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How the Heart Became Muscle: From René Descartes to Nicholas Steno

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by

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DEDICATION

For my parents, who supported my studies when their culture didn’t.

For my brother, who opened my head.

And for Noam Chomsky; keep truckin.

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ABSTRACT

This dissertation addresses the heartbeat and the systems of natural philosophy that were used to explain it in the 17th century. Thus, I work in two domains of explanation. The first domain is physiology, in which William Harvey correctly ordered the heart's systolic and diastolic motions, while René Descartes incorrectly reversed them. By looking at Harvey and Descartes' more complete physiological models I reconsider the controversy that spun out of their divergent accounts. The second domain is the junction of physics and metaphysics, representing the frameworks of natural philosophy behind physiology. I argue that Harvey's physiology was correct while his supporting principles were "wrong," and Descartes' physiology was incorrect while his supporting principles were "right." Thus, my thesis is that Harvey was "right" but perhaps for the wrong reasons, while Descartes was "wrong" but perhaps for the right reasons. Of course, this judgement is made from a contemporary perspective. By using a contextualist approach to history, I aim to show how the controversy between Harvey and Descartes resolved in Nicolas Steno, when he discovered that the heart is a muscle.

Figure 1: “From Vesalius’ *De humani corporis fabrica*” (French 2006)

CHAPTER ONE:

INTRODUCTION

This dissertation addresses the heartbeat and the systems of natural philosophy that were used to explain it in the 17th century. My thesis is that Harvey was "right" but perhaps for the wrong reasons, while Descartes was "wrong" but perhaps for the right reasons. Put differently, Harvey's physiology was correct while his supporting principles were "wrong," and Descartes' physiology was incorrect while his supporting principles were "right." Harvey and Descartes' divergence resolves in Nicolas Steno, when he discovered that the heart is a muscle. But what does Descartes have to do with the heart? Who is Harvey? The rest of this introduction is an initial answer to these questions, an explanation of the thesis, and a bit more on why it might matter.

What drew me to the topic of the heartbeat was the palpable strangeness surrounding it. Initially I had no story to explain why a philosopher like René Descartes, so busy dismantling the status quo, would devote space in his *Discourse on Method* to spell out the heart's structure and the path of its related blood. Yet the seemingly scientific descriptions in the *Discourse* are conservative compared to the far-out ideas in *The Passions of the Soul*. Therein one finds reference to vapors, animal spirits, alimentary juices, love, hate, and wonder, all in some way connecting to the heart. Elsewhere Descartes is found comparing the heat in the heart with piles of wet hay and fermenting wine. These analogies are used to explain the cause of the heartbeat, which in Descartes' mind was fermented blood. In his fermentation model, the idea is that a small amount of blood with extreme heat always remains in the heart, acting as a yeasty agent to expand the rest of the blood in the heart's chambers and thus to propel it into circulation through pressure. To me all this signified something gravid lurking below the surface of a philosopher cautiously touting mechanism. The human meat machine and "the species of fire" at its abdominal center was clearly important to Descartes, but why?

Wanting to know more on this subject I followed a thread from the *Discourse*, where William Harvey is credited as the first discoverer of the circulation of the blood. Harvey presents the idea in a medical text, surprisingly short in light of its title: *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus*. As a whole this work seems so tediously prosaic that no one would be surprised if a modern twenty something needed pharmaceutical grade amphetamines to read through it like a bromidic Hunter S. Thompson in tweed. But when I read *De Motu Cordis* I was again confronted by profound strangeness: William Harvey talking about the weather. What is typically insulting small talk anywhere outside the Midwest (Oh how's the weather?) was wildly out of place in a serious medical treatise credited with the first presentation of the circulation of the blood (or so I thought). What Harvey seems to suggest in passing is that the human body is a microcosm with the heart at its center, and that the heart affects the movement of blood in the same way that the sun affects the hydrologic cycle on planet earth. Here contextualism proved useful since a look into the history of medicine shows that other natural philosophers and physicians employed a microcosm-macrocosm scheme to discuss the human body; suspiciously Harvey favorably discusses some of them in his letters. As I'll argue, the microcosm-macrocosm scheme is important to Harvey's physiology because it provided a framework of meaning that made sense of the "pulsific faculty," which he believed caused the heartbeat and pushed blood through circulation.

More formally, the microcosm-macrocosm scheme describes the organization and motions of the human body as mirroring those aspects of larger natural systems like those studied in astronomy. Apart from pop cult references, the phrase "as above so below" is better known in the contemporary magic subculture as an occult principle disseminated by Aleister Crowley. Self-aggrandizing sorcerers aside, this saying has a long history careening from the ancient Middle East through medieval and early modern Europe. Its birthplace is a hermetic work known as *The Emerald Tablet of Hermes Trismegistus*, notably mentioned by Thomas Aquinas and Paracelsus (whose hippy parents really named him: Philippus Aureolus Theophrastus Bombastus von Hohenheim). Many interpretations of the phrase "as above so below" render a microcosm-macrocosm scheme, which by god, is even found in the far out musing of Isaac Newton, whose translation of the *Emerald Tablet* is currently held by the Kings College Library at Cambridge.[1] Much more will be said about microcosms in Chapter Four. Right now, it's sufficient to note that magic is at play here, and that is a strange enough occurrence to motivate my investigation into the heart of early modernity.

Apart from the manifest oddities in both Descartes and Harvey, it was apparent that my investigations circled a familiar theme in the history of early modern philosophy: the principle of motion. This was that gravid *je ne sais quoi* I sensed earlier in Descartes, and an article by Geoffrey Gorham was indispensable in helping me realize the connection between specific problems in early modern medicine and the more notable concerns expressed in philosophy of nature. He was the first scholar I read to so clearly point at Descartes and Harvey's shared interest in the heart's source of motion, a topic properly in the domain of physics and not medicine. Although Descartes and Harvey never corresponded directly, Gorham paints a

[1] For various interpretations of "The Emerald Tablet" in the 17th century see (Forshaw 2006, pp. 25-38).

hypothetical controversy dispelling old interpretations of Harvey as the empiricist and Descartes as the rationalist, highlighting the real differences between their theories, and most importantly, showing what was a stake and what their motivations were when discussing the cause of cardiac motion. The information I already gathered regarding Descartes' physiology and Harvey's reference to meteorology confirmed Gorham's thesis: Descartes and Harvey had different models to explain the heart's motion because the philosophers had divergent commitments in metaphysics and physics.

But pure abstract interest in this topic is not sufficient motivation for a dissertation. To recall, my thesis is that Harvey was "right" but perhaps for the wrong reasons, while Descartes was "wrong" but perhaps for the right reasons. From a contemporary scientific perspective Harvey is considered "right" because he described the systolic and diastolic motions of the heart in a way that is congruent with the current model. But I say this was for the wrong reasons because of the Aristotelian framework of metaphysics and physics he used to make sense of those motions. On the other hand, Descartes was wrong from a contemporary scientific perspective because he flipped the order of the diastolic and systolic motions. The ironic catch here is that the current scientific perspective is largely indebted to the methods and principles of Descartes. The framework of mechanistic physics Descartes used to make sense of the heartbeat is much more congruent with the contemporary scientific way of thinking than the framework of Harvey. From another angle, Descartes was wrong in the details, but the standards used to judge those details are largely derived from his work.

I recognize that it may not be accurate or fruitful to apply judgments of "right" and "wrong" in the history of science; from a Kuhnian perspective pointing to a single person who discovered a scientific fact and determining the moment when it was discovered is usually a problematic oversimplification. Plus, strictly according to today's medical models both Descartes and Harvey were wrong about the cause of heartbeat; neither pointed to electricity as the cause of the heart's contraction. Their anatomy seems spot on, but neither philosopher presented a comprehensive model of the heartbeat that we currently accept even though both were necessary for the current model's development (if only because of their eventual rejection). I take it that a contemporary scientific perspective is something akin to my understanding of Kuhn's notion of "normal science," that is, an accumulation of knowledge, a collection of facts, or a slow building up of truth that will eventually categorize all discoverable events and processes in nature.

Here's one reason my thesis might matter: to this day Harvey is credited with "discovering" the circulation of the blood because he collected empirical observations and used them to support a theory. William Harvey—a true champion of science amongst violent and ignorant Christians—a rational man, who if alive today would believe in climate change and support building spaceships to escape it. The celebration of Harvey as an enlightenment hero not only issues from the faceless collective hivemind of Wikipedia (an invaluable research tool for us modern androids) but also from scientists with high paying gigs at accredited universities—the simple perusal of a popular academic database yields numbingly numerous articles that celebrate this master of science, briefly commemorate the anniversary of his discovery, or hold up an empiricist victory in order to fill pages in a medical journal. But surprise, I think this perspective deserves mocking. Harvey was not an empiricist! I suppose my opposition to this common understanding of scientific achievement is worthwhile, precisely because the understanding is common.

Proponents of the current scientific perspective are so often unaware of its divergence from historical scientific theories and practices. Admittedly I don't derive this claim from reading copious amounts of academic science articles, and my historical understanding of early modern science is at an honest level of apprenticeship. Further, my target here is not scientific researchers themselves. Recent research like that of Nora Hangel and Jutta Schickore (2017), who surveyed over 80 working research scientists about how they view "norms and standards for good research," shows that current scientific practice doesn't meet the theoretical ideals of objectivity that are supposed to afford science the capacity for discovering truth; so, it doesn't seem to be the case that most practicing scientists are simply delusional about what they're doing. Regardless, really look at science in popular culture and take the grotesque seriously. Neil deGrasse Tyson, Richard Dawkins, Steven Pinker, Lawrence Krauss, Sam Harris, etc. are all scientific materialists that proselytize with old enlightenment tropes that science is progress and the only foundation of meaning. Their reductionist attitudes are an unnecessary step too far, and their tendency to appropriate figures like Harvey to support their narratives of naïve scientific realism and materialism is a blunt oversimplification of history for the sole purpose of making it consumable. In response popular culture votes, "educates" your children, and ultimately determines enrollment in philosophy classes: a vicious circle. I support science and think the world would be better to do the same, but I'm increasingly cognizant of its limits.

Often this popular science attitude separates Harvey's discovery of circulation from any mention of his heartbeat model, and I think this is a mistake. A slightly more nuanced approach should avoid such separation. Harvey offers the two topics together—so much of *de Motu Cordis* is devoted to describing the movements of the heart that drives blood through circulation—since obviously there is no circulation without the heartbeat. But if we view the topic of the heartbeat as a necessary part of the theory of the blood's circulation, then I think it makes less sense to say that Harvey was an exemplar of scientific progress.

Here is another reason my thesis might matter: perhaps I can add something new to the studies of early modern philosophy—after all this is what I've been told philosophy dissertations are supposed to do. It doesn't seem that my thesis is already stated by others directly, but it likely seems obvious enough to the few historians that are actively researching Harvey, Descartes, and the heartbeat in early modernism. But the research I use to justify my thesis may have more to offer. For instance, Harvey's implementation of the microcosm-macrocosm scheme is either left undeveloped by those that recognize it, or is all together denied by others. I take it that I've provided something new on this front, from gathering contextual occurrences of the theme in different sources, to drawing on Harvey's later work to develop an account of his Aristotelian principles of motion in cardiac physiology. I think I also provide a contribution to the studies of Alexander Ross by uncovering his account of the heartbeat and placing it in conversation with Harvey and Descartes. When Ross shows up in historical scholarship he is usually a short tangent, and from what I can tell no one has yet given a detailed discussion regarding his stance on the heartbeat and microcosm. In another fruitful turn I think I add to the new discussion developing around Nicholas Steno, specifically showing how his Cartesian background and activities relate to his work on the heart. But why would I discuss Ross and Steno at all? What do they have to do with my thesis on Descartes and Harvey?

The question that remained for me after developing my thesis was how the two divergent approaches represented by Descartes and Harvey played out in the 17th Century toward an eventual scientific consensus. Motivated to receive a grade, complete a course, and attain future employment, I looked for additional ways to unfold a story of how natural philosophy's controversy between Aristotelians and Mechanists developed around the issue of the heartbeat. To my good fortune Doug Jesseph was pushing the limits of niche by teaching a course on

Thomas Hobbes' natural philosophy through an examination of *De Corpore*, a book that few people read for obvious reasons. So ironically seemingly heartless Hobbes became another step in developing an account of how early modern thinkers understood the action of the heartbeat, and thus principles of motion in general. In the midst of my troublesome labor on Hobbes and the heartbeat, Rodolfo Garau published an excellent paper on the subject with translated chunks of Latin and all. Jesseph's instruction helped me add to Garau's findings by elaborating on Hobbes' mechanist physics. It's interesting that Hobbes was closer to Descartes on the heartbeat than to his fellow Englishman Harvey.

In the same spirit as my use of Hobbes, Alexander Ross offers a brilliant point of comparison for Descartes and Harvey. Ross was a hot-blooded Aristotelian, as derivative and nitpicky as they come. As such, he shows where Descartes and Harvey remained Aristotelian and where they didn't. With Descartes, we can see that his heartbeat model was generally the same as Ross', only differing in details, thus explaining why both wrongly ordered systole and diastole. So, Ross helps us see that Descartes remained Aristotelian in cardiac physiology while diverging from Aristotle's metaphysics and physics. The opposite is the case with Harvey. While Harvey and Ross only differ in the details of their microcosmic and cosmological ideas, we can see that Harvey departs from Ross in the domain of cardiac physiology.

The controversy and the stances of its disputants was now clear enough, but I still wanted at least a beginning picture of which side history would eventually favor and how the understanding of the heartbeat developed into the 18th century. For this purpose, there seems to be no better figure to observe than Nicholas Steno. Steno was known by his peers for his brilliance with a blade, and rightly, since his careful hand in dissection yielded the discovery of several previously unrecognized anatomical structures. I soon found that Steno was of profound importance to the history of medicine; it's quite a marvel that merely his name is largely unknown in the broader history of philosophy community. Still my own introduction to Steno was by circuitous route as he manifest in my lifeworld through Leibniz. Leibniz, the whiggish polymath whom every early modernist has a bout with, doesn't seem especially argumentative regarding the heartbeat. In fact, his tone in 1679 suggests that the topic achieved a mark of resolution. Leibniz, curt and compendious, states that Steno is the nail in the coffin for Descartes' account of the heartbeat. I find beautiful symmetry in Leibniz's remarks: Steno adheres to a mechanistic physics to explain the motion of the heart, mirroring Descartes' initial motivation to develop adopt a cardiac model similar to Aristotle's. So, my thesis that Descartes was wrong for the right reasons is confirmed by the work of a pivotal figure in the historical development of the debate; Steno acts out my narrative and perfectly plays the part of a Cartesian adhering to the master's principles to reform the master's results. Steno confirms my thesis: by discovering that the heart is merely muscle, and thus that the heartbeat is simply caused by its contraction, he shows that Harvey was correct in his ordering of systole and diastole, but for the wrong reasons since Steno's discovery was only possible because of his acceptance of Cartesian mechanics.

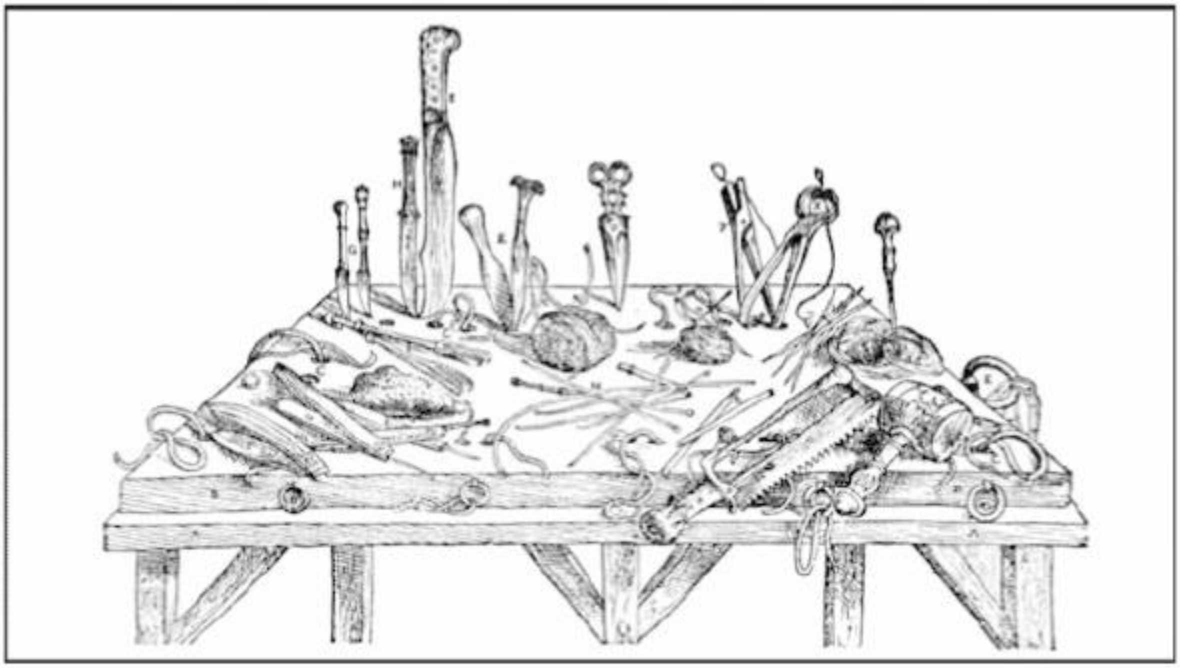

Figure 2: “Sixteenth Century anatomical instruments” (In Wright 2012).

The table is set. This introduction is Chapter One, and following chapters follow the order of topics already presented in this introduction, but with a few detours. The general structure of the chapters is: 1) present the controversy between Descartes and Harvey, 2) go into the details of Descartes, 3) go into the details of Harvey, 4) compare Descartes and Harvey to one of their contemporaries, and 5) show how Steno resolved the controversy. Below is a slightly more detailed roadmap this general structure.

Chapter Two explains Gorham’s thesis mentioned above, and the controversy between Harvey and Descartes that he skillfully elucidates. Since my conclusion is that Steno discovered the heart is a muscle with Cartesians means, I also consider other historical instances where people called the heart a muscle, but explain how people like Hippocrates and Leonardo da Vinci meant something different. I also consider why historians don’t attribute the discovery of the heart as a muscle to Harvey.

Chapter Three discusses the physiological theories of Descartes. I focus on the development of his account of the heartbeat, highlighting his correspondence with a physician in Leuven named Plempius. I dive into the details of the Cartesian fermentation model and aim to show how it was derived from the Aristotelian account, albeit, only physiologically. I then compare Descartes' fermentation model to that of Hobbes'. Lastly, I consider Descartes' criteria for categorizing muscles and their movement, and argue that it was possible in his system to call the heart a muscle, even though he did not.

Chapter Four aims at describing Harvey's Aristotelian cosmology, and the way it related to his cardiac physiology. I focus on Harvey's use of the microcosm-macrocosm theme, and delve into passages from his later work *Exercitationes de generatione animalium* to discuss his speculations on the soul, spirit, and how it integrates with the blood to manifest innate heat. I first point at several instances where some of Harvey's precursors and contemporaries used microcosmic ideas in cardiac physiology. Then I turn to Aristotle's physics and his later work *De caelo* to determine what it meant for celestial bodies to be "divine." Lastly, I compare Aristotle's meaning to the way Harvey describes the blood, so as to explain what he might mean when saying that the heart and blood "participate" in the divine or "correspond" to the heavens.

Chapter Five looks at Alexander Ross. Focusing specifically on Ross' work *Arcana Microcosmi* (second edition 1652), I highlight the principles of motion operative in Aristotelian cardiac physiology. After some words about Ross' context and a short story, I compare the models of Descartes and Ross. Next, I use some of Ross' explanations to elucidate the function of Harvey's pulsific faculty. I end by looking at Ross' direct objections to Harvey's microcosmic ideas, those discussed in Chapter Four. The clear conclusion is that Ross didn't object to the blood's circulation or Harvey's general integration of cosmology and physiology. Rather, Ross only objects to details about the meaning of “spirit” and how the blood is able to act as the “instrument of the soul.”

In Chapter Six I discuss Nicolas Steno to show how Harvey was “right” for the wrong reasons and how Descartes was “wrong” for the right reasons. I argue that Steno is a Cartesian, at least regarding his principles. I provide biographical information that emphasizes points of Cartesian influence in his education and scientific activity. This culminates in a discussion of Steno’s proclamation that the heart is a muscle, which was an essential step in the historical development toward our current explanation of the heart’s motion. I end by highlighting a few instances where Steno references microcosmic ideas, that show how the microcosm became mechanized.

Chapter Seven is a conclusion. It revisits the themes of this introduction after their development in the dissertation. I revel in history’s symmetry. I reconsider the narrative. And I suggest a consequence. All this, hopefully after convincingly showing that Harvey was “right” for the wrong reasons, while Descartes was “wrong” for the right reasons. Of course, this thesis depends on the underlying assumption that to this day, westerners are still somewhat Cartesian. Is the viewpoint from which we judge history is itself historical? Regardless, from what I can tell it’s largely outside anyone’s control. Despite the novice character and frivolous nature of this dissertation I’m grateful for the privilege that allowed me to write it. Especially since this is more strictly history performed in a philosophy department, and since philosophers increasingly become denizens in the academy their lineage established.

I am incredibly grateful that Roger Ariew and Douglas Jesseph strongly influenced the development of this project. Their most substantial contribution has been to pass along their method of historiography, teaching me to view historical events, people, and texts as belonging

to a cohesive context. It now seems obvious to me that all these pieces of history have the capacity to illuminate one another; an argument in a 17th century text means one thing when interpreted with the conventional concepts of a 21st century American, and another when informed by a stockpile of clues about the person that wrote it, his or her desires, problems, and relationships. I take it that this is generally what a contextualist approach to the history of philosophy looks like, or at least I hope, since it's what I attempted to employ in the proceeding pages. Still, knowing how to do something doesn't make you good at it. I don't count myself contextualism's strongest adherent. This is due to my own limitations (especially with languages), but also because I've found contextual histories often expressed as dried out strings of pure analysis, lacking any of the passion and personal connection that drew its authors in to begin with.[2] Maybe this is what good history demands, but I seek to share some fun along with the information. If I risk tangents lacking in rigor so be it, their impact is minimal in an academic climate where only four committee members will ever read them.

[2] For me Erik Jan Bos' narrative style of history especially is refreshing and avoids the typically boring presentation of pure analysis. He too is influential to me. My own avoidance of pure analysis isn't a lack of appreciation for the work presented in that form. This project was only possible because of many fantastic historians of philosophy and science who rigorously present an unbelievable breadth of information. Apart from those already mentioned, I stand on the shoulders of people like: Roger French, Walter Pagel, Marjorie Grene, Benjamin Goldberg, Hisao Ishizuka, Troels Kardel, Paul Maquet, Lucian Petrescu, Dennis Des Chene, Thomas Wright, Rodolfo Garau, and many others cited in the course of this work.

