 111: Practical Reasoning: Logic I (Spring 2009)

As teaching assistant/associate instructor (lead instructor in parentheses)
Indiana University. Bloomington, IN
COLL E104: Occult in Western Civilization (Spring 2011; W. R. Newman)
COLL E105: The Scientific Revolution (Fall 2010; D. Bertoloni Meli)

Virginia Tech. Blacksburg, VA
PHIL 1204: Knowledge and Reality (Spring 2008; J. Klagge)
PHIL 2125: Early Modern Philosophy (Fall 2007; W. Ott)
PHIL 1204: Knowledge and Reality (Spring 2007; J. Pitt)
PHIL 1304: Morality and Justice, online class (Fall 2006; R. Mayorga)

Future courses I can teach

100-200 level undergraduate courses
- Ancient and Mediaeval Philosophy
- Biomedical Ethics
- Early Modern Philosophy
- Introduction to Medical Humanities
  Introduction to Philosophy of Science
- Introduction to the Renaissance
- Philosophy and Science Fiction: An Introduction to Philosophy

300-400 level undergraduate courses
- Ancient Philosophy of Science
- Bodies of Women: the Histories of Menses, Hysteria, and Female Sexuality
- History and Philosophy of Biology
- Search for the Philosopher's Stone: The History of Alchemy and Chemistry
- The Scientific Revolution

PROFESSIONAL SERVICE

Committee Participation and Elected Positions

2014-2016	GSA Student Advisory Council, rep. for History and Philosophy of Geology Division
2014-2016	Committee for History and Philosophy of Geology Division, grad. rep. (GSA)
2013-2016	Programs Committee for HSS Forum for the History of Chemical Sciences, grad. rep.
2012-2014	Medieval Studies Institute Graduate Student Advisory Committee (IUB)
2012-2013	Committee for investigating HPS undergraduate major (IUB)
2011-2013	HPS Graduate Liaison to the Faculty (IUB)
2010-2011	HPS Events and Student Recruiting Coordinator (IUB)
2007-2008	Graduate Honors system investigative committee member (VT)
2006-2008	Graduate Honors system judicial panelist (VT)
2006-2008	Philosophy Dept. rep. in the Graduate Student Association (VT)

Conference Participation and Organization

2013, Nov.	Session Chair: "Negotiating Medical Knowledge in the Early Modern World". Annual Conf. for the History of Science Society. Boston, MA.
2012, Nov.	Session Chair: "Influences on Boyle's Medical Project". Early Modern Medicine and Natural Philosophy: A Conf. at the Department of History and Philosophy of Science, University of Pittsburgh.
2012, July	Co-Organizer: "Workshop on Renaissance Anatomy", sponsored by the Dept. of History and Philosophy of Science and by the Renaissance Studies Program, IUB
2011, July	Session Chair: "Past, Present, and Future". Annual Conf. for the British Society for the History of Science.
2010, Sept.	Front Desk 3rd Integrated History and Philosophy of Science Conference,
2008, June	Conference support staff. "Philosophy of Science & Evidence Relevant for Regulation and Policy Workshop" Blacksburg, Virginia.
2007, Fall	Submission reviewer. Virginia Tech Grad. Philosophy Conf.
2007, July	Session Chair: Mixed Session. Society for the Philosophy of Technology Biennial Conf. Charleston, South Carolina. July, 2007
2007, July	Front Desk. Society for the Philosophy of Technology Biennial Conf.
2006, Fall	Submission reviewer. Virginia Tech Grad. Philosophy Conf.

PROFESSIONAL ORGANIZATIONS

- American Philosophical Association
- Geological Society of America, History and Philosophy of Geology Division
- History of Science Society
- International Society for the History, Philosophy and Social Studies of Biology
- International Society for the History of Philosophy of Science
- Renaissance Society of America
- Society for the History of Alchemy and Chemistry