CHAPTER TWO:

CONTROVERSY AND CONTEXT

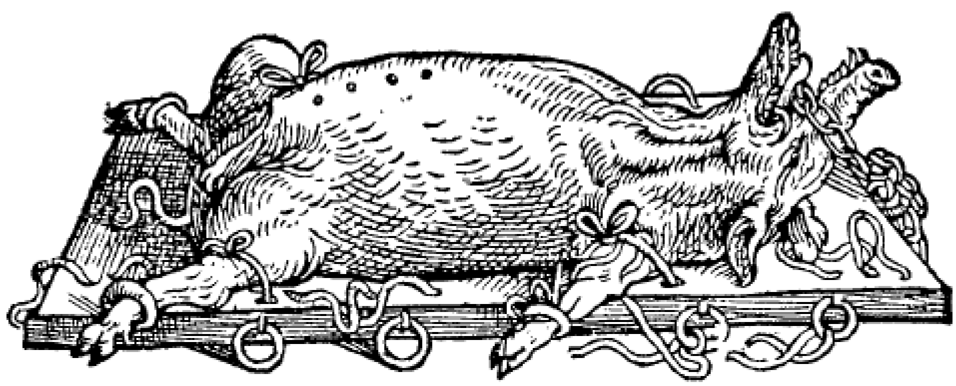

Figure 3: “A pig prepared for vivisection, from Vesalius’ *De humani corporis fabrica*” (French 2006).

1. Introduction

Harvey and Descartes are an interesting pair; in their differences a transition of the whole western intellect condenses and comes to a head. As far as scholars know the two never corresponded or met. But Descartes credits Harvey with discovering the blood’s circulation and Harvey doubtlessly read the French rapscallion.[3] Geoffrey Gorham is our Anglo-rapporteur, historically reconstructing the controversy that spun-out from their opposing accounts of cardiac motion.[4] He concludes that the controversy concerned metaphysics and physics. Harvey and

[3] For Descartes’ acknowledgement of Harvey, see the *Discourse* (CSM I, 136; AT VI, 50).

[4] Marjorie Grene (1993) draws similar conclusions from a different starting point and historical emphasis.

Descartes agreed on circulation, but locked horns explaining the cause of the heart's motion, which represented one instance of how natural bodies move in general. Harvey held to Aristotelian principles that Descartes sought to destroy. Their contemporaries aligned behind them in a diametric continuum, a splitting wake from the dialectic ship of history sailing onward. Europe embodied a desperate grip and a frenzied scramble as a paradigm crumbled in crisis. American settlements were still learning to plant corn.

2. Some Controversy and Context

A preliminary sketch of Harvey and Descartes' heartbeat models will bring Gorham's conclusion into relief. It's important to note that the heat of the heart and blood is closely related to the heart's motion in both accounts, though this won't be discussed fully until Chapters Three and Four. For now, let's start with a basic description of Harvey model. In *De motu cordis* his description of the blood's movement through the heart clearly stays on a level of efficient causes. Here's a dry and perhaps unnecessarily full description. His account describes the heart's motion starting with systole, when the venous blood first moves from the vena cava to fill the right auricle, it then contracts to fill the right ventricle. Once full, the right ventricle contracts to push the blood into the left auricle. As the heart contracts and the blood passes into the left auricle, the blood is then pushed through the aorta to the arteries. In this account he breaks from tradition by conceiving of systole as the active stage of the heart's motion. Subsequently the auricles and ventricles relax from their systolic contraction thus beginning the process of diastole in which the heart itself distends are refills with blood (Harvey 1628, pp. 29-32, 47). Phew, all that from cutting open screaming dogs.

What causes the contracting motion of systole for Harvey? Gorham highlights Harvey's consistent reference to "an innate pulsate element," which he also describes in a letter to Riolan as the "'pulsific faculty' responsible for the original contractile movement of the right auricle." Quoting from Harvey, Gorham explains,

> The heartbeat is not occasioned by vapors or the influence of an external agent; rather "it comes from an internal principle." Harvey goes so far in his vitalism as to liken the heart to an independent organism, a kind of "inner animal," he says, that uses the rest of the animal as its "dwelling-place." (Gorham 1994, p. 227)

Gorham's observation is that Harvey ascribes to a non-mechanistic cause to explain the heart's contraction. The pulsific faculty is an "active" power upon the heart muscle, meaning it has the principle or cause of motion within itself as opposed to reacting or resulting from an external impetus or motion.

While Harvey draws the concept of a pulsific faculty partially from Galen, his utilization of the idea was supported by Aristotelian commitments and not an acceptance of Galen's ligature experiments.[5] Harvey had a very Aristotelian (hylomorphic) conception of the human soul and

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[5] Explaining the way Galen supported the theory of a pulsfic faculty, Jerome Bylebyl remarks, "Galen claimed to derive conclusive evidence of an active pulsific faculty from his procedure for inserting a tube into an artery in a live animal. By tying a ligature around the part of the artery containing the tube, one could, in effect, ligate the wall of the artery without interrupting the flow of its contents. Galen asserted that when this is done, the artery immediately ceases pulsating distal to the ligature, thus showing that the pulse is transmitted through the arterial walls (by an immaterial faculty) and not through the lumen (by impelled spirits)" (Bylebyl 1985, p. 228). Gorham argues that Harvey's employment of a pulsific force was not indebted to Galen, stating, "It is true that Galen had invoked a certain 'pulse-making force' to

body. Highlighting it, Gorham explains how Harvey thought that “in human beings the rational soul informed and gave life to the body, but could not be separated from it, even in thought.” This mind/body monism allowed Harvey to speculate that “certain parts of the body are capable of self-movement” (Gorham 1994, p. 232). Additionally, “in accordance with his monism, the power of independent action was focused in the most important parts of the body itself—in the pulsatile faculty of the heart and the vital principle of the blood” (Gorham 1994, p. 233). At first glance Harvey’s appeal to a mysterious immaterial force may seem like a limited application of an Aristotelian idea, but as I’ll show later (Chapter Four) his main thesis of the blood’s circulation was formulated to fit into a larger Aristotelian understanding of nature.

Compare this to Descartes’ model. The basics of his cardiac physiology are relatively unchanged from *L’homme* (1632) to the *Passions of the Soul* (1649).[6] In the latter Descartes describes the heart’s motion in the following way: A fiery heat expands blood that fills the chambers of the heart. Once the chambers fill completely, pressure pushes the blood “from the right chamber into the arterial vein, and from the left into the great artery.” Subsequently the blood stops expanding, the heart relaxes, and “blood immediately enters the right chamber of the heart afresh from the vena cava, and the left from the venous artery.” Small membranes and valves keep blood from entering and exiting the heart by any other route than the one described (CSM I, 331; AT XI, 333-34). In Chapter Three I go into the details of Descartes’ model. It

explain the observed throbbing of the arteries. But this occult principle was in Galen’s theory unrelated to the contraction of the heart. Instead, Galen’s pulsatile force was thought to reside inherently in the walls of the heart and arteries. Galen’s account of the pulse is criticized at length by Harvey in de Motu Cordis and in his ‘First Letter to Riolan’” (Gorham 1994, p. 213).

[6] All Descartes references refer to one of the volumes in (Descartes 1985). From now on this is abbreviated as CSM I and CSMK. I also provide corresponding numbers for Adam and Tannery, the relatively complete collection of Descartes’ writings.

suffices to say now that, contrary to Harvey, Descartes has diastole as the "active" stage of the heart's motion; though, active might be a confounding term when applied to Cartesian physiology—Gorham accounts for the reason.

Gorham's main thesis is that the significant difference between Descartes and Harvey's cardiac models regarded what kind of theoretical devices could be used to explain the cause of the heart's motion (Gorham 1994, p. 211). Of course, his claim implies that the controversy wasn't some typical clash between a Baconian empiricist and a neo-Euclidian deductivist over the competing priority of reason or the senses.[7] The two philosophers demonstrate an inability to resolve their differences with a presentation of experiments, and this lends support to Gorham's interpretation that Harvey and Descartes were actually concerned with theoretical matters. Gorham specifically highlights Descartes' mind/body dualism and Harvey's monism as the primary ground of their disagreement. Comparing the two opposed ontologies, Gorham concludes that:

> On the one hand the operation of Harvey's heart did not depend in any way on our thought. In this respect it was the sort of phenomena that could exist in wholly inanimate

[7] Gorham argues against the view of many, like Richard Toellner, Rupert Hall, and Etienne Gilson. These three scholars in particular distinguish Harvey and Descartes by placing them in ahistorical categories of "empiricist" and "rationalist." Gorham dispenses with the categories by comparing the experimental activity of both philosophers. They conducted similar experiments to facilitate the observation of various phenomena in the hearts of various organisms. Perhaps the hope was that one theory of cardiac motion could be discarded if it wasn't able to account for some of the observed phenomena. Unsurprisingly each physician more or less explained all of the competitor's observations with his own theory, but the accounts of their experiments do provide enough evidence to say where the two disagreed. In his "Second Letter to Jean Riolan" Harvey responds to Descartes by discussing experiments. Harvey expresses gratitude for being recognized in Descartes' *Discourse*, but proceeds to criticize several aspects of his theory (Gorham 1994, p. 217). Three specific criticisms can be drawn from Harvey's letter, all of which present a different experiment to either bolster his own explanations of observed phenomena or attempt to problematize those of Descartes. For a description of these experiments along with Harvey and Descartes' hypothetical responses to one another, see (Gorham 1994, p. 217).

> bodies. On the other hand it acted of its own accord, which in Descartes's scheme implied the will of a conscious soul. In this respect it could not conceivably belong to the body proper. The sticking point for Descartes was that the vital force needed to drive Harvey's heart was at once physical (because unconscious) and spiritual (because active). Such a mix, while quite at home in Harvey's monism, is entirely foreign to Descartes's dualistic ontology. (Gorham 1994, p. 233)

This interpretation is corroborated by Descartes' concerned remark to Mersenne, found in a letter dated February 9th 1639. He tells Mersenne that if his own explanation of the heart's motion is incorrect then "all the rest of my philosophy comes to nothing" (CSMK, 134; AT II, 501; Gorham 1994, p. 216). As Gorham describes in a more analytical language, Cartesian physics viewed all bodies as passive, or as being unable to move themselves from by an internal principle. Of course, the Aristotelian picture of nature also explained some bodies as having passive motion, but this wasn't the case for Harvey's heart. Additionally, for the Aristotelians matter is always inseparably intertwined with a substantial form. In Descartes' mechanistic view, substantial forms are thrown out entirely making all bodies in motion necessarily passive.[8] This means one body can only move through an interaction with some other passive body already in motion (of course not including voluntary motion in human bodies).[9]

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[8] Descartes' only exception was the human soul, but this had no direct contact with the heart and no role in its motion. Descartes does discuss how the soul can indirectly influence the heart, but this is very different from how Harvey explains the final cause of the heartbeat; see (Chapter Three).

[9] For more on later scholastic explanations and 17th century explanations of movement, see (Nadler 2008, pp. 516-22).

There's no doubt that these commitments to differing principles in metaphysics and physics led to differences in Harvey and Descartes' development of physiological models. But notice that neither explain the heart's motion by calling it a muscle. Unlike our present view, this wasn't an explanatory option for Harvey and Descartes who were working on the shoulders of Aristotle in one way or another.

3. Some Context and Controversy

Recall that the narrative of this dissertation concludes by showing how Nicholas Steno was able to prove Descartes' model wrong by using the Cartesian principles behind it. Steno's historically ironic proclamation was: "there exists nothing in the heart that is not found also in a muscle, and that there is nothing missing in the heart which one finds in a muscle." Indeed, there is historical consensus that Steno is rightfully credited with first discovering that the heart is a muscle. But then, the immediate suspicion might be that my narrative and historical consensus are wrong; there were others before Steno who called the heart a muscle. Don't be hasty. Such cases reinforce my conclusion.

The first instance occurred with Hippocrates, recorded by a Hippocratic writer likely around 260 B.C. (much later than the other Hippocratic writings). The position is stated clearly: "The heart is an exceedingly strong muscle—'muscle' in the sense not of 'tendon' but of a compressed mass of flesh" (Hippocrates 1978; Cheng 2001, p. 176). For the most part Hippocrates isn't credited by historians with discovering that the heart is a muscle. In part this is because his calling it a muscle had no significance for the heart's motion. Hippocrates doesn't really give an explanation for why the heart moves, but there is enough information from the little tract on its anatomy to see that he didn't think its motion was explained because it was a muscle. Hippocrates had a notion of innate heat similar to what we will see in the next Chapters with the Aristotelian account, but he only located it in the heart's "left chamber," sharing the space with "man's intelligence, the principle which rules over the rest of the soul" (Hippocrates 1978, pp. 349, 351). There is also an ambiguous mention of "attractive powers" in the vessels and mention that the heart has bellows for the intake of air, like those found with the furnaces of smiths (Hippocrates 1978, p. 349). The other part of why historians don't count his statement as the first discovery is because Hippocrates had a different understanding of the muscles and their motion all together.[10]

But then we also have the case of our illustrious Leonardo da Vinci calling the heart a muscle during his dissection of the centenarian man. He even drew a picture:

[10] Hippocrates had no concept of a nervous system that would relate to our contemporary understanding. Although the term "nerve" appears in translations, the translator I. M. Lonie notes that the Greek *Neuron* referred to something closer to a ligament or tendon (Hippocrates 1978, p. 352).

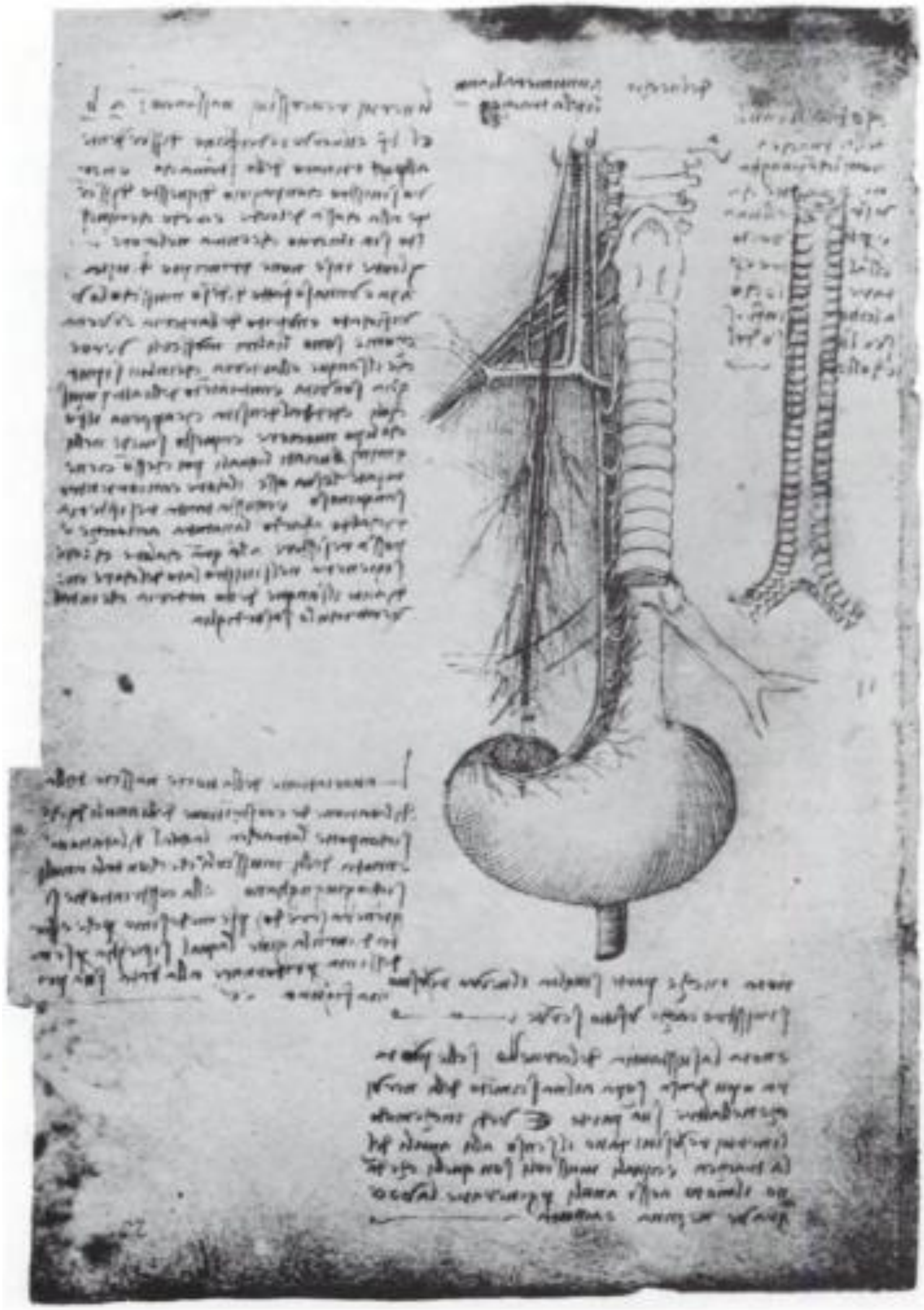

Figure 4: da Vinci’s heart, written and sketched sometime between 1504 and 1506. (From da Vinci 1952)

In the notes beside his sketch, da Vinci initially describes the "vagus nerve," but as the translators explain, this "immediately turns his mind to the nature of the heart in which he breaks with tradition." da Vinci states, "The heart of itself is not the beginning of life but is a vessel made of dense muscle vivified and nourished by an artery and a vein as are the other muscles. It is true that the blood and the artery which purges itself in it are the life and nourishment of the other muscles" (da Vinci 1952, p. 344). Historians don't count this as the first authentic discovery that the heart is a muscle either, and seemingly for the same reasons found in the case of Hippocrates. In da Vinci's notes he comments on the heart's innate heat: "The heart is of such density that fire can scarcely damage it.…Nature has made this great resistance to heat so that it can resist the great heat which is generated in the left side of the heart by means of the arterial blood which is subtilized in this ventricle." The translators explain the term "subtilizes," stating, "the heat of the heart subtilizes or distils some of this blood in the left ventricle into a higher form of spirit, the vital spirits, which is the essence of life carried by the arterial system" (da Vinci 1952, p. 344). Related to my discussions in Chapters Three and Five, this strongly suggests that da Vinci interpreted the heart's motion not from muscular contraction, but with either an Aristotelian or Galenic account; he was familiar with both.

Lastly, one might wonder why Harvey himself isn't credited with discovering that the heart is a muscle. The implication is even present in recent scholarship done by Thomas Wright. Wright has a fantastic narrative style, describing the gruesome imagery of 17th century dissection and the entertaining eccentricities of an English eclectic, but in one important instance his descriptive freedom could have been supplemented with a bit more historical rigor. When recounting the notes Harvey prepared for his Lumleian lectures, Wright provides precious few references, almost completely paraphrasing the notes as a narrative without citations. In one instance Wright tells us about Harvey's experiments on the heart of an eel, and that "what Harvey observed persuaded him that the heart was indeed a muscle whose active phase was contraction, not expansion as Galen had held" (Wright 2012, p. 123). In another place, Wright repeats the idea that Harvey concluded the heart was a muscle after considering the view of his Italian predecessor Columbo (Wright 2012, p. 112). Whether a mistake in phrasing or a misunderstanding of Harvey's position, Wright gives the idea that Harvey discovered the heart was a muscle, which I have found to be wrong.

Harvey never claims the heart is a muscle in his published writings. The closest he comes is in *De motu cordis* with a reference to Hippocrates. Harvey states, "Hippocrates, in the book *De Corde,* did not call the heart a muscle without good reason. Its action or function is that of a muscle, to contract and to move something, namely its content of blood" (Harvey 1628, p. 127). But he doesn't seem to follow Hippocrates in calling the heart a muscle. Rather, he finds Hippocrates claim significant because it highlights the fibers whose contractile motion functions to move the blood in Systole.[11] As Chauncey Leake explains in a footnote to his translation, "the conception of the heart as a muscle is not usually credited either to Harvey or the Hippocratic writer. It is characteristic of Harvey to attempt to fortify his ideas by reference to classical authorities" (Harvey 1628, p. 127, note 13). The idea Harvey wanted to fortify here, is that the heart's function is to pump blood via contraction, not that contraction is evidence of the heart

[11] Harvey continues by saying, "As in the muscles themselves, the actions and uses of the heart may be understood from the arrangement of its fibers and the structure of its movable parts. Anatomists generally agree with Galen that the heart is composed of a variety of fibers arranged straight, transversely, and obliquely. But in the boiled heart the fibers are seen to be arranged otherwise. All those in the walls and septum are circular as in a sphincter whereas those in the bands are longitudinally oblique. So, when all these muscles contract simultaneously the apex is pulled toward the base by the bands and the walls are drawn together in a sphere. The heart is contracted on all sides and the ventricles are compressed. Hence it must be recognized that since it acts by contraction, its function is to pump blood into the arteries" (Harvey 1628, p. 127).

being a muscle. Although Leake's assessment of who gets credit for the discovery was published in 1928, for the most part it seems to track with historians today. But in another note Leake can be seen expressing sympathy with Wright. Leake states,

> Niels Stensen (1638-1686), the Danish anatomist who later became a bishop of the Roman church, is usually credited with recognizing the muscular character of the heart {De Musculis et Glandulis Observationum Specimen, 1664). This is a little unfair to Harvey, and, for that matter, to the unknown author of the Hippocratic tract on the heart to which Harvey refers in Chapter XVII. Stensen, as far as I can determine, did little more than these in comparing the heart's contraction to that of a muscle, and then saying that it is nothing more than muscle. (Harvey 1628, p. 30, note 3)

In Chapter Six I'll argue why I think Leake is wrong about Steno doing "little more" than Harvey or the Hippocratic writer. But is he perhaps still correct to think the historical credit given to Steno is "a little unfair" in light of such statements from Harvey?

Hisao Ishizuka present a solid case against Wright and Leake. She starts by explaining that Harvey followed the obsession of his Italian teacher Fabricius ab Aquapendente, "whose favorite themes of study included muscular motion." Ishizuka then references the very lecture notes that Wright paraphrases, especially highlighting the collection on muscles that Harvey had planned to publish as separate work (but never did), *De motu locali animalium* (1627). She tells us that this planned work was

> a seemingly scholastic explication of previous writers' opinions on the muscles. Here, Harvey, in his usual manner, deliberately found a way to uphold Aristotle's view of muscular motion by almost misconstruing Aristotle's term '*nervus*' as 'sinew,' and by drawing on the authority of Fabricius and Jean Riolan who maintained that the chief organ of movement was in the sinewy parts of the muscles, not in the flesh, a point favoured by Aristotle. (Ishizuka 2006, p. 11)

She then quotes directly from Harvey who name drops Aristotle as an authority for the view that "[T]he heart is abundantly supplied with sinews on account of the movement." Harvey continues, "Is it not more correct to term the fibres [*fibrae*] concealed in the heart and in the intestines, and wheresoever there is movement, sinews and fibres rather than muscles?" (Ishizuka 2006, p 12). As Ishizuka also explains, "he went further by saying that since the sinew is a 'simple particle' whereas muscle has a complex structure, it is better to posit a 'multiplicity of fibres' as a single unit for a principal organ of motion, some of which can or cannot be stretched while others do otherwise." Ishizuka point is that Harvey went to great lengths to distinguish the moving fibers he observed in the heart from the category of muscles that he had observed elsewhere throughout the body. Sinews might be the basic component responsible for motion, but muscles are more complex than simple sinews. Therefore, in Harvey's view, although the heart and muscles both move by sinews, the heart is not a muscle. Harvey did all this twisting of words because he still held the all-important Aristotelian criteria for muscle: a necessary capacity for voluntary motion. The consequence for Harvey was that the heart couldn't be a muscle, because like the intestines, its motion was involuntary.

Thus, Ishizuka concludes:

> Certainly, it was not Harvey who first asserted that the heart was composed of nothing but muscles; it was Nicolaus Steno of the Netherlands in1664, and then Richard Lower of Britain in 1669. But Harvey delivered the decisive stroke in making the contradiction (that involuntary motion does involve muscles) visible and distinct, for his discovery of the circulatory system initiated the subsequent anatomical research into cardiac musculature" (Ishizuka 2006, p. 11).

Perhaps Harvey's discovery of circulation did spur research leading to Steno declaring the heart was a muscle, but I find it odd that she doesn't also mention Descartes as a precursor. Next Chapter I discuss Descartes' claims that are similar to Harvey's regarding the involuntary status of muscle movement, and in Chapter Six I'll point to Steno's Cartesian roots. Still I agree with Ishizuka that Harvey made visible to the Aristotelians the contradiction between muscles and involuntary motion. But I think it was Descartes who provided the conceptual scaffolding for Steno to assert that the heart was a muscle, nothing more and nothing less.

CHAPTER THREE:

THREADS AND MOTION IN DESCARTES' PHYSIOLOGY

1. Introduction

Did the heart become a muscle when Nicholas Steno named it that, or did it become a muscle when his reasons for choosing that name showed up—when Descartes birthed a new theoretical framework? The question is totally senseless to most westerners. Say the heart became a muscle when Steno coughed out some relevant Danish; could he have spoken about cardiac motion that way without first learning Descartes' ideas? This is hopeless; could Descartes have come up with his ideas without first learning Aristotle's? Hegemonic prison dwellers will snivel about how the heart has always been a muscle, the ignorant people in the dark ages just didn't know it; but without Descartes could the constricted brainstems of naïve scientific realists unselfconsciously produce drool over progress? Maybe I'm just behind different bars playing the history game. Historians and neurotics weave stories, arbitrarily choosing the beginning and the end, somehow hoping to make sense of their own concepts by turning away from them. But if history is what's happening, then it seems Descartes and Steno are just parts of a single story, one the relative beginning, the other the relative end.

This chapter examines the beginning, Descartes' cardiac physiology and the threads that ran from his early to late writings. I argue that Descartes could have called the heart a muscle, even though he did not. With the help of Marjorie Grene and Lucian Petrescu I compare

Descartes' fermentation model to Aristotle's account of the heartbeat, emphasizing that there were negligible differences in their cardiac physiologies. Along the way I point to a few minor developments in his account of the heart's structure and how the blood adopts different qualities. Last, I look at Descartes' criteria for distinguishing different types of muscle movement, and argue that the heart's motion could have been placed in that category. I suggest that it wasn't because of an Aristotelian influence.

2. Descartes' Opinion: Not New, but Old

Recall how Descartes thinks the heart moves: fermented blood. This section explores that model in detail to later compare it with Alexander Ross' Aristotelian explanation (Chapter Five, section three). A preliminary yet accurate description of the fermentation model is that an additive (a yeast) mixes with the blood causing it to vaporize as a reaction, and the vaporized blood then places pressure on the walls of the heart causing them to expand (diastole). The heart then contracts (relaxes) when the blood relieves its pressure by moving to the aorta along *the path of least resistance* (systole). In the fermentation model the outflow of blood doesn't result from contraction, but from dilation—the blood doesn't get pushed out of the heart, but rather expands through it. Scholars recognize this model as a commitment to mechanism, representing an intention to avoid hylomorphism and Aristotelian principles of motion. I agree, but want to stress that the fermentation model itself was largely inspired by the Aristotelian boiling model. Stemming from the keen work of Marjorie Grene, my following analysis does uphold a distinction between boiling and fermentation, but with enough nuance to justly highlight

Descartes' Aristotelian influence. For whatever reason this influence is under-emphasized in scholarship.[12]

However, it's not unrecognized: Grene and Lucian Petrescu noted that Descartes' fermentation model is similar to Aristotle's boiling. Grene highlights the following two passages, the first from a letter dated January 1638 where Plempius responds to Descartes about his defense of a fermentation model. Plemp remarks,

> I now see this opinion of yours is not new, but old, and indeed it was issued by Aristotle, in his book *On Respiration*, chap. 20; his words are: *the beating of the heart is similar to something boiling*… our Galen, on the other hand, has taught that the heart moves by some faculty, and that is what we medical doctors all teach at present. (AT I, 497-99)[13]

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[12] I really think the similarity between Descartes and Aristotle's models is important, but it's fine grained and I want to avoid delusions of grandeur. In a way Gorham's argument is already so pregnant with the implication that you couldn't confuse it with adipose tissue, and Petrescu essentially lays out my point in passing without much ado. Really Gorham and Petrescu argue for the same conclusion but from different angles. By comparing the experimental observations of Harvey and Descartes Gorham shows that what was really at stake was metaphysical, relating to whether or not the human soul had a role in physiology, and more generally whether or not Aristotelian forms had any place in physics at all. Petrescu concludes the same by fleshing out the fervent rejection of Descartes' physiology by Fromondus, Plempius, and the Leuven faculty. So, the focus of these scholars was on the metaphysical and theological consequences of Descartes' account of the heartbeat, and not on the efficient causes and motions of the fermentation model in particular. Thus, both scholars end their article referencing one of Descartes' not so hyperbolic concerns; Gorham reports bluntly, "if his theory of the heart's motion was false and Harvey's true, then Descartes was willing to 'concede that the rest of my philosophy comes to nothing'" (Gorham 1994, p 234). Petrescu references the same, stating: "the acceptance or rejection of his explanation of the motion of the heart will determine the faith of his philosophical project." Here both Gorham and Petrescu draw from (CSMK 134; AT II 501). Somehow, amongst all this, the point never gets explicitly argued that Descartes' account of the efficient motions of the heartbeat was largely similar to Aristotle's. Dennis Des Chene also references the same letters as Petrescu and Grene, but still passes over the fact that Descartes is Aristotelian here. Recognizing that Descartes is Aristotelian in the domain of efficient causes should throw Gorham and Petrescu's theses into even greater relief when they argue that Descartes is opposed to Aristotle in his foundations.

[13] I am incredibly grateful to Roger Ariew for giving me access to his translation of these letters (forthcoming), and for pointing me to this passage and many others. Honestly, my argument in this section (especially) wouldn't have happened without him.

As you will see later (Chapter Five), this means Alexander Ross was accurately reporting the Aristotelian theory of the efficient causes of the heartbeat, and as Plemp thinks, so was Descartes. This exchange with Plemp must have impacted Descartes, as echoes from 1638 reverberate in his writing ten years later. So Grene (1993, p.326) also cites the passage in *Descriptions of the Human Body* where Descartes says, "It may seem that Aristotle thought of this when he remarked, in Chapter Twenty of his book *On Respiration*, 'this movement is similar to the action of a liquid boiled by heat'" (CSM I, 319; AT XI, 244-45). Descartes ends the passage with a report about the reception of the boiling model. He says "Aristotle's view on this question was not adopted by anyone," but this comes with an implicit qualification of who counts as a someone, showing he likely wasn't familiar with Ross, who anyway, didn't publish his medical views in *Arcana Microcosmi* until 1651, after Descartes' death.[14]

It's interesting that the comparison between Descartes' model and Chapter Twenty in Aristotle's *On Respiration* also shows up in Utrecht, between the time Descartes exchanged letters with Plemp and when he wrote *Descriptions of the Human Body*. Petrescu explains that Henricus Regius, one of Descartes' early supporters in medicine, setup a disputation in Utrecht to defend blood circulation and Descartes' model of the heartbeat. "The disputation took place on 10 June 1640, through one of Regius' students, Johannes Hayman" (Petrescu 2013, p. 411). Petrescu continues by noting that the disputation "quoted a passage from Aristotle's *De Respiratione*, 20, about the heart's pulse as an ebullition, to support Descartes' account," and that "This is the same passage quoted by Plempius in his first letter to Descartes on the circulation" (Petrescu 2013, p. 412). So like Grene, Petrescu is clearly aware of the parallel between

[14] For Grene's discussion of these passages see (Grene 1993, p. 326).

Descartes and Aristotle, but still his focus is elsewhere and he doesn't explicitly say Descartes' model is Aristotelian. But he does describe how "Descartes had always been careful not to openly provoke the Aristotelianism of the schools, largely by ignoring its theses in his published work." In contrast, Regius directly contradicted that tactic since he closely read "the formulations of Aristotelian physiology and replaced every one of them with Cartesian ideas" (Petrescu 2013, pp. 416-17). I think Regius' move here was only possible because of the overt similarities between the Cartesian and Aristotelian models to begin with.

The way Descartes categorizes his fermentation model isn't immediately straightforward, or rather, it relies heavily on unstated assumptions. Here's what I find so confusing when those assumptions aren't stated in the *Discourse*: at one-point Descartes describes how the blood gets heated "just as all liquids generally do when one lets them fall drop by drop into some vessel that is very hot" (CSM I, 135; AT VI, 48-9), and this doesn't sound like fermentation at all (but rather boiling). Yet only shortly before this he offers the well-known analogy comparing cardiac heat to wet hay or fermenting wine, which isn't boiling, but a chemical model (CSM I, 134; AT VI, 46). To me this comes across as vaguely confounding, if not as complete indecision between two different models. The rest of this section is my best attempt at clarifying what the terms "fermentation" and "boiling" meant to Descartes and how those meanings were influenced by Aristotle.

It needs to be said explicitly that what Descartes meant by "fermentation" and "boiling" is not what we mean when we use those words. Historians know this in principle. I'm sure that in certain contexts Descartes' usage of the words really is the same as how most people use them today: of course Descartes ate soup and drank beer. But Descartes' theoretical underpinnings were vastly different from our own when discussing fermentation and boiling as scientific processes. Even so, when reading Descartes' description of fermentation, it's easy to think biologically, conceiving billions of little organisms that make up yeast (but this isn't his understanding). Descartes tells Plemp,

> Is there anything more akin to blood than milk? Placed near a fire, when it comes to a certain degree of heat, it also bubbles up in this way. But there is no need of other strange examples, of which chemistry could supply a great number… When the blood in the heart begins to boil, most of it is ejected outside the heart through the aorta and arterial vein, but some quantity of it remains inside it, which, filling the intimate recesses of the ventricles, acquires a new degree of heat and becomes as it were a kind of yeast; soon afterwards, when the heart is deflated, this yeast mixing very quickly with the new blood coming through the vena cava and arterial vein causes it to boil very quickly and departs into the arteries, but not without leaving a bit of itself, in order to act again as yeast. Yeast-leavened bread is usually made with a small amount of dough already risen, as is the fermentation of wine from the remains of grapes. (Descartes to Plemp 15 February 1638)

So most accurately Descartes' fermentation model is chemical because there is a yeasty additive that brings about the reaction. This yeast however is not a copious number of small organisms, but a small amount of blood with a unique size, shape, and motion of its parts.[15]

[15] In Descartes' correspondence with Plemp it isn't fully clear how the blood left in the "recesses of the heart" differs in its yeasty qualities from the fresh blood entering into it, or how it becomes different in the first place (AT I, 521-34). We know that the yeasty blood is much hotter, but it seems like there is more going on, especially when Descartes talks about even more variations of blood in the *Passions*. We get some insight on the subject when Descartes writes to Regius in May of 1640. He proposes a correction to one of Regius theses that deals with the digestion of food and the resulting "preparation of

Plemp responds with skepticism, saying “I am afraid this fermentation may be a figment of your imagination. And if it is not, how will it be rarefied so quickly? Indeed, it is contrary to the nature and characteristics of a ferment” (Plemp to Descartes, March 1638). Plemp doesn’t see fermentation in Descartes’ account, rather he sees a reflection of Aristotle’s model in which blood expands through contact with a hot surface (the walls of the heart). But he would have done well to remember a point communicated to him the previous year when he was acting as an intermediary for Descartes and Fromondus. His resistance might have been assuaged through a comparison of the theoretical underpinnings of the different models. For Descartes told Fromondus,

> Aristotle said that rarefaction is done by an augmentation of the quantity. That is why so many of his followers are convinced that a rarefied body occupies more space along all its dimensions than if it is condensed.... But my crass philosophy does not contain such an augmentation of quantity, and I do not think of rarefaction other than what happens when the parts of a body get farther from one another and its pores or the spaces between

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the insensible particles out of which the nutriments consist.” To explain how nutrients are added to the blood from food, the digestive system and the liver become closely integrated in the Cartesian account of the cardiovascular system. Descartes describes three important instances of when nutrient particles mix with blood, and they appear to be interconnected. The first occurs “when the food and drink masticated and ingested through the mouth is dissolved and transformed into chyle by the force of the heat communicated to it from the heart.” The second occurs when the chyle mixes with the blood and moves to the liver where it’s “fermented…digested, and changed into chyme.” It’s then suggested that the chyme spreads through the body, since the third and last instance of the “preparation” occurs in the heart, “when the chyme mixed with the blood returning from the rest of the body, and undergoing preparation at the same time in the liver, through a fermentation that causes the beating of the pulse, is changed into a true and perfect blood” (AT III, 67). Descartes’ subsequent explanation of these changes is that “wherever there is motion, there can be some alteration of the particles that are moved” and he further states, “I think the chyle ferments in the liver and is digested there exactly in the same sense the Chemists use this word, namely, it is altered on account of remaining there for some time” (AT III, 68). It’s interesting to note that fermentation occurs in another organ, and that the same principles undergird the fermentation processes in both places. Of course, whether it’s in the liver or the heart, Descartes breaks it down to motion.

> its parts are increased. (Descartes to Plemp for Fromondus, 3 October 1637; AT I, 413-30)

Descartes categorizes fermentation as a kind of instantaneous rarefaction that doesn't change the quantity of the liquid, but simply changes its shape. Aristotle's boiling on the other hand must occur when the quantity of liquid increases. Therefore, the difference between the models reduces down to (1) the source heating the blood (either a bit of yeasty blood or the walls of the heart) and (2) whether or not there's an increase in the blood's quantity.

To Descartes (1) really isn't that important. He tells Plemp,

> I am very surprised that what I offered as a kind of fermentation is seen by you as a figment of my imagination to which I fled as a last refuge… For certainly my opinion is explained and demonstrated easily without it; even so, it is also necessary to admit that some of the blood rarefied in the heart remains in it from one diastole to the next, and mixing with the new blood flowing in, it assists in the rarefaction of the latter. (Descartes to Plemp 23 March 1638; AT II, 62-9)

(2) is closer to the crux and in line with what Gorham, Petrescu, and Grene all emphasize: Descartes' concern with mechanism. But this already departs from strict physiological description and delves into physics. If we define something as "Aristotelian" because of its underlying principles, then of course Descartes' model isn't Aristotelian. But if something is Aristotelian because of a general similarity to one of Aristotle's models, then Descartes' model is

Aristotelian. Did Descartes believe that fermentation and boiling were different? No doubt, but that difference was negligible. [16]

This conclusion is further supported by Descartes' last letter to Plemp, dated August 1638, in which he discusses the possibility of publishing their exchange. Descartes is grateful for Plemp's objections, specifically highlighting those against the blood's circulation, even saying "they deserve to be ranked among the strongest I received." Holding the objections in high regard while also noting Plemp's hesitation to have them published seems to have motivated Descartes' only caveat, that if published he wouldn't change the wording in them "except to insert here and there some words, as appropriate, to the effect that you proposed these objections to me for the sake of friendship of because I asked you, rather than because you think they are true" (AT II, 344). Thus, in a footnote to his translation (forthcoming), Ariew notes "Apparently, Plemp has already come round to the idea of the circulation of the blood—hence Descartes's offer to insert a few words to the effect that Plemp proposes his objections only because Descartes had urged him to do so." This reflects Plemp's willingness to accept Descartes' physiological explanations (significantly, changing his mind because of Descartes and not Harvey), even though in the end he still resisted Descartes' explanation of the hearts motion. This resistance then wasn't to Cartesian physiology, but to his metaphysical principles and their operation in physics.

[16] The contemporary understanding of boiling really does sound like Descartes' sense of rarefaction, since a greater space develops between the particles of the liquid and there is no change in quantity of particles (although, getting into the details of our current scientific understanding obviously makes this seeming similarity fall apart too). Grene has a nice ode to this theme at the end of her article that leaves a bit of mystery to the lifeworld of a 17th century thinker: "The unique, biologically grounded nature of fermentation, of course, was to become clear only in the nineteenth century, and even then, when first proposed, it appeared absurd to the leading chemists of the day. Descartes was happy to distinguish various bubblings…Why he should not have been troubled by the difference between those, like bread and beer, that need a fermenting agent, and those, like water, that can boil up with only an external source of heat, it would be difficult to say" (Grene 1993, pp. 331-32).

Of course, the consequence of Descartes using the fermentation model is a reversal of systole and diastole. Again, because of fermentation, the heart dilates when filling with vaporized blood, and contracts when the blood moves to the aorta along the path of least resistance. The outflow of blood doesn't result from contraction (systole), but from dilation (diastole). Conversely, the present view is that the heart contracts to *push* the blood into the aorta, thus making the outflow of blood a result of contraction. Next chapter we'll see that the present view is consistent with Harvey's model. Although Harvey wasn't completely right either, since he didn't think the heart contracted because it is a muscle; as shown previously, he didn't think the heart was a muscle at all, and neither did Descartes. Looking at different types of motion in Descartes' physiology will begin to answer why the heart wasn't considered a muscle in the early 17th century. I elucidate this theme in the last section of this chapter and in Chapter Five with a further comparison to Ross. But first, let's compare Descartes' fermentation model to the fermentation of his contemporary, Hobbes.

3. Hobbes' on Fermentation and Systole

I tried to show that Descartes' heartbeat account was strongly influenced by Aristotle, or, that an Aristotelian basis was the best starting point for a mechanistic account. Looking at another mechanist's account allows us to view Descartes' model on a spectrum, with one pole being faithfully Aristotelian and the other being the opposite. Hobbes is an optimal point of comparison to Descartes since he too argued that diastole resulted from heat vaporizing blood that expands the heart. In the same vein, Hobbes chose that model because of a commitment to mechanistic physics. However, Hobbes seemingly differs from Descartes and Aristotle in his account of systole.

With the exception of Douglas Jesseph's recent work, Hobbes' natural philosophy in general seems sparsely mentioned in contemporary scholarship. Its basis is systemically presented in *De Corpore*, and as Tom Sorell points out, "*De corpore* fails to mention medicine, even though Harvey is one of the pioneers of the new science praised in the *De corpore's* epistle dedicatory" (Sorell 1996, p. 52).[17] We can then conclude that Hobbes saw a connection between his physics and medicine. But Ariew speculates that Hobbes himself had a quickly waning interest in his own medical views since he never translated *De Homine* into the vernacular with his other Latin works. Contemporary scholars have followed suit. Fortunately, Rodolfo Garau recently translated some excerpts of *De Homine* for an analysis on Hobbes' account of the heartbeat. Garau's translations and his corresponding explanations will be useful here in grasping how Hobbes might have seen a connection between his mechanistic physics in *De corpore* and his account of the heartbeat in *De Homine*.

Garau reports Hobbes' physiological theory of the heartbeat in a few steps. First, air enters the lungs and is carried to the heart by the venous artery (Garau 2016, p. 235). Then, an unusual particle in the air, "nitre," causes motion in the blood, which then expands and causes the diastolic motion of the heart. The subsequent evacuation of blood from the heart through the arteries represents the systolic motion (Garau 2016, p. 236). The most curious element in Hobbes's explanation is his reference to nitre. As Garau translates from *De Homine*, Hobbes describes nitre as small corpuscles in the air. Hobbes states, "Certainly, as the salt in the sea, so

[17] It's also interesting to observe Harvey's legal will, where he allocates "tenne pounds," "to my good friend Mr Tho Hobbs to buy something to keepe in remembrance of me" (Willis 1847, p. xciv). I imagine Hobbes getting very drunk on "tenne pounds."

there is in the air some homologous salt, as the nitre, that once received in the blood by means of respiration, agitates and ferments, inflates the veins and the arteries, and is distributed to the whole body" (Garau 2016, pp. 236-37).[18] Hobbes characterizes the motion of the nitre corpuscles as a "simple motion" that is "the cause of every fermentation" (Hobbes 1656, p. 4). Garau provides an interesting discussion on nitre and its appearance in other early modern physiologies, but our interest here is in Hobbes' concept of fermentation.

Precisely like Descartes, Hobbes employs a fermentation model. They differ on what mechanism vaporizes the blood, but in both accounts it's a general additive that acts as yeast producing heat and motion. This is where both Descartes and Hobbes differ from Aristotle. For Hobbes (like Descartes), fermentation simply boils down to a specific kind of motion in particles. At the minute level, the movement of a body through a fluid medium causes other bodies resting in the medium to collect together or disperse apart depending on their size and weight. If bodies share the same size and weight they are "homogenous" and will move together. If the bodies are different in size and weight they are "heterogeneous" and will be "stirred up and carried away by that motion, and consequently they will be hindered from returning to that place to which they sink naturally." The motion of fermentation not only collects or disperses bodies floating in a fluid medium, but it also produces heat (Hobbes 1656, p. 240). So like Aristotle and Descartes both, Hobbes thinks heat is the efficient cause that moves the heart.

[18] "*Sunt ergo in aere corpuscula aliqua prae exiguitate invisibilia, quae motum hunc san- guinis in venis, quo cor movetur, efficiunt motu suo naturali. Nimirum, ut in mari sal, ita est in aere sali aliquid homologum, ceu nitrum, quod per respiratione in sanguinem receptum agitat fermentatque, venas et cor distendit, et per cordi systolem, mediantibus arteriis, in habitum corporis humani distribuitur*" (*De Homine*).

So far, all our attention has been placed on why the blood expands, thus providing an explanation of the diastolic motion. For Descartes systole occurs when the heart fibers relax. This relaxation occurs when the heart is cooled by air from the lungs. This is a strictly mechanistic account for Descartes, but Aristotle used the same explanation to account for the efficient causes of systolic motion (see Chapter Five). When Hobbes explains the systolic motion, he doesn't use the Aristotelian theory of cold air from the lungs (perhaps because he uses the lungs in his explanation of diastole), but rather draws from concepts in his physics. Descartes' explanation undoubtedly reduces to similar foundational concepts, but it's interesting to note how one mechanist (Hobbes) dispenses with Aristotle's explanation in physiology all together while the other mechanist (Descartes) maintains it.

Garau underlines two concepts that form the basis for Hobbes' explanation of systole: "conatus" and "elasticity." As Jesseph explains, Hobbes often renders the Latin "conatus" as the English "endeavor," and in chapter 15 of *De Corpore* he defines "endeavour to be Motion made in less Space and Time then can be given; that is, less then can be determined or assigned by Exposition or Number; that is, Motion made through the length of a Point, and in an Instant or Point of Time" (Jesseph 2017, p. 71). Thus, conatus refers to a motion, but one that is so minute and that seemingly occurs in an instant, so that it can't even be represented by numbers. Jesseph notes a consequence of this definition that is important for our current topic since it allows for the concept of conatus to have application in the heartbeat model: "the conatus of a body is a finite magnitude that will stand in a given ratio to the conatus of another body" (Jesseph 2017, p. 71).

Although the motions produced by a body's conatus are imperceptible, Hobbes is able to use them to explain motions that we do see, and this is how Garau characterizes "elasticity," or rather “restitution.” Garau quotes an example given in *De Corpore*, that explains how:

> the cause of the “restitution” of a plate of steel…is in the parts of the steel itself. Wherefore, whilst it remains bent, there is in the parts, of which it consisteth, some motion though invisible; that is to say, some endeavour at least that way by which the restitution is to be made; and therefore this endeavour of all the parts together is the first beginning of restitution; so that the impediment being removed, that is to say, the force by which it was held bent, it will be restored again. (Hobbes 1656, p. 175)

I take it that the restitution of the steel plate is a description of Hobbes’ principle of “resistance” in action. Jesseph describes the principle as “a body in motion encounters resistance to its motion when it comes into contact with another body having a contrary conatus.” (Jesseph 2017, p. 74). Put differently, every motion in a Hobbesian universe will always eventually result in an opposing or counter-motion. Thus, Hobbes’ definition of “restore” as “A body which is pressed and not wholly removed is said to restore itself, (when the pressing body be taken away) the parts which were moved, do by reason of the internal constitution of the pressed body, return every one into its own place” (Hobbes 1656, p. 155).

Garau connects the example of restitution to a passage from *Leviathan*, where Hobbes states, “For what is the ‘heart’ but a ‘spring’; and the ‘nerves’ but so many ‘strings’” (Hobbes 1651, p. 3). The idea here is that the heart is continually entering a state of restitution when systolic motion occurs. The fermentation that is kicked off by the nitre moves with a conatus that expands the walls of the heart, and the contrary conatus restores the minute parts of the heart wall to their original place. Thus, Hobbes thinks the heart is like a spring, retaining its original shape even after being stretched. While this account of systole and his account of diastole make Hobbes similar to Descartes because of the general commitment to mechanism, Hobbes is further away from Aristotle's physiology since he scraps the cold air explanation for systole and replaces it with an explanation directly derived from his physics.

4. Before the Heart was a Muscle

Eventually, I'll try to explain how it turned out for Descartes' heartbeat model, or at least, what it turned toward. I don't think I'll spoil anything if I offer a reminder of the present: the heart is considered a muscle. But the "obvious" always has a birthplace and a set of parents who lived through a time when it wasn't obvious at all. I'll show you, Harvey didn't think the heart was a muscle, neither did Aristotle or Galen. Descartes wasn't different. But here we are with the idea, the heart is a muscle. If I'm going to point to that idea's conceptual midwife, Nicholas Steno, and even begin to understand his methods of delivery, then the pregnancy is a proper starting place for inquiry. Grasping Aristotelian reasons (and therefore Harvey's) for not viewing the heart as a muscle is straightforward enough. But Descartes' preemptive cradle rocking manifests in a whole different language with largely mechanistic rules. He may have been the first person with the theoretical capacity for explaining cardiac motion as muscle movement, still he did not. This section aims to explain why, and thus prefigures Chapter Six.

The *Discourse* (1637) contains a more detailed account of the heart's structure and its movement than *L'Homme*. But it's surprising that Descartes doesn't describe the heart as being composed of fibers in either work. Although Descartes doesn't say it explicitly early on, we can reasonably assume he thought the heart was fibrous all along since he notes in *L'homme* that "the fact that every type of skin and flesh appears to be similarly composed of many fibres or threads, and that the same thing is observed in all plants, [and] such fibrous composition is apparently a common property of all bodies that can grow" (CSM I, 107; AT XI, 201). He explicitly states that the heart is fibrous in 1638 (AT II, 62-9). Descartes continued to view the heart as fibrous and again mentions it in *Description of a Human Body*, written sometime during the winter of 1647. But importantly, flesh having fibers does not mean that it is a muscle.

Even though I see the possibility, it makes sense that Descartes didn't call the heart a muscle. This is because of the way that he talks about muscles and movements of the body in general. The conception is laid out in *The Passions*, and similarities abound in the *Principles*, *Description of the Human Body*, and even partially in the *Discourse*. There are three sources for the motions that occur in the human machine: (1) some motions are caused by the soul like when we have a volition to walk (AT XI, 343); (2) some motions are caused by external objects but don't involve the soul, like flinching (AT XI, 338-39); and (3) other motions are caused by the bodily machine regulating itself without any relation to an external object, such as the activity of breathing (AT XI, 341). Thus, Descartes categorizes motions (2) and (3) as:

> all the movements we make without our will contributing… depend only on the arrangement of our members, and on the course which the spirits excited by the heat of the heart follow naturally in the brain, nerves, and muscles—in the same way a watch's

> movement is produced by the sheer force of its spring and the shape of its wheels. (AT XI, 341-42)[19]

The spirits and the heat of the heart together are then mechanical, functional within the rest of the body because of their relation to it. It's also clear that the heartbeat is the third kind of motion because it doesn't occur as a response to any external object.

I don't doubt that Descartes had muscle spasms after so many hard days of work, pulling out hearts of living beings. Yes, Descartes talks about convulsions (though not ostensibly his own) in several places. Once specifically when writing to More, 5 February 1649, and he describes how animals are nothing but machines. He then says that human bodies are no different, and that "This is very clear in convulsions, when the mechanism of the body moves despite the mind, and often moves more violently and in a more varied manner than usually happens when it is moved by the will" (CSMK 366; AT V, 277). Since the mind isn't involved in convulsions at all, it's very likely he would think that some muscular movements fit into category (3) as well.

Still Descartes never explicitly says the heart is or isn't a muscle. Though, he gives enough information to assume one and not the other. Whereas the previous example in the *Passions* references a watch, Descartes had previously compared the human body to fountains in the royal gardens. The man himself says in *L'homme,*

> one may compare the nerves of the machine I am describing with the pipes in the works of these fountains, its muscles and tendons with the various devices and springs which

[19] Also see "Meditation Six."

> serve to set them in motion, its animal spirits with the water which drives them, the heart with the source of the water, and the cavities of the brain with the storage tanks. (CSM I, 100; AT XI, 131)

The type of machine he uses in analogy changes, but from 1633-1649 Descartes never changes the parallel between springs and muscles. In the analogy from *L'homme* the heart is labeled under a category distinctly different from the muscles. I think this is sufficient evidence to say that Descartes didn't conceive of the heart as a muscle, even though he could have.

One can't help imagine the rainbow from Descartes' fountain as human consciousness, an emergent property flowing out of a machine, purely arising from the organization of its parts.

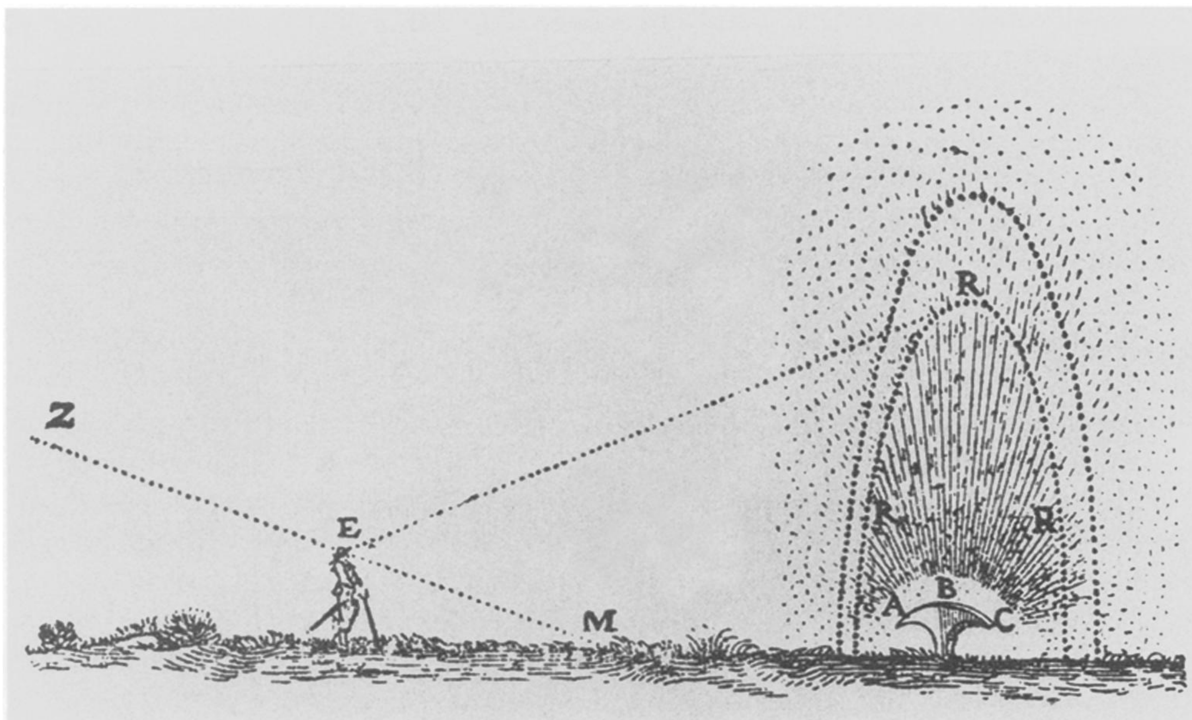

Figure 5: "Descartes' refraction fountain in the *Météores*" (From Werrett 2001)

I say Descartes could have called the heart a muscle since he already explained muscle convulsions with the same kind of criteria as the heart's motion anyway. What's important here is that both convulsions and the heartbeat consist of motions that are passive (non-volitional) and not a response to the stimulus of an external object. It also wouldn't have been a stretch for Descartes to consider the heart a muscle since some remarks to Princess Elizabeth even show that he thought the heart contained muscles, or, at least was acted upon by them!

> We can move our hands or our feet more or less at the same instant as the thought of moving them occurs, because the idea of this movement formed in the brain sends the spirits into the muscles appropriate for this result. In the same way the idea of a pleasant thing, if it takes the mind by surprise, immediately sends the spirits into the nerves that open the orifices of the heart. By the surprise it involves, wonder simply increases the force of the movement which gives rise to joy. The effect of this is that, the orifices of the heart being suddenly dilated, the blood flows into the heart from the vena cava and out again via the arterial vein, thus causing the lungs suddenly to inflate. (Descartes to Princess Elizabeth, May 1646; CSMK 287; AT IV, 409-10)

Descartes tells Elizabeth several other times that muscles open and close the heart's orifices. In another letter the year before Descartes discusses the passion of fear, describing how if you make a certain judgment with a corresponding act of imagination, then it affects the heart: "When a soul does this it acts upon the spirits which travel from the brain through the nerves into the muscles, and makes them enter the muscles whose function is to close the openings of the heart" (Descartes to Princess Elizabeth, 6 October 1645; CSMK 286; AT IV, 408). Surely the dilation and contraction of the heart's orifices isn't so different from the same movements of the heart's ventricles that characterize the heartbeat. So, it seems Descartes had another reason (conscious or not) for not making the heart a muscle and explaining its motion as such.[20]

It's time I lay out a few objections my mind made against itself concerning the implications of what I've just said. If I don't clear the air now, it'll just be messier later. The first potential issue regards something Geoffrey Gorham said. He addresses muscle movements in a footnote, largely noting what I've characterized above as class (2) motions. He remarks,

> Neither did Descartes require that all muscular activity originate with an action of the mind-only, those movements of the muscles that are known to involve conscious volition. All other muscular movements, the various reflexes for example, can be given a mechanistic reduction, in which case they do not involve self-movement. (CSM I, 330-35; AT XI, 332-42; Gorham 1994, p. 233, footnote 63)

This might make it seem like a muscle couldn't fulfill the function of the heartbeat for Descartes as I've suggested; isn't the heartbeat self-moving? Well, kind of not really. Gorham's footnote branches out from a discussion of Harvey on self-motion, and Gorham rightly points to how Harvey thought the blood was "the first instrument in natural things [and] contains the internal

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[20] Sifting through Descartes' physiology and William Harvey's *De Motu Cordis* side by side, one can't help notice a relevant parallel. Harvey quite possibly had Aristotle' *De Anima* in mind (See Aristotle's *De Anima*, Book I Chapter Four) when he remarked, "as Aristotle says… grief, and love, and envy, and anxiety, and all affections of the mind of a similar kind are accompanied with emaciation and decay, or with cacochemy and crudity, which engender all manner of diseases and consume the boy of man. For every affection of the mind that is attended with either pain or pleasure, hope or fear, is the cause of an agitation whose influence extends to the heart, and there induces change from the natural constitution (Harvey 1628, p. 70). So, based on this, I can tell you that Descartes echoed an Aristotelian notion that passions affect the heart.

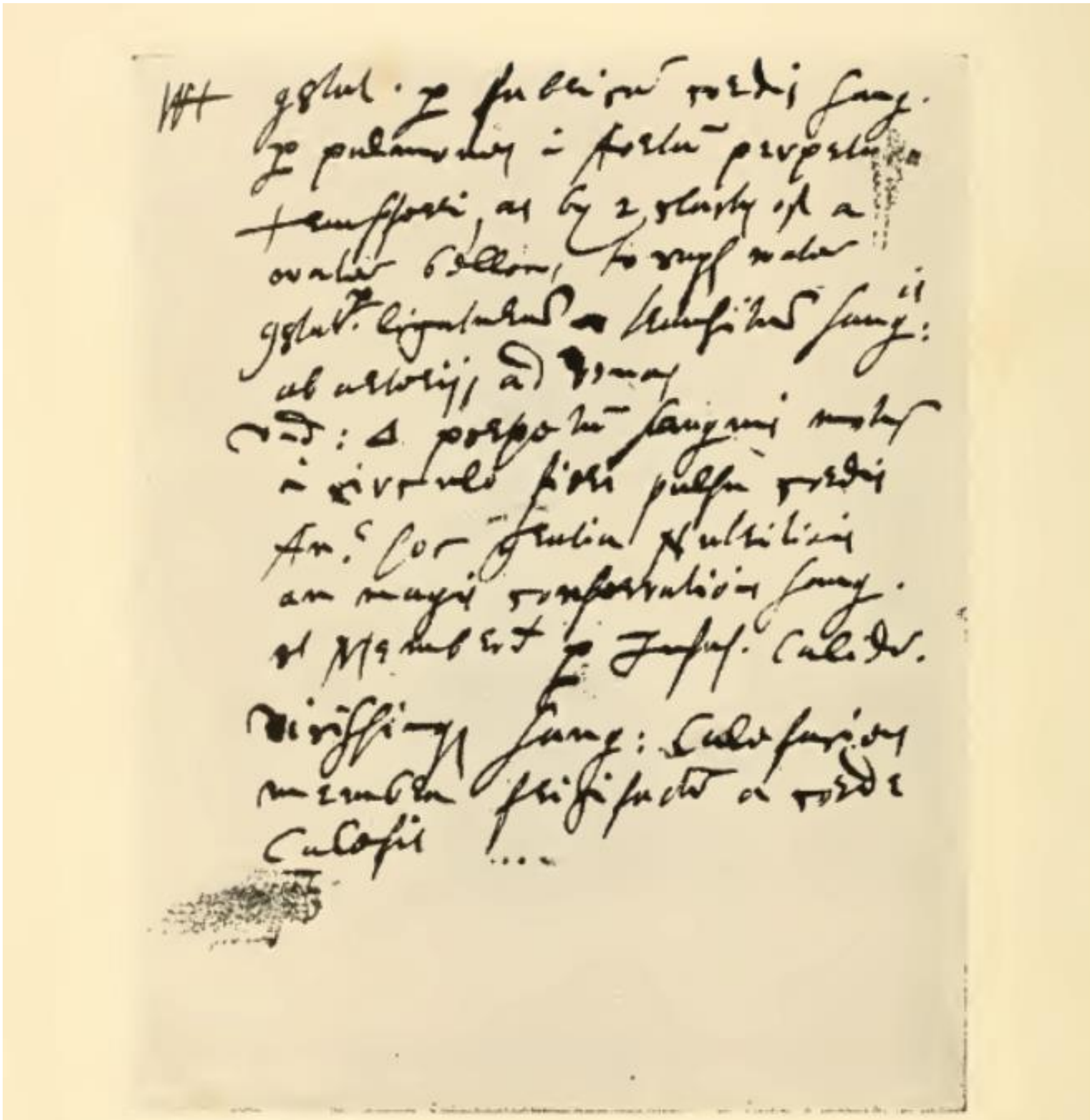
moving cause within itself" (Harvey 1628, p. 511; Gorham 1994, p. 232). So, when Gorham says the various reflexes in Descartes "don't involve self-movement," he means a reflex doesn't have an "internal moving cause within itself." And he's right! Descartes' fermentation model has the heart moving as a result of a reaction to other moving stuff, but that's how the muscles move too.

There are some potential reasons why Descartes didn't think the heart was a muscle though, and these might also be considered as objections to the idea that Descartes chose his position because he was familiar with it from Aristotle. First, it seems that a defining characteristic of muscles for Descartes is at least a capacity to be moved both by the will and in response to external stimulus. The heart (like the liver) has neither of these capacities. The second reason comes from what Descartes told More about convulsions: that the body (and thus muscles) "moves more violently and in a more varied manner than usually happens when it is moved by the will." This means muscle might not be able to provide the continuous and steady motion that the heart seems to exhibit.

Here's a couple responses to these possible objections. Regarding the first, the requirement of a capacity to be moved by the will seems at least diluted by what Descartes tells Elizabeth about how the passions affect the heart. If simply thinking about something lovely (or fearful) can move muscles that open the heart's orifices, then wouldn't this count as the will affecting the heart (albeit through the mediation of emotion)? Regarding the second, I suggest that Descartes didn't think all convulsions were characterized by a more violent and varied motion. He tells Elizabeth, "A sardonic grin may be due to a convulsion of the nerves of the face" (To Princess Elizabeth, May 1646; CSMK 287; AT IV, 410). Sardonic grins hardly seem violent and varied.

Whether or not making the heart a muscle would have fulfilled all the perceived functions of the heart is another question, one I'll only spend a little time answering later. I'll also revisit the idea that Descartes didn't think the heart was a muscle because of an Aristotelian influence. If it had crossed Descartes' mind at all, then it's likely he dismissed it for increasing the potential of adding more drama and resistance to his plate. After all, Descartes wanted his physiology to be accepted, and no one else thought of the heart as a muscle, or had systems like his own that could accommodate the claim.[21]

[21] For the reasons that Descartes and contemporaries didn't view the heart as a muscle, see: Chapter Five, section 3.



The First Notation of the Discovery of the Circulation of the Blood, in Harvey's Handwriting

Figure 6: (From Harvey 1628)

CHAPTER FOUR:

HARVEY AND THE WEATHER—*PROPRIAE MOTIONES* IN THE MICROCOSM

1. Introduction

When Harvey first writes to the public about discovering the blood's circulation, he tells us he is fearful. When he made the discovery himself we can suspect he was ecstatic. Surely all of his experiments and observations made circulation a natural conclusion, but every experience can be interpreted in various and incongruent ways. Watching a blue-collar theist and an atheistic scientist explain a rainbow is evidence enough. Experience rarely speaks for itself; our form of life is accompanied by a theoretical background that acts as our perceptual lexigraphy. An apple didn't hit Newton on the head, and split veins didn't simply shout circulation at Harvey. Both men had educational backgrounds that were essential components in their scientific discoveries, backgrounds that provided the interpretive inspiration for their own eventual demise. In Harvey's words, "I began to think whether there might not be a motion, as it were, in a circle. Now this I afterwards found to be true" (Harvey 1628, p. 46). First, the circulation hypothesis popped into Harvey's head, afterwards the evidence confirmed it. The background that inspired his hypothesis was Aristotle, not specifically the physician, but metaphysician.

The best-known evidence for this appears in *De motu cordis* (1628). When describing the blood's path through the body, Harvey says that the motion can be called circular,

> in the same way as Aristotle says that the air and the rain emulate the circular motion of the superior bodies; for the moist earth, warmed by the sun, evaporates; the vapours draw upwards are condensed, and the descending in the form of rain, moisten the earth again; and by this arrangement are generations of living things produced; and in like manner too are tempests and meteors engendered by the circular motion, and by the approach and recession of the sun. And so, in all likelihood, does it come to pass in the body, through the motion of the blood; the various parts are nourished, cherished, quickened by the warmer, more prefect vaporous, spiritous, and , as I may say, alimentive blood; which on the contrary, in contact with these parts becomes cooled, coagulated, and so to speak, effete; whence it returns to its sovereign the heart. (Harvey 1628, p. 46)

Here the human body is described as microcosm, a system reflecting the principles and motions of the larger cosmos. This is the only place in *De motu cordis* where Harvey uses microcosmic language and talks about the final cause or purpose of the heart's motion.[22] This is especially strange since, as Roger French shows, Harvey's research program would not only have included a search for final causes, but wouldn't have reached a conclusion in *scientia* until final causes were confidently put forth. This method was based on Aristotle's process as it appears in his animal books, a research approach that Harvey likely inherited from his teacher at Padua, Fabricius ab Aquapendente (French 2006, p. 66). Of course, this leaves historians wanting.

[22] Even when challenged by Caspar Hoffman to explain the purpose of the circulation, Harvey proffers an account of the efficient causes and argues that knowing the final causes of circulation isn't necessary to prove that circulation in fact takes place. See Harvey's reply to Hoffman, May 1636, in (Whitteridge 1971, pp. 237-47).

The guiding question I hope to answer in this chapter is whether or not Harvey honestly bought into microcosmic ideas, and if so, to what extent and in what form. If he did not, then the following analysis will have to explain his use of microcosmic language and look for an explanation of his motives for employing it. If he did, then we're interested in what role they played in his physiological explanations. As a physician at Cambridge, it was an option for Harvey to not discuss such topics in print, and in large part he doesn't. However, toward the end of his last work *de generatione*, he devotes a considerable number of pages to the subject, specifically aiming to explain the source of the innate heat in the heart and blood. I argue that the microcosmic ideas in *de generation* shows that Harvey took the microcosm-macrocosm scheme seriously, and that he held some form of these ideas even before publishing *De motu cordis*. I also aim to show that the microcosm-macrocosm scheme wasn't just a metaphor for Harvey, but a functional framework for explaining the final cause of the heart and blood's motion; although some doubt may remain, and I do my best to assuage it.

On the surface our task here is to overcome a mere obstacle of translation, changing Harvey's words into our own to grasp their meaning. But even in doing this we fail to attain an understanding of his perspective—a mode of experience, not just a lens mediating perception, but perception itself—such that our understanding can never be the same as Harvey's. Looking at other historical uses of microcosmic ideas helps, and I'll do that first. But ultimately a cursory understanding of the early modern microcosmic perspective will have to do. Thankfully Harvey, perhaps in clairvoyance, saw a need for definitions. Later I'll turn to *de generatione* where Harvey tells readers that he wants to explain "what is meant by the word 'spirit,' and what by the phrases 'superior in action to the forces of the elements,' 'to have the properties of another body, and that more divine than those bodies which are called elements,' and 'the nature inherent in this spirit which answers to the essence of the stars'" (Harvey 1651, p 506). This kind of encyclopedic information helps us interpret his words in *de Motu Cordis*, but only gets us part way up a path that can't be explored to the end. Just as reading instructions for driving in an English roundabout never fully transmits the knowledge needed to perform the act (Wrathall 1999), here, merely reading encyclopedic entries on the microcosmic hallucination will never give us psychedelic initiates a view of the historical other-side.

2. A Microcosmic Mosaic

Walter Pagel is the leading culprit in disseminating the notion that microcosmic ideas played a large role in medical history. Amongst other places, Pagel presents the idea in his 1951 article "Giordano Bruno: The Philosophy of Circles and the Circular Movement of the Blood," his 1957 article "The Philosophy of Circles," and in his book from 1967 *William Harvey's Biological Ideas*. More recently early modern scholars focusing on the heart and blood have shown a little interest in the subject. Thomas Fuchs (2001) shows an affinity for Pagel, perhaps in some form of unconscious German tribalism. Fuchs argues that Harvey draws his microcosmic ideas mostly from Galen. But I find his reliance on the twentieth century notion of "pre-ideas" in philosophy of science to be an

Figure 7: "Sachs a Loewnheimb, Frontispiece to Oceanus macro-microcosmicus, Breslau 1664" (From Pagel 1967)

insufficient substitute for evidence that connects any two thinkers, let alone Harvey and Galen on this subject.

Others have resisted Pagel (and Fuchs) for being ahistorical. This seems to kick off with Marjorie Grene (coincidentally the translator of Fuchs 2001) who simply can't get on board with the notion of a "philosophy of circles." This is fair resistance. At times the way Pagel talks about the microcosm and circular motion makes Aristotle sound more like Pythagoras, with renaissance and early modern physicians being his mystical followers. Benjamin Goldberg is sympathetic with Grene when he states, "there is absolutely no sense in which it can be said that Aristotle has a 'philosophy of circles' or that the symbolism of the circle is fundamental to his work."[23] He continues by recognizing circular motion in Aristotle's *Meteorology*, as well his views that celestial orbits interact with cycles in the terrestrial sphere like the weather (Goldberg 2012, p. 9). But Goldberg points out that celestial orbits have different characteristics than the weather and that none of this adds up to a "philosophy of circles." Very true, but perhaps Goldberg is a bit hasty when he says "there is precious little evidence that he [Harvey] gave much credence to the idea of microcosm-macrocosm correspondence" (Goldberg 2012, p. 9).

I agree with Grene and Goldberg's skepticism on the philosophy of circles, and their judgement that Pagel and Fuchs can be ahistorical in their musings. But Pagel's collection of historical data regarding microcosmic ideas can't be ignored. He provides plenty of instances in which a microcosm-macrocosm correspondence was taken seriously by Harvey's predecessors to help us understand what that theory looked like and how it depended on and differed from Aristotle. Even more important, he unfolds a crease of history that entails Harvey's connection to

[23] Goldberg further discredits Fuchs for ahistorically applying the category of vitalism to Harvey, since the 18th century concept wasn't operative in his time. The "vital principle" derived it's meaning from Aristotle and Galen, who were not adherents to "vitalism."

Stephan Roderic de Castro. Castro was a proponent of microcosmic ideas and Harvey gives his work credence; this is precious evidence indeed. In what follows I'll point to some significant instances of microcosmic ideas in the history of medicine, ones that I think Harvey was likely aware of, and I'll also point to some contemporaries of Harvey that accepted the microcosm-macrocosm scheme in one way or another. Castro will be last in the series, since outside of Harvey's published works, it's the most direct link between him and a support for microcosmic ideas. After this, I consider Aristotle cosmology and interpret Harvey's later work directly.

Other than Aristotle, Galen was the most prolific of ancient physicians to have a heavy influence on early modern medicine. As Goldberg points out, Harvey's medical theories represented a hybrid of Aristotelian and Galenic ideas. While more often than not he walked the peripatetic line, it's significant that Harvey's model of the heartbeat was based on Galen (see Chapter Five). Galen himself accepted some form of a microcosmic theory to relate his medical practices to a larger system of nature. As French outlines, "Galen could relate therapeutic techniques like the letting of blood to the structure of the body, to its functioning, and from here by a microcosmic-macrocosmic parallel to the fundamentals of the world picture" (French 2006, p. 5). But Galen's understanding of the cosmos differed significantly from that of Aristotle's. In part, Galen's conception of Nature stemmed from Pliny and Stoics such as Marcus Aurelius who was his emperor. In other ways his conception was influenced by Plato and Aristotle (French 2006, p. 5). French further notes how Galen's leading natural-philosophical work, *On the Use of the Parts of the Body*, was highly compatible with Christian views in the west because of its microcosm-macrocosm themes. He thought every part of the body, composed of various types of material, "has its own natural actions, which nature has selected as appropriate for the overall function of the complex parts and the body as a whole," and that this demonstrated that "the body was created by a higher agency, which created with wisdom and foresight" (French 2006, p. 5). So, for Galen it wasn't so much that the same sorts of motion and properties were manifest in both the stars and the human body, but rather, his microcosmic ideas focused on the harmonious and symmetrical organization of parts within a system and the principles used by a deity to create it.

Another significant forerunner to Harvey is Thomas Aquinas, who likely wasn't directly responsible for any of Harvey's theories, but as a well-trained Aristotelian Harvey probably encountered his views nonetheless. The titles of medieval philosophical treatises often appear generic, and Pagel spots that Harvey's treatise on the motion of the heart and blood shared such a moniker with Aquinas' "*Opusculum*, or rather *Letter De Motu Cordis*" (Pagel 1967, p. 103). For Pagel, the significance of Aquinas' little letter has less to do with microcosmic ideas directly, and more with circular motion in cardiac movement. Aquinas never discusses the blood as having circular motion, but instead applies the concept to the heart. In so doing, Aquinas claims that the heart expresses the natural motion of Aristotle's physics, "not in the ordinary sense of *motus naturalis*, predicated of a body because it is heavy or light and thus follows one direction, but because movement is immanent to the heart that is animated by a certain kind of soul and not due to an external force" (Pagel 1967, p. 91). I'll say more on natural motion and how it relates to Harvey's theory later. It's interesting to note that Aquinas did represent microcosmic ideas in ways that Pagel doesn't reference. Often referred to as the counter-reformation's "sun of the Church," images of Aquinas adorned many of the medical texts published by faculty at Louvain (French 2006, p. 201). The image below (ii) is worthy of attention, since it appeared in a text by Fortunatus Vopiscus Plemp (Plempius). Here you can see Aquinas with a bright sun at the heart of his chest.

Figure 8: Published in Plempius' *Fundamenta medicinae* (From French 2006)

In addition to his forebearers, it's also worth highlighting some of Harvey's contemporaries who appreciated his theory of circulation and who utilized microcosmic schemes themselves.[24] Some of his contemporaries simply fill in the context a bit, showing that the theory of the blood's circulation and microcosmic ideas were easily comingled after Harvey published *de Motu Cordis*, and that microcosmic ideas weren't fringe or out of date around that time. Robert Fludd and Stephan Roderic de Castro however offer something more direct, as possible

[24] There are many others I don't discuss who were contemporaries to Harvey and who used some form of microcosmic ideas in natural philosophy, and at times, in political philosophy. Amongst others this includes: Andrea Argoli, Werner Rolfink, Jean Riolan II, Francis Glisson, James Primrose, Helkiah Crooke, Sir Francis Drake, Walter Charleton, Giordano Bruno, Philip Jacob Sachs von Lewenheimb, and Johannes Kepler.

influences on Harvey that may have lent to his acceptance of microcosmic ideas. The first figure to discuss is examined by both Pagel and French: Robert Fludd, who Gassendi and Mersenne labelled as a heretic and black magician (French 2006, p. 126).[25]

Fludd likely attended Harvey's early anatomical lectures that served as a precursor to the ideas published in *de Motu Cordis*. As Pagel notes, "The evidence for this derives from Fludd's *Clavis*—a reply to the anatomical and physiological arguments assembled by Gassendi against Fludd's ideas on the movement of the blood." There in, Fludd describes having witnessed cadaver heart dissections "by several of my colleagues and particularly by Dr Harvey, most expert anatomist" (Pagel 1967, p. 114). Pagel continues by laying out the evidence of Harvey and Fludd's relationship, calling them close friends and compatriots. The idea of these two as real buddy buddies seems like fanciful imagery that Pagel extrapolates from the evidence to serve his grand narrative, but the evidence of their personal relationship is there nonetheless.[26] Fludd's *Medicina catholica* contains the first recognition in print of Harvey's circulation theory (Pagel 1967, p. 114; Debus 1970, p. 82). Additionally, Fludd supposedly describes the blood as, "obeying the systole and diastole with a movement resembling the ebb and flood of the tide, and moving in the same way as the world in its orbit." Pagel further paraphrases Fludd who apparently connects the discovery of circulation to his own microcosmic ideas: "such considerations confirm, Fludd says, *exacte* the verdict and opinion of his friend, colleague and compatriot, Harvey, who was well versed not only in anatomy, but also in the deepest mysteries of philosophy" (Pagel 1967, pp. 114-15). Pagel gives several more clues regarding Harvey and

[25] Drawing on Debus, French reports, "Mersenne had attacked Fludd's 'black magic' in his *Celebrated Questions on Genesis* of 1623. In 1628 he sent a number of Fludd's works to Gassendi, along with Harvey's book on the motion of the heart. Gassendi quickly composed a refutation of Fludd (published in 1630)" (French 2006, p. 125 note 39).

[26] Also see (Debus 1970, p. 85).

Fludd's relationship, including instances where Harvey mentions Fludd in his *Prelectiones Anatomiae Universalis* and *de motu locali animalium*.

Pagel's account is interesting and it's a start to getting a thermometer reading on the immediate reception of Harvey's ideas. The conclusions he draws from Harvey and Fludd's relationship is corroborated by French, who places Fludd and the reception of Harvey's circulation theory in the larger context of chemical philosophy. Fludd spent time on the European continent where he picked up an influence from Paracelsus and the alchemists. French reports,

> in England at least chemistry was part of an alternative to classical medicine, along with Platonic and Hermetic doctrines. Many of these had micro- and macrocosmic schemes of correspondence, of which circularity was often a feature. Not only was Harvey, as censor of an increasingly defensive college, acutely aware of the power of such systems, but—it has been argued—they prepared the ground for Fludd's synthesis and for the reception of Harvey's doctrine of circulation. (French 2006, p. 130)

French's point isn't just that Fludd's own interest in microcosmic ideas made him open to Harvey's circulation theory, but also that Fludd was part of a bigger movement in medicine with many members equally sympathetic to Harvey's discovery. Harvey was aware of this alternative approach to medicine, and not only through his relationship with Fludd. A common point of agreement for members of this medical subculture was a microcosm-macrocosm scheme for the cosmos and the human bodies within it. French remarks, "like all chemists [Fludd] was already familiar with the *circulatio* of distillation, and more than most he was ready to appreciate Harvey's macro-microcosmic parallels."

French further highlights Fludd's point of intersection with some of Harvey's theoretical precursors Servetus and Colombo (who Harvey names in *de Motu Cordis*), and another of his contemporaries, the German physician Daniel Sennert. French states,

> In place of the Platonic or Aristotelian *psyche,* Fludd and Sennert saw the soul in Old Testament terms as the blood. Such a position is not distant from Harvey's later opinion, although we cannot tell if any religious concerns were important to him. But it is significant that in the cases of Servetus, Colombo, Fludd and Sennert it was a similar religious concern that led their attention to the animation of the blood. (French 2006, p. 130)

As I'll explain later, Harvey shared the view of Severtus, Columbo, Fludd, and Sennert that the blood was animate and the seat of the soul. This isn't only significant for distinguishing Harvey from other Aristotelians, but also because it was the direct consequence of a microcosmic view, one also held by Fludd and Sennert.

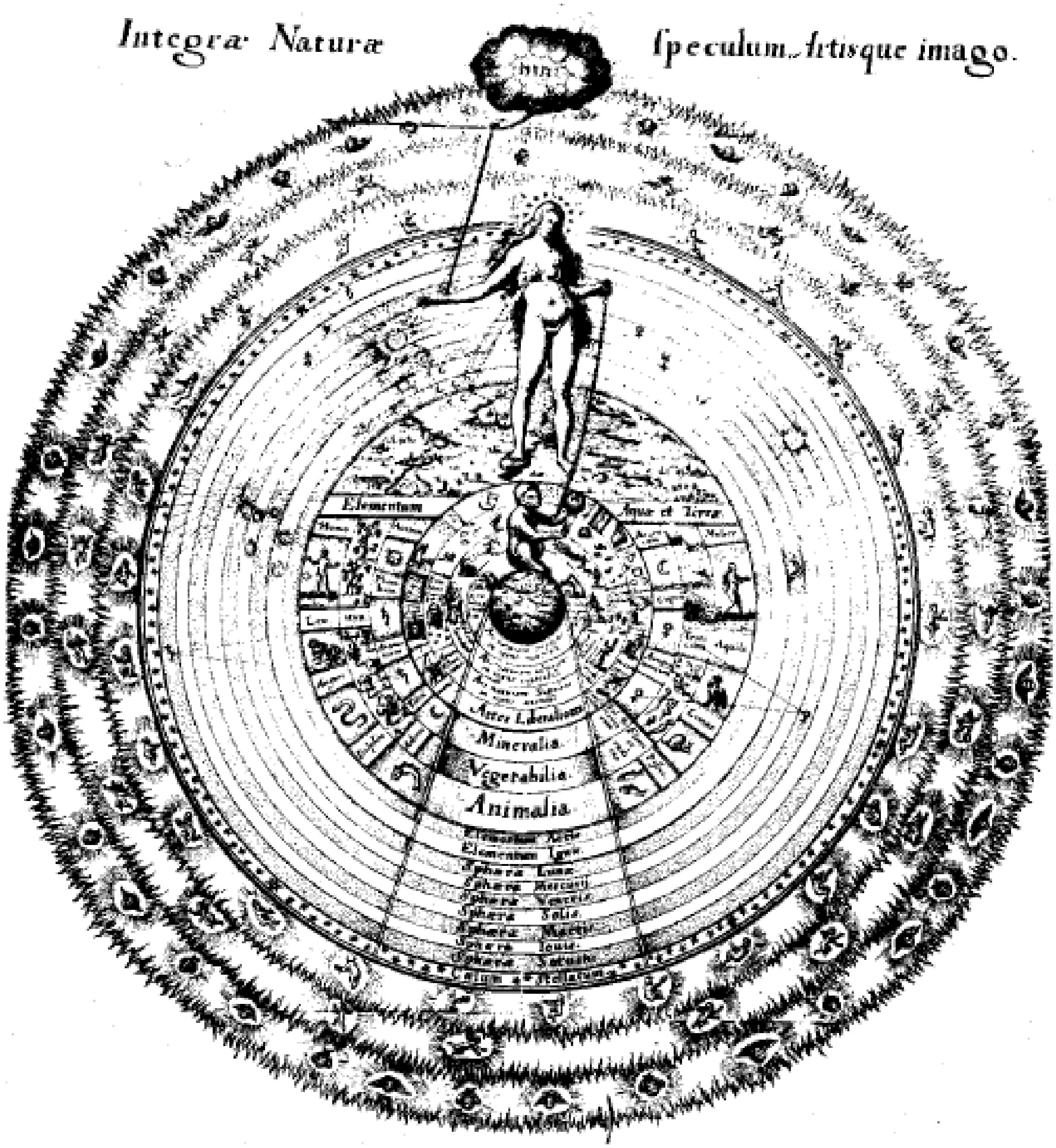


Figure 9: "The Universe of Robert Fludd" (From Debus 1977)

The most significant of Harvey's microcosmic thinking contemporaries was Stephan Roderic de Castro (1559-1627), a Professor of Medicine at Pisa and at one time the personal physician to the Grand Duke of Tuscany. In addition to a then well-known work in medicine, Castro also published on atmospheric phenomena in a work titled *De meteoris microcosmi*

(1621). Therein he describes how diseases in the human body correspond to the equally morbid phenomena of rain, hail, snow, frost, storms, and comets, all of which plagued the much larger atmosphere (Pagel 1967, p. 97).[27] For Castro, analogies could be drawn between physiological events and celestial events because both exhibit similar kinds of motion, albeit, amongst very different substances. Hence, Castro offers microcosmic anatomical descriptions such as, "life is fire contained in the blood—its origin is the heart, the microcosmic sun," and further, that "it is through the pulse of the arteries that the microcosm receives the signature of the celestial world" (Pagel 1967, pp. 98-9).

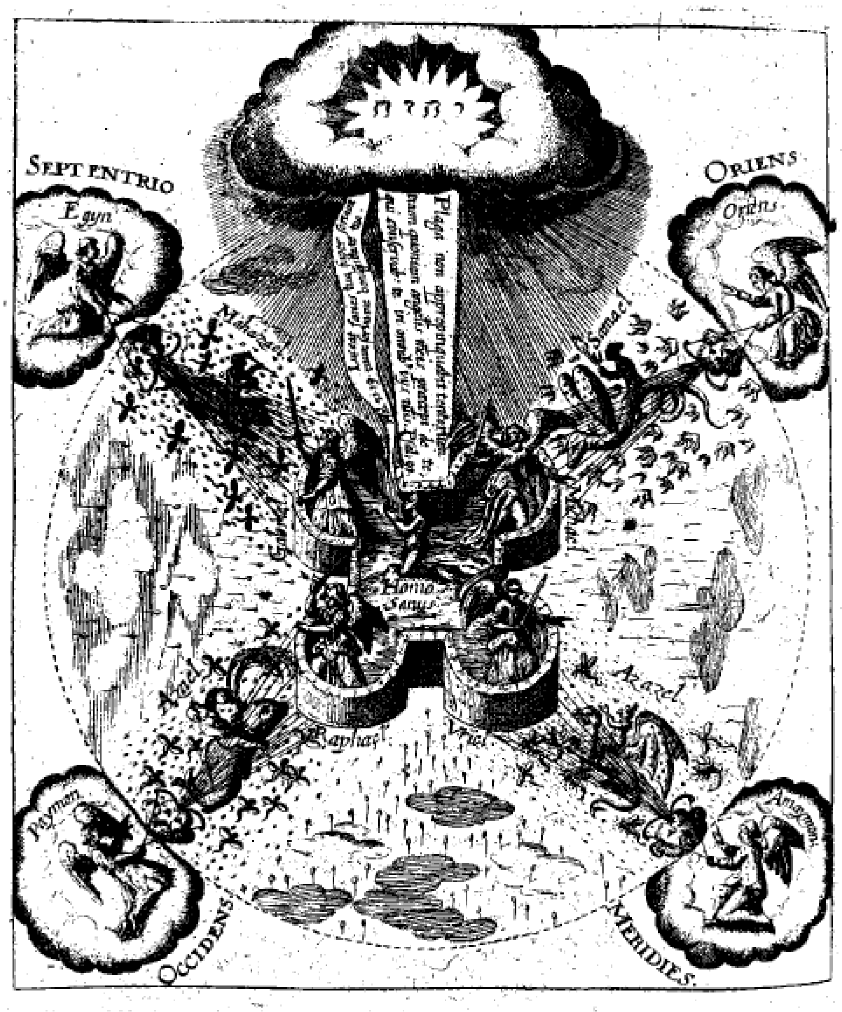


Figure 10: "Man besieged in his castle of health. From Robert Fludd, *Integrum morborum mysterium*… 1631" (From Debus 1977)

[27] Pagel correctly notes that although Castro was Aristotelian, his theory was also greatly influenced by Hippocrates, who for instance in his book *On Winds*, describes the spirits in the blood as the source of disease (Pagel 1967, p. 98).

IOH. BEVEROVICII
EXERCITATIO
IN
HIPPOCRATIS
APHORISMVM
de Calculo
AD N. V.
CLAVDIVM SALMASIVM
Equitem, & Conf. Regium.
Accedunt ejusdem argumenti
Doctorum Epistolæ.

LVGD. BATAVORVM,
Ex Officinâ Elseviriorum.
cIɔ Iɔ c XLI.

SPICIL. DE CALCVLO. 191

Ex Hippocratis, Galeni, & aliorum sententia glutinosum requiri ad Calculi generationem: neque stuporem renum eo videri necessarium.

IOHANNI BEVEROVICIO,
Senatori, & Medico Dordrechtano,
GVL. HARVEVS S.D.

Quod in itinere Germanico pridem à me suscepto, Vir præstantissime, te, patriæ artisque Medicæ decus, vidisse non contigerit, pariter uti te, tuæ literæ gratissima mihi (quas cum libello, præterita septimana, accepimus) dolore non mediocri affectum significarunt; ita quoque doleam, scire poteris, ubi noveris quo sim animo in viros cordatos, sagacesque rerum naturalium indagatores tui similes Quod sanguinis circulatio inventa, tam docto capiti non displiceat, eo quidem nomine mihi jam nunc demum magis placere cœpit, animumque dabit plura & multo majora meditanti, cum conatus nostros, eruditis placere intellexerim. Pergratus mihi doctus & elegans, vereque singularis liber tuus de Calculo renum & vesica, in quo firma solidaque nominis famaque jecisti

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jecisti fundamenta; quin pergas porro indies superstruere, splendidumque ingenii tui monumentum exædificare. Ego calculum haud illubens adjiciam meum, nec suos opinor tibi denegabunt alii, iique, quos præsens ætas fert melioris notæ, Medici.

Stephanus Rodericus Castrensis magni Hetruriæ ducis Medicus, & Sennertus vester, quam parum à sententia tua absint, is judicabit optime, qui hujus Institutiones, illius de Microcosmi meteoris libros perspectos habet. Paracelso, ejusque sequacibus ex certe gemma placere debet, quam ex illius minera erutam, magis tamen authoritate antiquorum politam & optimis observationibus & argumentis illustrem & ornatam in omnium manus tradidisti. Nec Hippocrati quidem, nec Galeno, si jam postliminio revocari possint, eam displicere posse putem. ea cum reverentia sententias eorum tractas, ac si priscorum Medicinæ procerum scita placitaque non tam refellenda, quam candide explicita, in meliorem sensum accipienda judices. Si quis denique libertatis philosophicæ assertor, è rebus ipsis, & naturæ sinu, quam è libris, sapere, quam discere malit, scire quam credere, habes quod etiam

Figure 11: “Harvey’s letter to Beverwijck, from *In Hippocratis aphorismum de calculo*”
“Beverwijck, Leyden 1641” (From Pagel 1967)

Apart from being interesting in its own right, Castro’s *De meteoris microcosmi* supports the idea that Harvey was disposed to interpret the motion of the blood and heart in terms of circular motion in an Aristotelian cosmos. In a letter to John Beverwijck of Dordrecht dated April 20th 1638, Harvey tells his correspondent, “[the views of] Stephanus Rodericus Casternisis, physician to the Grandduke of Toscana and your Sennert—how little they differ from your view, he will best judge who has perused the *Institutions* of the latter and the books on the *Meteora of the microsom* of the former” (Pagel 1967, p. 100). Later in the same letter, Harvey references Aristotle’s *Meteorology* as a means of increasing his understanding of the origin of kidney stones. It’s important that Harvey recommended Castro’s work on the intersection between Aristotelian meteorology and the microcosm to a fellow physician.

3. Harvey's Microcosmic Ideas and the Seat of the Soul

Thomas Wright tells us that Harvey had a special attraction to silence and darkness. He sequestered "a special 'meditating apartment' in his London home, and in the grounds of a country house he purchased at Combe he had some caves dug 'in the Earth, in which in Summer time he delighted to meditate'" (Wright 2012, p. 156). Perhaps like the chemical philosophers, Harvey worshiped his God through quiet prayer, contemplating the macrocosm he encountered in medical investigations of the microcosm.[28] Apart from the contextual evidence of Harvey's forebearers and contemporaries, there is significant evidence from Harvey's own work that he employed microcosmic ideas. In the efforts leading to *De motu cordis*, Harvey began the honored task of conducting the Lumleian anatomy lectures at the Royal College of Physicians in 1616. French recounts that "Harvey opened his anatomy lectures with a general statement on the nature of anatomy, that is, a kind of introduction, or more strictly, an *accessus*, to anatomy." This introduction included an

> account of the kinds of anatomy, the different ways in which it can be practised. The first was public, teaching anatomy, concerned with *historia* of the major organs in the 'three venters' (abdomen, thorax, head) of the body. The second was philosophical anatomy, concerned with the purposes of the organs (the 'action, function and purpose' of his anatomical *accessus)* and the relationship of the body, the microcosm, with the world at large, the macrocosm. (French 2006, p. 3)

[28] See Debus (1977, pp. 66-7) for information on the contemplative habits of chemical philosophers.

So, there's evidence that even before Harvey reached the conclusion that the blood circulates, a part of his medical philosophy was viewing the body as a microcosm.

I think there are two naïve ways to interpret Harvey's use of microcosmic language. The first is too literal and the second is too metaphorical. On the one hand you could take contemporary notions and read them back into history, thinking Harvey perceived a direct causal link between the human body and the stars. But there is no evidence of his belief in some chain of efficient causes between the heavens and blood. On the other hand, you could think that Harvey was using pure analogy, saying nothing more than 'stars are hot, and so is blood.' This second view has a bit more credibility than the first, and I will deal with it as a potential objection at the end of this section. Regardless, both of these interpretations are overly simplistic and in one way or another disregard some part of Harvey's overt Aristotelian commitments.

3.1. Elements, Celestial Bodies, and Divine Motion in Aristotle

The following explanation of Aristotle's physics is tedious, but necessary. The goal is to first determine what characterizes the elements, then explain how celestial bodies are "divine," and thus show how the two cosmological entities are different. Elucidating how motion and change result from their interaction will also be essential for our understanding of Harvey.

The "elements" are of primary importance in Aristotle's cosmology. Whether you're a wu wu new ager into astrology or an uncomfortable philosophy geek eager to make jokes about funk bands, you're likely no stranger to Earth, Water, Air, and Fire. These four refer to the most basic constituents of all material objects in an Aristotelian cosmos, and are more strictly called the primary elements. As basic constituents they can't be broken down into anything simpler, so you rarely have a direct experience of the pure elements themselves. Rather Aristotle finds the elements useful in discussing the qualities or properties of ordinary objects in nature as they help delimit characteristics. He considers Fire "hot and dry" and water "cold and moist," thus representing "contraries" in our experience. The contraries prove their usefulness as a theoretical basis for the difference between liquids and solids and for describing varying degrees of temperature. Thus, Aristotle says in *De Generatione et Corruptione*, "[M]oist is that which, being readily adaptable in shape, is not determinable by any limit of its own; while dry is that which is readily determinable by its own limit, but not readily adaptable in shape" (*DG* II.2, 329b30f.)

Gary Herbert (1989) does a good job laying out how the primary elements and their contrary properties form the backdrop for an Aristotelian account of motion. Aristotle considers each element to have its "natural place" in relation to the others, or, a physical location that is determined according to their "weight." Earth is heavier than water, and as Doug Jesseph quipped, this explains why rocks sink and bowls hold liquid. Of course, you might then assume that nature would exist as a static block, with elements resting forever layered in perfect order. By and large the elements do form concentric rings around each other, with earth as a spherical core, surrounded by a ring of water, which itself is surrounded by air, etc. But the elements clearly don't maintain strict boundaries because water falls out of the air all the time (rain). So, Aristotle's contrary properties play another explanatory role; what is hot and dry is always "potentially" cold and moist. The contraries are subject to change, and this explains how the elements are always transforming and moving to and fro from their natural place. When the cold and moist becomes hot and moist, the water transforms and takes its place amongst the air. When the transformation of properties takes place, Aristotle calls this "alteration."

The cause of the contraries' alteration is crucial in understanding what Harvey and others are up to (and what they aren't) when talking about the human microcosm and how it relates to the larger cosmos. As Herbert explains,

> This alteration of elements occurs because of the influence of the motion of celestial bodies, for example, the sun as it alternately approaches the earth and recedes, thus causing an alteration of the seasons, the heating (and evaporation) of water, etc. Consequently, for Aristotelian physics, motion becomes "the characteristic fact of nature." (Herbert 1989, p. 30)

The hydrologic cycle is the best example of how the stars' motion affects the motion of sublunary elements (earth, water, air). The celestial bodies (superlunary) move in a circle, and this movement disrupts the sublunary elements that then mirror that circular motion: water evaporates (into air) and re-condenses to form rain (water) which then moves to its natural place below the sky. More on this in a moment—first, a bit about αἰθήρ (aether).

The influence of celestial bodies on the sublunary elements conjures an interesting question about a fifth element: aether. Did aether factor into Harvey's interpretation of the cosmos or not? The term never pops up in the work of Aristotle that Harvey cites when talking about the microcosm (*de Generatione Animalium*; see below), nor does it show up in the *Physics* or many of Aristotle's other works for that matter. Aristotle really only employs it in *De caelo*, a later work focusing on the heavens and celestial bodies. Surely Harvey was aware of *De caelo*, and as I show later, the way he discusses fire shows that he distinguished it from the element comprising celestial bodies.[29]

What's important about aether is the tendency toward circular motion; for Aristotle this is part of what makes celestial bodies and the heavens "divine." Aristotle obviously wasn't Christian, and even though Harvey was his meaning of "divine" in a medical context is clearly based on Aristotle's. Regarding the celestial element, Friedrich Solmsen comments, "the body engaged in the circular movement is of a superior order, immune to the changes and mutual transformations to which the others are liable" (Solmsen 1960, p. 291). Thus, the first characteristic of the divine, or what makes the celestial superior to the sublunary elements, is circular motion. The second is immutability. In a similar vein, Thomas Johansen shows how the heavens are divine by pointing to several instances in *De caelo* where Aristotle calls the celestial bodies animate. In one place Aristotle remarks, "We think of the stars as mere bodies, and as units with a serial order indeed but entirely inanimate; but we should rather conceive of them as enjoying action (πράξις) and life (ζωή)" (*De caelo* 292a18-21; Johansen 2009, p. 22).[30] According to Johansen, ζωή connotes eternal life, meaning that eternality is another characteristic of the divine (Johansen 2009, p. 18). Additionally, being animate means that the stars exhibit actions, presumably similar to other animate bodies, which implies that a fourth characteristic of the divine is some form of growth and self-sustenance. A consequence of saying the celestial bodies have actions and are animate is the further suggestion that they have a soul.

[29] Aristotle suggests that fire (as being geographically closest to aether) can show similar characteristics to aether. He remarks, "there is an element whose natural movement is circular. In so saying we are only following the same line of thought as those who say that the stars are fiery because they believe the upper body to be fire, the presumption being that a thing is composed of the same stuff as that in which it is situated… the stars are neither fiery nor move in fire" (*De caelo* 2, 289a).

[30] Johansen also cites another place in *De caelo* where Aristotle suggests that the heavens are alive based on the "functions" or behavior of the stars (*De caelo* 2.2, 285a27-30).

Even though it's bizarre, Johansen explains how this isn't far off. Surely this doesn't mean that the stars are conscious, but it does mean that they have an immaterial form that guides and regulates their motion.

Teleology is built into all the elements, superlunary and sublunary alike, but in different ways. When a sublunary element's properties (e.g., hot and dry) become altered, it's spurred into motion, and this is characterized as "violent motion." In response, Aristotle thinks the sublunary elements then 'strive' to return to their natural place, and when they return it is called "natural motion."[31] Mary Gill notes how this sublunary striving is still very much passive.[32] However, the celestial element's tendency toward circular motion is active (thus explaining why Aristotle describes the heavens as animate). Aether, (and perhaps fire) has an internal principle that directs its motion, such that it has an underlying immaterial source of self-movement. This organizing principle of course comes from a form.[33]

What we can gather then, is that celestial bodies are divine and distinguishable from sublunary elements because of five characteristics: circular motion, immutability, eternality, action relating to growth, and an active internal principle guiding their motion. Soul or form is

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[31] I take it that this is the original inspiration for the concepts of *impetus* and *conatus* in early modern physics, the former being found in Descartes and the later in Hobbes and Spinoza. For a discussion of *conatus* see Jesseph (2016), especially page 85 where he cites Hobbes discussing the Aristotelian notion of "heaviness."

[32] Mary Gill references Aristotle's physics to explain how the natural motion of sublunary elements doesn't result from the active principle of a soul, rather, "Once some earth has been generated, it automatically moves toward the center if unimpeded. What serves as its active principle is the place itself, which controls and terminates its motion" (Gill 2009, p. 157).

[33] But like the sublunary elements, the motion of the celestial bodies is still in *some* regard determined by their place, so Johansen finds a regulatory role more promising for the celestial form (or soul), acting as a kind of guiding limit or directional influence for their motion. She states, "Because the heavens have a soul, we can apply to them the functional notion of directionality that we use to explain animal motion. And when we talk about "up and down," and "left and right" in functional terms, we are also led to think of one of each of these pairs as better and the other as worse. The deployment of soul and that of teleology go hand in hand" (Johansen 2009, p. 21).

essential to the understanding of the celestial bodies motion, and thus represents hylomorphism in Aristotelian physics, which would eventually piss Descartes off to no end. But these characteristics of the divine and the way that they distinguish celestial bodies from sublunary elemental bodies is the key for interpreting Harvey's microcosmic language.

As for Harvey, he thinks people are generally ill informed about microcosmic ideas, and he cements the point by quoting Aristotle at length. I think it's worth doing the same here to plainly lay out the evidence and show just how similar Aristotle's words are to those of Harvey and all the others microcosmic scholiasts. Below is Harvey's chosen excerpt from *de Generatione Animalium*:

> every virtue or faculty of the soul appears to partake of another body more divine than those which are called elements….. For there is in every seed a certain something which causes it to be fruitful, viz. what is called heat, and that not fire or any faculty of the kind, but a spirit such as is contained in semen and frothy bodies; and the nature inherent in that spirit is responsive in its proportions to the element of the stars. Wherefore fire engenders no animal; neither is anything seen to be constituted of the dense, or moist, or dry. But the heat of the sun and animals, and not only that which is matter, although diverse in nature, still contains a vital principle. For the rest, it is obvious from this that the heat contained in animals is not fire, neither does it derive its origin from fire. (Harvey 1651, p 505; Aristotle, *De Gen Anim* Chap 3).

After the quote Harvey makes a clear statement: he maintains "the same things of the innate heat and blood." He then spends several pages after explaining how his understanding of innate heat aligns with Aristotle. Thus, this reference provides us with an orientation point for Harvey, showing the source for his basic commonality with Aristotle. Since Harvey thinks the heart moves because of a pulsific faculty, he then in some way ought to agree with Aristotle that "every virtue or faculty of the soul appears to partake of another body more divine than those which are called elements." Although we'll have to get clear on what Harvey might mean by spirit, he also ought to have some affinity with the statement that "the nature inherent in that spirit is responsive in its proportions to the element of the stars." Lastly, if we take Harvey at his word, then we can expect his acceptance of some form of the statement that "the heat of the sun and animals…still contains a vital principle."

3.2. Harvey's Microcosm—Flames and Floods

With at least a cursory depiction of Aristotle's cosmic theory, we're now in a better place to look at Harvey's direct exegesis on the above quote from Aristotle's *de Generatione Animalium*. We'll specifically look for whether or not Harvey shares Aristotle's criteria of what makes celestial bodies divine. What also proves key in this analysis is parsing Harvey's interpretation of what it means for the blood to "participate in" or "correspond to" the divine. If we can grasp that, then we should be able to say whether or not Harvey honestly employed microcosmic ideas, and if so to what extent.

It's initially difficult to parse where his apparent analogies end and where possibly earnest cosmological description begins. For instance, he gives two statements back to back that seem to represent spirit in different ways: "We speak of a running stream as 'living water,'" and that "Air is also appropriately spoken of as 'spirit,' having received the title from the act of respiration" (Harvey 1651, p. 507). It seems that Harvey does use two different explanatory modes to interpret these statements: one has to do with the weather, and the other with the involvement of a soul.[34] Both explanations represent different ways that sublunary elements can be influenced by the celestial bodies or manifest their divine characteristics.

Let's first talk about the weather. Harvey says that "The inferior world, according to Aristotle, is so continuous and connected with the superior orbits, that all its motions and changes appear to take their rise and to receive direction from thence" (Harvey 1651, p. 508). This of course describes the concepts of alteration and natural motion discussed above. Harvey casually inserts a bit of Christendom suggesting it all relates back to the "Creator," but the point is that movement of water as rain and running streams occurs because the circular motion of the celestial bodies alters the sublunary elements and disrupts their natural place. Under this explanation, the elements participate in the divine in the sense that they respond to motion originating in the heavens; the stars' motion causes motion on earth in the form of weather. If this is all that Harvey meant when speaking of the microcosm, and if the blood's circular motion simply resembled the circular motion of celestial bodies, then we should interpret Harvey's microcosmic language as metaphorical. To have a serious concept of a microcosm, a link is needed between stars and the human body.

[34] Harvey remarks, "all natural bodies fall to be considered under a twofold point of view, viz. either as they are specially regarded, and are comprehended within the limits of their own proper nature, or are viewed as the instruments of some more noble agent and superior power. For as regards their peculiar powers, there is, no doubt but that all things subject to generation by birth, and to death and decay, derive their origin from the elements, and perform their offices agreeably to their proper standard; but in so far as they are the instruments of a more excellent agent, and are governed by that, not acting of their own proper nature, but by the regimen of another; therefore it is, therein is it, that they seem to participate with another and more divine body, and to surpass the powers of the ordinary elements" (Harvey 1651, pp. 507-08).

Harvey describes other Aristotelians who, perceiving the need of that link, make claims about the human blood. They say that one part is composed of the sublunary elements while the other is composed of the celestial material itself, thus explaining the source of innate heat. These other Aristotelians call the celestial element in the blood "spirit," but Harvey finds this reasoning lazy and unsubstantiated (Harvey 1651, p. 508). He has his own understanding of spirit that closely relates to his other mode of microcosmic explanation regarding the soul. Beautifully, his microcosmic explanations involving spirit also relate to why Aristotle described the celestial bodies as divine. Thus, Harvey's conversation on spirit naturally flows into a discussion of the celestial, and provides us with the key to understanding the sense in which he thought the human body was a microcosm.

Harvey says that there are three "simple bodies" that can appropriately be understood to "perform the office of 'spirit,' viz. fire, air, and water."[35] There is no doubt that these simple bodies are the Aristotelian elements, the most basic constituents comprising nature. What's peculiar is the reason Harvey thinks these three (and not earth) are prone to expressing spirit. He explains that flames, wind, and floods all have a flow, and through this "flux and motion" they appear to "have the properties of life." He remarks, "Flame, like an animal, is self-motive, self-nutrient, self-augmentative, is the symbol of our life" (Harvey 1651, p. 506). Flames move easily, spreading from log to log; consuming the logs while spreading, flames augment by growing larger. Despite noting various rituals and religions based on fire, the symbol isn't what's important to Harvey. Spirit is characterized by properties of life, which are all capacities based in the living thing itself, like moving about, nutrition, and physical change. It's not that animals

[35] Although Harvey never mentions aether, this conclusively shows that he believed it was aether and not fire that comprised the outermost celestial sphere. If fire can manifest spirit, then my following analysis shows that fire can partake in the divine and is thus distinct from it.

choose to metabolize food and grow, or even always choose to move themselves (e.g. blinking), but those capacities are built into and arise out of the individual. Similarly, when Aristotle calls the celestial bodies animate, it's not that he thinks of them as aware or volitional. What's important here to both Harvey and Aristotle is that the capacities of a living thing are inherent to the living thing.

That Harvey characterizes spirit with the properties of life and connects it to the flowing motion of natural processes is simply fascinating; it's then remarkable but unsurprising when he connects spirit to the flow of blood. There's ground for confusion here since early modern physicians usually discuss spirits in the blood as a noun—a distinct structure with its own physiological role. But as just seen Harvey uses spirit more as a descriptive attribute, or as a characteristic that manifests in natural processes like flames and floods. Rejecting others' theories, he declares that "the remarkable virtues which the learned attribute to the spirits and the innate heat belong to the blood alone." Describing the blood, he then applies the sense of spirit that manifests properties of life in flames, wind, and streams. I quote Harvey in length, because it's astounding through and through:

> The blood considered absolutely and by itself, without the veins, in so far as it is an elementary fluid, and composed of several parts—of thin and serous particles, and of thick and concrete particles called cruor—possesses but few, and these not very obvious virtues. Contained within the veins, however, inasmuch as it is an integral part of the body, and is animated, regenerative, and the immediate instrument and principle seat of the soul, inasmuch, moreover, as it seems to partake of the nature of another more divine body, and is transfused by divine animal heat, it obtains remarkable and most excellent

> powers, and is analogous to the essence of the stars. In so far as it is spirit, it is the hearth, the Vesta, the household divinity, the innate heat, the sun of the microcosm, the fire of Plato; not because like common fire it lightens, burns, and destroys, but because by a vague and incessant motion it preserves, nourishes, and aggrandizes itself. (Harvey 1651, p. 510)

Draw blood from a body and let it stagnate in a pool—for Harvey it has no power. But let it remain in flow, coursing through veins in circular motion, and it acts as the seat of the soul. The extraordinary power of moving blood is still "analogous to the essence of the stars," it doesn't heat the sublunary elements, and it isn't actually eternal or immutable either. But just as he discusses how spirit is manifest in flames and floods because of a process in "flux and motion," the flow of blood manifests properties that truly make the whole greater than its parts.

Recall Aristotle's other criteria for what makes the celestial bodies divine and sets them apart from sublunary elements: circular motion, action relating to growth, and an active internal principle guiding their motion. Through the blood's circular motion, Harvey thinks that it manifests the same kind of activities and life-like properties as the divine celestial bodies. For the same reasons that Aristotle calls the heavens animate, Harvey thinks the blood is animate, "it preserves, nourishes, and aggrandizes itself." This certainly qualifies as action relating to growth.

His explanation of how blood meets the final bit of divine criteria is perhaps more complicated. One part of the blood's self-motion seems to bloom out of its natural place in the veins of the larger body (just as elements have natural motion by returning to their natural place). But as Harvey explains, since the blood is spirit it is also the "instrumental agent." As an instrument it points beyond itself—there's something using the instrument. In the case of the human body the wielder of spirit is the immaterial form of a vegetative soul, and this is the other part of the blood's principle for self-motion. The blood as instrumental agent fulfills the same role that Johansen posits for the soul that regulates the motion of celestial bodies in Aristotle's *De caelo*. Elsewhere Harvey comments, "We must, therefore, make the distinction and say, that whilst no primary agent or prime efficient produces effect beyond its powers, every instrumental agent may exceed its own proper powers in action; for it acts not merely by its own virtue, but by the virtue of a superior efficient" (Harvey 1651, p. 509). The superior efficient here again refers to the vegetative soul that is able to act on the blood since the blood is spirit (Harvey 1651, p. 507). Because the principle of the blood's motion is internal, Harvey calls blood the seat of the soul.[36] Although these ideas are complicated and seem strange to us, Harvey most likely got them from one of his Aristotelian professors during his early years in Italian medical school.[37]

The true meaning of Harvey's microcosmic language is now hopefully clear enough. The blood with its innate heat is not divine like the heavens—it's neither eternal nor immutable—but

[36] An amusing linguistic parallel pops out of Harvey's belief that the blood is the seat of the soul. When Descartes writes to Plemp for Fromondus on October 3rd 1637, he says "like the Bible, I believe, and thought I had clearly explained, that the souls of animals are nothing but their blood, the blood which is turned into spirits by the warmth of the heart and travels through the arteries to the brain and from it to the nerves and muscles" (CSMK 62; AT I, 414). I call this a linguistic parallel because the similarity really only exists in the words used and not in their meaning. The "souls of animals" didn't exist for Descartes because he thought all animals were machines. It seems Descartes may have tried to cover his tracks with equivocation.

[37] French tells us, "Another aspect of Paduan Aristotelianism in Harvey's time is that of Cesare Cremonini, another of his teachers. Cremonini was a philosopher, and although he taught medicine as well as philosophy at Padua (from 1590) he disapproved of the anatomy-based rationalism of the Galenic doctor. His revived Aristotelianism—they called him *Aristoteles redivivus*—emphasized the fundamentals of Aristotelian philosophy at the expense of both the theory of medicine and the emerging neoteric philosophy. He even followed Aristotle into areas that got him into trouble with the Inquisition. Cremonini's book on innate heat was not published until 1626 and is defensive in particular against neoteric chemists. The Aristotelian principles of soul, Act and heat—instrumental to the soul and located in the heart—would surely be what Cremonini taught when Harvey was in Padua (and when Harvey came to write on the generation of animals he agreed with Cremonini on the nature of the heat of the blood)" (French 2006, p. 64).

it does have circular motion brought forth by an internal principle, and as such the blood is animate and manifests capacities of nutrition and growth. Because of these three characteristics the blood "participates in" or "corresponds to" the divine celestial bodies.

Harvey obviously doesn't think there's a direct chain of efficient causes from the star's motion down to the blood, but neither does he use microcosmic ideas just as a metaphor. The teleological principles of motion operative in the heavens are also operative in the blood, and this is the source of the innate heat in both the sun and the heart. Viewing the body as a microcosm has explanatory usefulness, zooming in on how the soul comingles with the matter of the body, thus providing a basis for Harvey's use of a pulsific faculty and a conclusive final cause for the motion of the heart and blood.

3.3. A Potential Objection and Conclusion

I'd like to consider a potential objection to my interpretation of Harvey's microcosmic ideas. The objection is that Harvey didn't buy into the microcosm-macrocosm scheme at all, but used it to garner support amongst all those that did buy in. He ends his section on innate heat, the microcosm, and teleology by recounting a short fable from the "excellent historian" Thuanus. The story surrounds an awe-inspiring stone from the "East Indies" that manifests mysterious qualities: "wonderfully radiant with light… as if burning in flames… tossed hither and thither, it filled the ambient air with beams," and it was "extremely impatient of the earth; if you essayed to cover it, it forthwith and of itself burst forth with violence, and mounted on high" (Harvey 1651, pp. 511-12). For Harvey, the magic stone and people's resulting fascination clearly symbolizes the blood. As most fables go, this is a cautionary tale. Harvey concludes,

> Who would not admire so remarkable a stone, or believe that it acted with a force superior to the forces of the elements, that it participated in the nature of another body, and possessed an ethereal spirit? Especially when he found that it responded in its proportions to the essence of the sun. In the same way did I paint the blood under the garb of a fable, and gave it the title of the philosopher's stone, and propose all its wonderful faculties and operations in enigmatical language, many would doubtless think a great deal of it. (Harvey 1651, p. 512)

It's difficult to tell if we've just been duped—if so, that's one of two ways to read the fable. The first way to interpret Harvey here is that he doesn't believe in microcosmic ideas at all, and that he simply used them as a "garb" to conceal a less exciting estimation of the heart and blood. This seems to be supported by how he introduces the fable, stating, "The word blood, signifying a substance, which we have before our eyes, and can touch, has nothing of grandiloquence about it; but before such titles as spirits, and calidum innatum or innate heat, we stand agape. But the mask removed, as the error disappears, so does the idle admiration" (Harvey 1651, p. 511). It's true, *calidum innatum* and "spirit" definitely ring with grandiloquence. So maybe the objection is right, Harvey's use of microcosmic ideas was simply to garner support from the freaks.

But perhaps we could just as easily assume the contrary to the objection: that Harvey's use of the fable is itself the mask to insure himself against orthodox physicians wary of microcosmic ideas and final causes in general. Surely readers that bought into the microcosmic ideas wouldn't have been dissuaded by the short fable, but it may have been enough for the mainstream physicians. This is the second way of reading Harvey's fable. Admittedly, the fable still seems pretty damning.

Here's something to consider as a response to the fable objection, which also neatly suggests why Harvey avoided developing an account of the heartbeat's final cause in *De motu cordis*. French tells us that Harvey served as a college censor at Cambridge in 1613, 1625, 1627, and 1629. As censor, it was Harvey's duty to monitor and enforce medical orthodoxy upon students and faculty, which in Cambridge at that time involved a relatively strict adherence to Galenism. When serving as censor in 1629, it was "the year after the book [*De motu cordis*] appeared and Harvey was in the anomalous position of a radical innovator examining candidates for the orthodoxy on which the college insisted, and imposing penalties upon illicit practitioners" (French 2006, p. 135). The penalties were steep, exemplified by cases in which students received £20 fines and even imprisonment. As French suggests, Harvey dealt with the apparent ambivalence of his personal views and public office by separating the two. French comments, "It seems likely that Harvey saw his work on the heart and blood as philosophical rather than medical. As his opponents argued loudly, the circulation had no medical use. Harvey made little attempt to explain the medical significance of circulation, and conspicuously avoided building up a system on it in the years after 1628" (French 2006, p. 136). Harvey must have carefully walked a delicate line.[38] French's statement is a bit confusing since *De motu cordis* is about the heart and blood, but also seems considerably bent toward the medical by heavily describing experiments

[38] French gives additional context by comparing Harvey's situation to that of others on the continent: "Similar external forces were acting in universities like Paris. Sir Theodore Mayerne, Harvey's colleague at the college, was accused by the faculty in Paris of neglecting Hippocrates and Galen. What they may have been concerned about was his espousal of chemical medicines. The danger here was the potential development of a chemical medicine as a whole alternative practice, over which the colleges and faculties would have no control" (French 2006, p. 136).

and anatomical observations and skimping on talk about final causes. But if French is right, then Harvey's work on the heart and blood was philosophical and as such included a serious account of final causes for the heart and blood's motion that wasn't represented in *De motu cordis*.

On the one hand I don't' think this is sufficient for fully dismissing the fable objection, but it's enough to question Harvey's true intentions in giving the fable in the first place. On the other hand, Harvey's positive relationship with Fludd and his recommendation of Castro's book on meteorology and the microcosm is enough evidence for us to give serious consideration to Harvey's explanation of spirit and the blood. That understanding of the microcosm fits in quite well with the rest of Harvey's system. He kept to the mainstream Galenic conception of the heartbeat which posited a pulsific faculty, and Galen himself utilized a form of the microcosmic scheme. As an Aristotelian (albeit a strange one) and personal friend of chemists, it's very reasonable to expect that Harvey would have microcosmic ideas. Since Harvey's research program was inherently philosophical and included a search for final causes, his honest acceptance of a microcosmic view seems more likely than not.

CHAPTER FIVE:

ARISTOTLE'S SPUTUM

1. Introduction

How do you really know when someone's an outsider? To make a vain judgment like that requires a sense of who constitutes the in group; to really know the outsiders, you have to know who they are outsiders to. What clues point to who belongs and who doesn't, or, what's acceptable and what isn't? Is the mainstream a group of people massaging themselves on vocal cord vibrations of the familiarly pious? Do the orthodox comfort themselves in a huddle, warmed with the caloric heat produced by consuming their own excrement? Surely what's mainstream can't just be a matter of taste. Whatever the motivations for conformity, members of a popular group are usually excited to announce it. This helps historians of philosophy, like myself, to see how past people categorized themselves. Self-adorned categories then act as guideposts in interpreting, for example, what it meant to be an Aristotelian in medicine. Alexander Ross is an exemplar of Aristotelian medical views, and as such he offers a good point of comparison for Harvey and Descartes. If we want to judge the degree of Descartes' novelty or gather evidence for the Aristotelian nature of Harvey's microcosmic ideas, then Ross is our inside man.

It's not that 17th century Aristotelians were singing the medical equivalent of pop songs, they might rather be equated to muzak, calibrated not to offend a target audience of consumers. Galenists held the mainstream place of honor with many medical theories. But Ross is a fine example of how Aristotle's medical ideas weren't philosophically inert at the time. Sure, he believed chameleons only ate air (Ross 1651, p. 137), but his text *Arcana Microcosmi* (1652)[39] contains many orthodox Aristotelian views on the heartbeat.

This chapter compares Ross' views in *Arcana Microcosmi* to Descartes' cardiac physiology and Harvey's microcosm scheme. On the one hand it reinforces the claims made in Chapter Three regarding Descartes' Aristotelian influences. On the other hand, it suggests how the seemingly intentional missing gaps of Harvey's teleological explanations might be filled in. Ross is thorough and well organized, and this helps us see how the soul might have related to the puslific faculty in Harvey's account, and what kind of additional Aristotelian distinctions laid behind the concept of innate heat.

2. Ross' Unbearable Karma

There are lots of *minores* still left in the dark, hidden away from contemporary salute, but even a bygone as reasonably obscure as Ross has received a bit of tender scholarly treatment. David Allen had a few good insights about Ross. First and foremost, Allen gives contextually enlightening biographical information: Ross was Scottish. As a not quite English sounding Brit, Ross very likely attended King's College in Aberdeen.[40] The location of his study is important,

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[39] The full title is: *Arcana microcosmi, or, The hid secrets of man's body discovered in an anatomical duel between Aristotle and Galen concerning the parts thereof : as also, by a discovery of the strange and marveilous diseases, symptomes & accidents of man's body : with a refutation of Doctor Brown's Vulgar errors, the Lord Bacon's natural history, and Doctor Harvy's book, De generatione, Comenius, and others: whereto is annexed a letter from Doctor Pr. to the author, and his answer thereto, touching Doctor Harvy's book De Generatione*.

[40] There may be some dispute over where Ross actually did his advanced studies. J.F.K Johnstone says that Ross went to Marischal College in Aberdeen where he worked under the tutelage of Thomas Reid and some guy named "Wedderburn." But Allan does a good job dismissing that account and establishing

because it helps explain why Ross was such a derivative sod. Follow Allan's comma ridden report: "King's was also, as it happens, widely known, during Ross's adolescence, for institutional conservatism" (Allan 2001, p. 69). This conservatism in part played out as a controversy over Scottish university reform, a resistance to the importation of Huguenot ideas after the reformation, and as a rekindling of Scholastic fervor. Allan's description of the atmosphere at King's College is succinct, and it would be pointless to reiterate it as a paraphrase:

> From around 1600, it was discernibly travelling backwards 'towards a Protestant version of the Aristotelian scholasticism which had previously been denounced,' reflecting a growing tendency to regard 'the more radically anti-scholastic ideas as politically suspect.' As the surviving undergraduate class theses confirm, Aristotle was the cornerstone of an increasingly conservative philosophical education. Ross would therefore have been exposed to an arts curriculum at King's in which an ultra-orthodox scholastic reaction was being triumphantly re-asserted. (Allan 2001, p. 70)

Fruit absorbs the alcohol it's soaked in, and Ross was undoubtedly soaked in mainstream Aristotelianism.

It will be clear in section 3 that the in group of physicians, or what the majority of physicians considered as the appropriate and popular belief in medicine, was not always Aristotelian, and this is especially true regarding the heartbeat. Ross appears to march to a different tune—he wasn't a physician. Rather his "ultra-orthodox scholastic" schooling directed

proof of Ross attending King's College (Aberdeen). He says: "it seems to be on firmer ground in opting for an education at King's College—for this claim is supported both by the weight of earlier commentary and by the clinching evidence that there was in fact a contemporary graduate of the same name (Allan 2001, p. 69).

his preferences. So, my point here isn't that the in group in medicine was objectively Aristotelian, but only that Ross thought that it should be.

3. A Weird Gang of Strange Men: An Inconsequential Section on Three Inconsequential People

This section is inconsequential, to the extent that tired associate professors or department chairs could skip it entirely and miss nothing essential to the argument; full professors should probably read it though. This section is not important, but it's interesting. Interesting stories do a good job at sucking the listener into another world, and that's where you have to go to ultimately get a better idea of what Descartes and Harvey were up to. At the midpoint of the 17th century, two men in England formed a little nexus of drama with a third man in 1747. This nexus happens to relate to the man of current interest, Alexander Ross.

In 1747 William Lauder sought out controversy and defamation. You likely don't know Lauder's name because he was a nobody. A long-deceased English literature scholar named David Masson describes Lauder as a "sallow-faced, loud-voiced, violent-tempered man… permanently lamed by an accident," and it seems Lauder had a reputation amongst his peers for being an "ill-conditioned and unsafe kind of person" (Masson 1890, pp. 123-24). Apparently, Lauder's personality and overall off-puttingness prevented him from attaining institutional employment at a school even though he was noted as well qualified; he was real let down. He then seemingly sought recognition through attacking someone noteworthy, and as Masson recounts, Lauder put his knowledge of letters to use in accusing John Milton of plagiarism. Yes, John (writer of *Paradise Lost*) Milton. Lauder whined all about his grievances in interviews, and declared he had proof for all of Milton's injustice. So, starting in 1747 he began laying out quotations from Milton and other authors in a comparative fashion, publishing them side by side in a series of articles in *Gentleman's Magazine* (the content of which was more boring than you'd hope) (Masson 1890, p. 124).

Amongst many instances of literary debt, Lauder argues that Milton plagiarized from Alexander Ross. Specifically, the supposed plagiarism was drawn from Ross' *Virgilius Evangelizans* (*Virgilii Evangelisantis Christiados Libri xiii*) (1634). Lauder was a sad man and easy for millennials with google to laugh at, but his accusations (at least regarding Milton's general use of Ross) may have corroboration. Someone in our time named Alexandré Sjöström argues that Milton's "treatment of the catalogue of fallen angels" was influenced by Ross' book *Pansebeia*.

It's not only likely that Milton was familiar with Ross' work, but also plausible that he knew the man himself. Now with the drama unfolding, enter player three: a printer. Thomas Newcomb printed his first book as a credited member of the Stationer's Company and book trade, and was promptly arrested for it on September 1st 1649. But Newcomb's luck quickly changed; he was released from imprisonment three weeks later, likely at the behest of John Milton (Baron 2002, p. 228). Only a few months before this, Milton had acquired the most voluble title of "The Secretary for Foreign Tongues" for being a blathering supporter of the Parliamentarians during the civil war.[41] It's not surprising that Milton would leverage this position for Newcomb's release, since their connection ran deep. On the one hand Newcomb's printing apprenticeship was done under Gregory Dexter who printed illegally for Milton in the

[41] Also known as the "Latin Secretary," the primary duties of this office were to draft and translate letters and papers used as communication between the English government and its foreign entities. Under the title, Milton was also given the duty of producing propaganda, at least partially in the form of pamphlets (see, Sullivan 2013).

early 1640's. On the other hand, Newcomb had married Ruth Raworth, who printed Milton's *Poems* in 1645. Milton's close ties to Newcomb likely made him standout as a trustworthy ally against the Royalists, and upon Newcomb's release from imprisonment he became the printer of many government contracts including "the official state newsbook, *Mercurius Politicus*" (Baron 2002, pp. 227-28).

The finale to this little nexus of drama, of course, is that Newcomb printed *Arcana Microcosmi* for Alexander Ross in 1651. This was after Newcomb became entrenched as an official printer of the Parliamentarian government. So, does the fact that Milton quite possibly new Ross and quite probably plagiarized from him give any additional information about Ross' medical views on the heartbeat? Not really. The three main figures of this section are pretty inconsequential in that regard. But it does place Ross' work in a context and give a bit of insight into how it was received by the powers that be in the 1650's of England. Even though Ross dedicates *Arcana Microcosmi* to a known Royalist (Edward Watson Son of Lord Rockingham) who was at the time being punished for his support of the monarchy,[42] the book was still legally printed by someone deeply enmeshed in the government. Perhaps this simply reveals Ross' conservative political stance was inconsequential and that the content of his book was not the least bit concerning to people in power; perhaps not. Alternatively, Ross may gesture his resignation to the fresh-faced government in the opening paragraph when he refers to the "commonwealth of learning." Whatever additional insight is good, but the pure case is that historians historicize as the tongue salivates. This bit of context helps me reach a page count, and you, one of the people tasked with reading this dissertation, tend to find these kinds of stories interesting in their own right anyway.

[42] See, (Wise 1891).

4. Ross and Descartes

Recall part of the thesis for this dissertation: Descartes is considered wrong from a presentist perspective because he reversed the order of systole and diastole. In Chapter Three I showed how Descartes' fermentation model of the heartbeat was largely similar to Aristotle's boiling model. Perhaps following Aristotle was advantageous at the time, and where the similarities with Aristotle existed in Descartes' account, it surely didn't come across to his contemporaries as abnormal content. But in the long run there were consequences of this choice that Descartes couldn't have predicted. It seems the similarities with Aristotle were precisely what made Descartes' account wrong. Looking at Ross' explanation of the efficient causes in cardiac physiology shows the same reversal of systole and diastole.

Considering Ross' educational background, it's not surprising that he faithfully records Aristotelian medical theories. From the outset of *Arcana Microcosmi* those theories are contrasted to the often more popular Galenist theories. He points to two groups of people: "the *philosophers* and *physitians*."[43] These groups represent "two great factions concerning the fabrick of Mans Body"; quite simply, the "*philosophers*" are Aristotelians and the "*physitians*" are Galenists. With extremely few exceptions, the remainder of the book is Ross trumpeting his identity as an Aristotelian and defending their tenants in physiology and metaphysics. No doubt Ross' incessant need to identify himself within a group makes this work ideal for identifying the details of a standard perspective for Aristotelian medicine at the time.

[43] Here and for the remainder of this paper, all *italics* in quotations of Ross are in the original and not my own.

When Ross describes anatomical structures of the heart and the efficient causes behind its motion, he doesn't seem to differ from anyone, Harvey and Descartes included. He uses the same language of diastole and systole, clarifies that the heart's motion is involuntary, identifies animal spirits as being involved in that motion, and says the heart is made of a fibrous material; I agree, it's *prima facie* boring. But nested in Ross' details rests familiar descriptions, and it's the familiarity that's interesting.

You might expect Ross' heartbeat model to be similar to Harvey's since they were both Aristotelians. But take a look at Ross' clear and distinct description of the heart's efficient motions:

> The *Aristotelians* make heat the efficient cause of the hearts publick motion: Others will have the soul; Others, the vegetative faculty; but *Aristotle* is in the right…the heat then of the heart rarifying the blood into vapors, which require more room, dilate the heart; but by expelling some of these vapors into the arteries, and receiving also some cold air by the lungs, the heart is contracted, this is called *Systole,* the other *Diastole*: And as heat is the efficient cause, so it is also the end of this motion…. I understand not here by heat, a bare quality, but that which is called [*Calidum innatum*]. (Ross 1652, pp. 6-7)

Like a good little peripatetic, Ross faithfully describes Aristotle's model of the heartbeat. Heat in the walls of the heart transfers to the blood causing it to expand into vapor, thus dilating or inflating the heart. Expelling blood from the swollen heart then starts the contraction. This was not Harvey's view, and Ross' description is faithful to the Aristotelian "boiling" model because the liquid blood transforms to vapor upon contact with a hot surface (the walls of the heart).

We can now see that Ross and Descartes share the same consequence for the same mistake. Compare Ross' description to Descartes' model: the heart expands because a small amount of fermented blood mixes with fresh blood as it pours into the ventricles, thus causing the heart to expand. As previously noted, the source of heat is different in Descartes and Aristotle's models, but the important similarity is that the vaporization of the blood is the cause for the expansion of the heart. Ross describes (and supports) this view perfectly. Thus, the fermentation model itself was largely inspired by the Aristotelian boiling model.[44] So the most important consequence of Descartes' general sympathy with the Aristotelians on this issue is the reversal of systole and diastole. Ross messes this up too, and we can now see for the same reasons. Whether you're Aristotle describing boiling or Descartes describing fermentation, believing that the outflow of blood from the ventricles results from the heart's dilation means you will mix up systole and diastole. Hobbes also made the mistake. Of course, this means that Descartes follows Aristotle in wrongly identifying the position of the heart when the pulse occurs in the chest. Ross notes, "The heart strikes the breast in its dilatation, not in its contraction or Systole, because the left ventricle, which is the originall of the Arteries, is distended in the Diastole, and so toucheth the breast about the left pap" (Ross 1652, p. 56). Marjorie Grene takes time to marvel at how Descartes not only wrongly identifies that the heart strikes the chest in diastole (it strikes in systole), but that he also wrongly summarizes Harvey's position on the matter. Even though Descartes claims to have read *De Motu Cordis*, he erroneously says that Harvey thinks the ventricles are dilated in systole (Grene 1993, pp. 328-29).

[44] The buck doesn't just stop with the fermentation model. It's interesting to note that Descartes also agrees with Ross and the Aristotelians against Galen in another subtle aspect regarding the heart. In part five of the *Discourse* Descartes passingly states that the heartbeat is "the first and most general movement that one observes in Animals" (CSM I, 134; AT VI, 46-47). In Ross' drawn-out war between Aristotelians and Galenists, he shows that this is an Aristotelian belief as well, and that the Galenists thought that the heart came into motion with all the other major organs collectively (Ross 1652, pp. 7, 9).

We should also note that Descartes and Ross shared the same physiological explanation for systolic motion, since that was a feature that distinguished Descartes from Hobbes. To draw from the quote above, Ross explains that after the blood is vaporized it is expelled “into the arteries, and receiving also some cold air by the lungs, the heart is contracted, this is called *Systole*.” This point was already made in Chapter Three, but seeing Ross with the same systolic explanation as Descartes shows us that the account would have been readily recognizable as an Aristotelian explanation in the first half of the 17th century.

Even though Galen’s model was the mainstream view, Ross’ account in general was still held by some of Descartes’ other contemporaries. When Regius’ student used Aristotle as an authority to defend the Cartesian heartbeat model in the disputation at Utrecht, it wasn’t an act of desperation or a romantic relic of the renaissance, trendily quoting an out of date theory from an ancient. Remembering that Ross was truly unoriginal may even suggest that the Aristotelian model was held by faculty at more conservative universities like his alma mater (Kings College in Aberdeen), but this last part is wholly conjecture. Another historical consequence is enjoyably strange. There is irony in the way contemporary classifications get blurred: Descartes, the traditional enemy of Aristotle, is largely Aristotelian in physiology, whereas Harvey, often an Aristotelian, breaks rank in this domain and adopts a Galenist model.

It’s likely that Descartes chose to develop his cardiac model from Aristotle’s because, physiologically, it was the closest to a mechanistic account out of those that were available. Galen’s model would have been much more difficult to inconspicuously fit into Cartesian physics. And Descartes often aimed for the inconspicuous, even shaping the format of the *Principles* with a scholastic audience in mind. Perhaps another motivation for basing his model on the Aristotelian was to further disguise his mechanism. It’s only comical then that Descartes’ commitment to mechanism would lead modern people to discredit his theory of cardiac motion further down the road.

4.1. An Omen of Steno

While discussing Ross' Aristotelianism in this chapter, it's worthwhile to note some passages that prefigure a guiding theme of the next chapter on Nicholas Steno and muscle. Comparing Descartes and Aristotle's physiological accounts of the heartbeat revealed negligible differences on the surface, and this shows that even the strongest metaphysical divergence doesn't necessarily result in crucial differences on the level of physiology. However, one aspect of the Aristotelian model shows that underlying principles can result in radical shifts of physiological explanation; the definition of "muscle" eventually becomes a fulcrum point, marking movement away from early modern models toward the contemporary explanation of the heart's motion.

One position is the same across all accounts so far considered: the heart is fibrous. Galen, Harvey, Ross, and Descartes all at some point talk about the fibers of the heart. For instance, when talking about contraction and blood expulsion Galen says "you can observe such a motion of the fibers in the heart" (Galen 1968, p. 294) Similarly Harvey states,

> the motion of the heart consists in a certain universal tension—both contraction in the line of its fibres, and constriction in every sense. It becomes erect, hard, and of diminished size during its action; the motion is plainly of the same nature as that of the muscles when they contract in the line of their sinews and fibres. (Harvey 1628, p. 22)

This not only shows that Harvey thought the heart was fibrous, but more interestingly it shows that those fibers did not belong to a muscle. He makes a distinction between the heart and muscles, but says they have a similar motion. It isn't exactly clear in *De Motu Cordis* why such a distinction exists—Harvey never says. But I think Ross can help explain.

Though human imagination seems endless, my capacity to conjure belittling descriptions of Ross' Aristotelianism seems stunted (though my will is strong); I'll simply say when Ross explains why the heart isn't a muscle, he is still Aristotelian. Ross:

> The heart hath a peculiar hard flesh of its own, that it might be the better able to undergo its perpetual motion, to contain the spirits and life-blood, and to resist external injuries. This flesh is not musculous, because the motion of the muscles is voluntary, but the hearts motion is natural. The heart hath both straight, transverse, and circular fibers, for attraction and expulsion; and oblique fibers also for retension; but these fibers are of the same substance with the heart, and not of a different, as the fibers of the Muscles, which are parts of the nerves and Tendons. (Ross 1652, pp. 54-5)

Like Harvey, Ross thinks the fibers in the heart are just like the fibers in the muscles. Though the heart still "is not musculous, because the motion of the muscles is voluntary." So, the reason the heart isn't a muscle comes from Aristotle. The distinction between voluntary and involuntary is likely familiar to most from the *Nicomachean Ethics*, but is also directly related to the heart in Aristotle's *De motu animalium*. The physiological observations show no difference between the heart and the muscles, but a theoretical distinction determines how the heart is defined.

This isn't so different from Descartes' position. Recall the points made from the *Passions of the Soul* at the end of Chapter Three. I showed that Descartes outlines three kinds of bodily motion: (1) some motions are caused by the soul, like when we have a volition to walk; (2) some motions are caused by external objects but don't involve the soul, like flinching; and (3) other motions are caused by the bodily machine regulating itself without any relation to an external object, such as the activity of breathing. Clearly the heart doesn't move because we will it, and it isn't moving in response to an external stimulus either. And as I just discussed, Descartes wants to explain the heartbeat with a fully mechanistic account, which most easily fits cardiac motion in category (3). But there is evidence that Descartes viewed some muscle movements as belonging to (3) as well. Even though most of his examples of muscle movement fit into categories (1) and (2), he references convulsions that are clearly muscular, and neither result from the will or respond to external stimulus.

So, his system could accommodate the heart being a muscle, and with the example of convulsions it even seems possible that Descartes could have explained the heartbeat solely by calling it a muscle. Still he goes with fermentation. There are benefits with the fermentation picture that fit nicely with other parts of his physiology, like notion of different 'qualities' of blood—different size, shape, and motion—which then have various roles depending on where the animal spirits consequently get sent in the body. Another benefit Descartes derived from fermentation is a source of heat, and this might not have been as easily explained with a muscular cause of the heart's motion. As I'll show in the next section, Ross and Harvey each explain the heat in a way quite incompatible with Descartes' mechanistic physics. If Descartes had used muscle, then he would have needed to add another element to explain the "fire without light" in our chests. And of course, fermentation has the upshot of being strikingly close to the

Aristotelian boiling (at least close enough to warrant a drawn-out clarification in letters with Plemp), which theoretically could have eased the model's acceptance in universities.

Ultimately, Ross and Harvey didn't view the heart as a muscle because it was an involuntary motion, and my point here is that Descartes had the same reason but expressed it in a mechanistic language appropriate for his own system. Once Descartes' system was out there though, Steno picked up where Descartes left off but didn't have the same concern over voluntary and involuntary motion. As I'll argue next chapter, Steno was able to call the heart a muscle thereby disagreeing with Descartes, only because Descartes had made such a disagreement possible by draining so many other Aristotelian principles out of physiology.

5. Ross and Harvey: Soul, Motion, Cosmos

Last section, heartbeat talk was restricted to efficient causes in physiology, and that made similarities between Descartes and Aristotle standout. Their cardiac similarities go no further. Yet in another domain Ross and Harvey are the kindred spirits, sharing what acidheads might blurrily call a soul bond, but what is more accurately a bond over soul. Descartes is praised as a radical dude, since when it came to the soul pulling strings behind physiology, the dude did not abide.

Gorham did a good job explaining how Harvey's understanding of bodily motion related to an Aristotelian conception of the soul. The contrast between Aristotelians and Galenists Ross enjoys prodding in physiology doesn't come up as much when he discusses the soul's role in bodily motions, since as Goldberg explains, Galen often agreed with Aristotle and at times even followed him on matters relating to mind-body monism. Both Ancient masters "agreed on the teleology of the soul body relation" and "stood firm against those who attempt to understand nature, and especially animal bodies, by purely material means" (Goldberg 2012, pp. 68-9). This explains how Harvey was an Aristotelian who at the same time employed the notion of a pulsific faculty that was popular amongst his Galenist peers. This is also why Ross thinks that "When *Aristotle* saith, that the motion of the heart is caused by heat and cold, he contradicts not the Physitians in affirming the soul, or its vital faculty to be the cause of this motion" (Ross 1652, p. 57). This section compares Ross and Harvey, considers Ross' direct objection to Harvey, and aims to show how Harvey's use of the Galenists pulsific faculty still rests comfortably in an Aristotelian framework.

5.1. The Role of Faculties

Here's a restricted explanation of how Aristotelians used faculties in physiology, and how they related to efficient causes like heat. Ross points at all sorts of "faculties" of the soul, like the vital, pulsific, and vegetative, and he says they're all "effects of the soul." These faculties have different roles in cardiac physiology, and Goldberg explains how Harvey uses the nutritive faculty to fulfill many physiological functions, thus highlighting its importance. For our purpose we need only focus on the vital and pulsific faculties, as they most directly influenced cardiac motion for Harvey and Ross.[45] Ross records that, "the soul works by its faculties, and these by heat; so that heat is the immediate cause of this [heart's] motion, and the souls instrument" (Ross 1652, pp. 6-7). Admittedly something about hierarchy feels good—there's apparent safety in order and abasement—the Aristotelians relish its symmetrical beauty, mapping it onto motions in

[45] For breakdown, comparison, and relation of different faculties and their roles in cardiac physiology see (Ross 1652, pp. 55-6).

the human body. Different kinds of causes abound in this structure, and the heart's heat is merely an efficient cause void of purpose. But the heat is an instrument as Ross explains, a tool controlled by the vital faculty, which itself is only a middleman for egoic soul. Heat is hot, the soul is not, so it's not as if the soul vaporizes blood and just disguises itself as heat. But since the heat is purely efficient, it doesn't contain any instructions, and fire has the potential to harm. You wouldn't want the fire inside your chest getting too hot, then you're just a zealot on fire, burning alive—sounds like living hell. To prevent something like that, the vital faculty regulates the heat. Heat is an instrument because it has this regulator, something using it for a purpose: here moving the heart. In an imperfect analogy, the regulating vital faculty is like a person continually choosing how much wood to put on a fire, keeping the fire contained so as to not burn up the dusty picture of old aunt Agnes on the mantel. The pulsific faculty is a bit like that person using a bellow and poker to direct the position or flow of heat. Though in this analogy, this person wouldn't being "enjoying" the heat, perhaps thinking about politics or how women might just be half-baked men (Aristotle's rational soul).

This faculty talk brings up a difference between Ross and Harvey that I'll now briefly note. Ross describes how the pulsific faculty is subservient to the vital, the latter having more general responsibilities like producing spirits, whereas the former is solely charged with regulating the contraction and expansion of the heart fibers. Remember on the level of efficient causes, Ross is insistent that heat is what vaporizes the blood (the boiling model). But the pulsific faculty can be said to dilate the heart and constrict it because it uses the heat in the heart as it's instrument for achieving this motion. Harvey, pulls out the boiling step all together. Gorham points out that,

> in the "Second Letter to Riolan" he holds the "pulsific faculty" responsible for the original contractile movement of the right auricle (Harvey [1963], p. 169). The heartbeat is not occasioned by vapors or the influence of an external agent; rather "it comes from an internal principle" (Harvey [1963], p. 175). (Gorham 1994, p. 227).

Harvey's Galenic model seems simpler than Ross' Aristotelian picture, but they both have an internal principle of motion. You'll easily recall that this internal principle of motion was precisely what Descartes averted. Ross on the other hand represents it in spades, but has the additional boiling and vapors. So, Harvey's pulsific faculty model rests easy in the background context of a hierarchy between the soul, faculties, and efficient causes.

5.2. Objections Harvey Never Asked For

A new question about Harvey now arises: if not from the walls of the heart and boiling blood, where does the heat in the heart come from? Ross responded directly to Harvey about the blood and soul, and the core of his objections exposes an answer about heat. Consequently, it also highlights another interesting similarity that stems from their shared Aristotelianism. Traversing to the peaks of Ross and Harvey's intellectual landscapes shows that they differ on how the soul makes contact with body, but agree on the cosmic fabric in which bodies are woven.

Perhaps Ross was foolish—I'll ask you to ignore his claim that Ostriches eat iron (Ross 1652, p. 143)—he certainly borders on foolish when objecting to Harvey. I quote Ross in length, because the intersection with Harvey is pure, and windows to their shared world are rarely cleaner. Ross:

> Because the soule is a pure and celestiall substance, and our bodies are grosse and earthy, on which so sublimate an entity cannot operate without a *medium,* that may in some sort participate of both natures, therefore God in his wisdom hath interposed the animall and vital spirits as the immediate instruments of the soul to work upon the body. But Dr. *Harvy* (*Exercit.* 70) *will have the blood to be this immediat instrument of the soul, because it is every where present, and runs to and fro with great celerity. Answ.* Neither can the blood be the immediat instrument of the soul, because the spirits being of a purer essence, come nearer to the nature of the soule, and therefore must be more immediat; neither is there any ubiquitary presence or celerity of motion in the blood, but by the reason of the spirits which drive it to and fro. Besides, all animals have not blood, some being exanguious, yet they have spirits by which they are moved. Again, he saith, *That the blood works above the power of the elements, being the part first begot, and the innate heat doth fabricate the other parts of the body. Answ.* The blood works not at all, much lesse above the elementary powers, but by vertue of the spirits. (Ross 1652, pp. 230-31)

Seeing what Ross disliked in Harvey's explanations help us to better understand what Harvey was saying in the first place. First and foremost, Harvey discusses the above topics to explain the origin of innate heat [*calidum innatum*] in the heart, although this is not stated by Ross who seems more concerned with Harvey's conclusions than with the explanations behind them. Ross' concerns stem from Aristotelian reasoning as they manifest in traditional semantic caviling, and

I'll tell you up front, all of his objections boil down to what appropriately counts as "instrument" and "immediate."

Let's compare Ross' justifications to Harvey's then. First consider the issue, "*Harvy* (*Exercit.* 70) *will have the blood to be this immediat instrument of the soul, because it is every where present, and runs to and fro with great celerity*."[46] The contentious claim is that the blood is the immediate instrument of the soul. Ross gives three reasons he thinks this is wrong: (1) the spirits are purer than the blood, (2) the spirits are what give the blood motion through the whole body in the first place, and (3) not all animals have blood, but all have spirits. These objections hardly seem worthwhile since Harvey had already responded to every single one.

Harvey already disqualified (1) by stating, "nor are the spirits which are distinguished from the blood at any time found distinct from it; for the blood without heat or spirit is no longer blood." He subsequently quotes Aristotle, who said that blood "is hot in a certain manner, in that namely, in virtue of which it exists as blood… heat is in its essence or nature, in the same way as whiteness is in the essence of a white man" (Harvey 1651, p. 502). Lastly, for a moment he seems to represent the historically naïve sketch of the empiricist champion by calling out those (like Ross) who argue for spirits being the soul's instrument, saying that no one has actually demonstrated the existence of "such a spirit, and counting himself among those "who use our simple sense in studying natural things," he hasn't been able "to find anything of the sort" (Harvey 1651, p. 503). This of course was only part of Harvey's method, and only comes after his Aristotelian rebuttals.

[46] Ross derives this from Harvey's statement: "The blood consequently suffices, and is adequate to be the immediate instrument of the soul, inasmuch as it is everywhere present, and moves hither and thither with the greatest rapidity" (Harvey 1651, p 504).

These reasons themselves seem to cover how Harvey would response to (2), but his explanation of the blood's motion is further justified when he considers how other Aristotelians describe the nature of spirits. He agrees with them, saying, "it is admitted, moreover, that the spirits are in a perpetual state of flux, and most readily dissipated and corrupted." He then rhetorically questions, "what occasion is there, then, I ask, for this extraneous inmate, for this ethereal heat? When the blood is competent to perform all the offices ascribed to it, and the spirits cannot separate from the blood even by a hair's breadth without destruction." Thus, he flips Ross' objection back on him, saying "without the blood, indeed, the spirits can neither move nor penetrate anywhere as distinct and independent matters" (Harvey 1651, p 504). To recall, Harvey considers "spirit" more a quality than a distinct structure (see Chapter Four). Whether translated to and fro or hither tither, Harvey thinks that the blood being present everywhere and moving in a quick circular pattern is just what blood does.

The third part of Ross' objection (3) comes directly from Fernelius. I know this because Harvey already cites him as the source of the idea that not all animals have blood. Harvey's response is straightforward. Associating himself with physicians in general, Harvey remarks, "we maintain that so long as an animal lives, the cavities of the heart and the arteries are filled with blood" (Harvey 1651, p. 503). So, unless Ross was talking about dead animals, the objection he draws from Fernelius simply seems out of date. Did Ross copy his objections from Harvey and just hope no one would actually read his book? Alternatively, perhaps Harvey just had the foresight that someone as annoying as Ross would disagree with part of his book as soon as it was published.

The rest of Ross' quibbles present a similar disregard for subtly and an unwillingness to address Harvey's definitions. It would be largely unhelpful and even less interesting to go through them, especially since I already outlined justifications from Harvey that would work equally well as responses to the rest of Ross' fussing. It's already clear enough that if Ross and Harvey were having a conversation, they would be talking past each other. Although, it is important to note one thing about when Ross objects to Harvey's position: "*That the blood works above the power of the elements, being the part first begot, and the innate heat doth fabricate the other parts of the body*"[47]; Ross is not objecting to something in the human body working "above the power of the elements," but is disagreeing about which part of the body manifests this characteristic. For all of Ross' words, it really does just boil down to whether it's the blood or the spirits that act as the seat of the soul, which I told you in the beginning.

As Walter Pagel points out, Ross significantly avoids criticizing Harvey on the circulation of the blood. But I think it's equally obvious from Ross' response that he sees eye to eye with Harvey on general Aristotelian cosmology; Ross only objects to specific details within a larger scheme he readily accepts. Pagel's brilliant breadth seems to necessitate a lack of depth, and consequently he has no mention of the parallels between Ross and Harvey on microcosmic ideas (see Pagel 1967, pp. 346-48). This is especially surprising since the sentences Ross cherrypicked from Harvey to criticize are in a macroscopic context of comparing the celestial and elemental.

[47] Ross derives this from Harvey's statement: "The blood, in like manner, 'acts with powers superior to the powers of the elements' in the fact of its existence, in the forms of primordial and innate heat, in semen and spirit, and its producing all the other parts of the body in succession; proceeding at all times with such foresight and understanding, and with definite ends in view, as if it employed reasoning in its acts" (Harvey 1651, p. 507).

5.3. Microcosmi Perfecti

Ross' hairsplitting is not all that interesting or helpful in itself; it's the monolith of Aristotelian *Κόσμος* that inspires wonder. Ross' belief in giants and centaurs now seems more salient, as if those thoughts belonged to a greater more complicated world we know nothing about. Last chapters' abecedarian introduction to this landscape is still relatively meaningless—our contemporary footing for comprehension simply leaves us imagining. But we can compare Ross' microcosmic language to that of Harvey and see overt similarities. Like Harvey, Ross at one point mentions the hydrologic cycle as an example of terrestrial motions mirroring the celestial's (Ross 1652, p. 54), but the last chapter already discounted this as a sufficient link between the human microcosm and heavenly bodies. Ross has plenty of passing statements with microcosmic metaphors, such as: "the Heart is placed in the midst of the breast, as the Sun in the midst of the world, that it might impart its vital heat and motion to all parts: So the seed is in the midst of the fruit" (Ross 1652, p. 26). His numerous statements like this show his explanatory use of microcosmic ideas, but by themselves they're so simple that they still don't amount to anything greater than metaphor. However, Ross' theoretical distinctions on types of heat is much more revealing of the extent to which he accepted the microcosm-macrocosm scheme as the legitimate organization of nature.

His first distinction separates different types of heat in the body based on their function. He says:

> There is in us a twofold heat, the one celestial, the other elementary: that preserves us, this destroys us: that concocts our food, and turns it into nutriment, this corrupts and

putrifies it, and turns it into noxious humours and excrements, as we see in burning Fevers. It is not then every heat that chylifieth or sanguifieth, or assimulateth, but this celestial heat: Neither is it the quantity, but the quality thereof, and affinity it hath with the things concocted. (Ross 1652, p. 19)

Ross must have hated most of his own body because he has nothing good to say about the "elementary heat," which seems to represent all the chaotic and destructive events in our physiological life. "Celestial heat" is the relative opposite, responsible for all the processes behind our physical growth and stability. The quantity of the heat doesn't matter, it's the quality that's demarcates the radical differences between the two forces. Thus, the characteristics Ross associates with the celestial heat—it "preserves" and "sanguifieth"—reflect those described by Harvey regarding the blood: "by a vague and incessant motion it preserves, nourishes and aggrandizes itself" (Harvey 1651, p. 510).[48]

An even more telling similarity comes from Ross' connection of the celestial heat with nutrition, since for Harvey, the blood as "spirit" was the seat of the soul, specifically "the vegetative soul" (Harvey 1651, p. 507). Elsewhere Ross says that the existence of celestial heat in the body "is manifest," since "the fire or elementary heat, neither in part, nor in whole, is the cause of generation" (Ross 1652, pp. 23-4). He continues this line of reasoning by explaining that:

elementary heat remains after the celestial is gone, as may be seen in spices, which retain or rather increase their elementary heat, as they grow drier, being separate from the Tree;

[48] Ross' "sanguifieth" means "to turn into blood," and here it parallels Harvey's "aggrandizes itself."

> and yet they want that celestial heat by which they did live and had vegetation; for now being dead, nutrition, attraction, vegetation, growth, and other functions of life cease, which were the effects of the celestial heat. (Ross 1652, p. 24)

So again, it seems Harvey and Ross alike think of the blood (whether as "spirit" or through its constituent spirits) as the seat of the vegetative soul because of its life-giving functions.
While Ross' objections to Harvey clearly showed their disagreement over the nature of spirit or spirits, elsewhere Ross seems much closer to Harvey on the subject. Ross states that "The animal and vital spirits in our bodies are not a celestial substance, as some have thought." This seems analogous to Harvey's position that the blood is just blood, and that it isn't composed of the celestial element itself. Similarly, Ross and Harvey share the same reasoning for this position, which Harvey is familiar with as generally Aristotelian. Ross explains that the animal and vital spirits must be elementary because they are "subject to generation and corruption" while the "Heavens cannot be diminished" (Ross 1652, p. 24).[49] So the same issue that pressed Harvey seems to arise for Ross: how does the blood have its innate heat, or more specifically, how does the blood adopt the divine lifelike qualities of the celestial bodies?

The different options Ross weighs for an answer and his subsequent choice of explanation again mirror Harvey. Ross states,

> Our spirits must either be united to the bodies of the Heavens, and so continuated bodies with them, or else separated and divided; both which are absurdities… it remains then that these spirits are aerial in their nature and substance, but the instruments of the soul in

[49] For the same reasoning from Harvey see, (Harvey 1651, p. 504).

> regard of their function, in which regard only we consider them as they are in our bodies; for many actions proceed from them, as they are the souls instruments, which cannot be effected by the air, as air. (Ross 1652, pp. 24-5)

According to Ross the spirits are composed from the terrestrial element of air, and one then wonders if he held the same sort of view as Harvey about the “flux and motion” of wind. Nonetheless they undoubtedly agree that the spiritual component or quality of blood is what allows it to act as an instrument of the soul. This instrumental capacity doesn’t stem from the element the blood and spirit are made from, but rather from they’re motion. Ross remarks, “Seeing the Heavens have but one motion which is circular; how can any part therof come down into our bodies, except it hath also a strait motion?” (Ross 1652, p. 24). Like Harvey, Ross thinks that the blood’s circular motion is what makes the human body a microcosm.

6. Conclusions

Ross’ *Arcana Microcosmi* presents Aristotelian medical views that have considerable overlap with those of Descartes and Harvey, albeit in different domains. With Descartes, we see similar a physiological model for the heartbeat. Both explain diastolic motion via heat in the heart that vaporizes blood, which then expands the walls of the heart. Similarly, both think the systolic motion is caused by a cooling air from the lungs. Of course, Descartes and Ross differ from Harvey on these matters. Instead Ross and Harvey overlap in metaphysics, as they have similar schemes regarding the soul’s use of a pulsific faculty to explain the heartbeat. Further, they situate the faculties of the soul in an Aristotelian cosmos that they extensively agree upon. Ross’ direct objections to Harvey reveal a disagreement about the nature of animal and vital spirits, but this is ultimately splitting hairs. So, in physiology Ross overlaps with Descartes but differs from Harvey, while in metaphysics Ross overlaps with Harvey but differs from Descartes. Despite his historical usefulness Ross was no revolutionary thinker himself, but we shouldn't have expected anything different from a man who convinced himself that "Christ never laughed" (Ross 1652, pp 176-77).

CHAPTER SIX:

MODERNITY'S MUSCULAR MIDWIFE

1. Introduction

I'm not sure everyone gets serendipity; how could anyone know a place is right when it's just what's happening at the time. Every so often people appear like perfect assortments, as if the whole scene around them funneled itself to a point. Nicolas Steno—Niels Stensen—reflected his time. He sits in history as the skilled anatomist turned mediocre theologian, but he assessed himself in entirely different terms. We do our dance and afterwards apply the scale, pasting good or bad to memories so thought can resonate with feeling. His own eventual discomfort with Cartesianism could never erase the role it played in his scientific work. He's now credited with a number of anatomical discoveries. Steno was so delicate with a blade that in 1665 a physician in Paris reported that he "could count the bones of a flea—if fleas have bones" (Tubbs et al. 2010).

Only later did he become the titular bishop at Titiopolis, all for the meager price of Baruch Spinoza's eternal soul.

This chapter focuses on his Cartesian background and how it led to his declaration that the heart is a muscle, nothing more nothing less. Steno scholars have an enviable vestige, the *Chaos Manuscript*: some of Steno's notebooks from the years at his first university. From these we can conclude that a Cartesian influence in his most formative years is undeniable. Historians have also tracked his later scientific activities in Parisian circles that point to his status as being part of the club, a Cartesian among Cartesians. Descartes' influence isn't especially manifest in the conclusions of Steno's anatomical discoveries (which often disproved Cartesian theories), but rather in the method and world view used to produce them. Kardel and Maquet's (2018) biographical information, commentary, and translations of Steno's scientific works are indispensable here and the condition for the possibility of my argument.[50]

Providing a more linear history of Steno's developments in anatomy and Cartesian thinking is important since he eventually turned away from both. For instance, Steno's adherence to Cartesianism in his last work on muscles (1667) might seem contentious since it was published the same year that he had a radical religious conversion. His movement from tepid Lutheranism to fervent Catholicism is often associated with an increasing disavowal of his Cartesian roots. But Troels Kardel shows that the ideological divorce wasn't a wholesale about-face, since the application of Descartes' method even played a role in Steno's conversion. It seems as though Steno—perhaps unselfconsciously—followed in the footsteps of Pascal, doubting his own Cartesian roots to emphasize religious faith as a gift from God. But for the

[50] All my references of Steno's primary works and letters are pulled from Kardel and Maquet's translations of Steno's originals, as collected and published in: *Nicolai Stenonis Opera Philosophica* (OPH, I-II), (1910. Edited by Vilhelm Maar, Copenhagen, Vilhelm Tryde Publ.). For the OPH citations that correspond to my references, see the pages listed for Kardel and Maquet (2018).

hair-shirt genius and the nimble-fingered anatomist alike, Cartesianism was a necessary precondition for spiritual and ideological movement. In Steno's words:

> There is this danger of the Cartesian philosophy from which God, as I have said, has liberated me at that time in which I was associated with the reformers, or rather the deformers, of Descartes. He gave me, against all expectation, the knowledge of the true structure of the heart and of the muscle which alone, at a glance and without a word, overthrew all the constructions of the most subtle minds. (Kardel and Maquet 2018, p. 186-87)

Here Steno appears like one of our modern-day gladiatorial analogs, a professional athlete with finger raised to the sky to inform the opiated masses his talents come from God. But everybody knows in their gut the touchdown was produced from a mix of luck, hard work, and the finest coaching staffs and training facilities money can buy. Steno had all the education, a strong influence from Cartesian intellectual connections, and practice applying them in countless dissections. Still he wants us to believe along with him—discovering the heart is muscle was nothing but a miracle.

Pre-conversion Steno tells a different story. He continually praises Descartes throughout his works, complimenting his ingenuity in physiology and philosophy even when presenting a theory that disproved a Cartesian one. As Kardel puts it,

> In Cartesianism Stensen praised and liked primarily its method to discover prejudices and the rule of doubting everything. Not because he wanted to surrender to a universal doubt

> but because, as a man of science, he strove for certainty and clearly recognized the human capability of errors, he eagerly seized any means that promised certain knowledge. Stensen's scientific method was strongly influenced by Descartes who taught him critically to test even the foundations of his faith and thus took him away from strict orthodoxy quite so thoroughly that it almost cost him the Christian faith. Stensen… actually reproached Descartes, and even more so Spinoza, to have reached, against their own method, an idealistic rationalism from which he himself only escaped as if it were by a miracle.

So, Steno's approach as a scientist was influenced by Descartes, and the framework in which he interpreted his anatomical findings was mechanistic. Of course, this ultimately led him away from Descartes' physiology toward the establishment of cardiac myology.

In the next section, I emphasize how the pre-conversion Steno tells a different story than the religious sublimation above. There are many solid reasons to believe that Steno's post-conversion narrative—that the discovery of the heart as muscle was a gift from God—is historically inaccurate, and, if not delusional than dishonest. I highlight the chronology for some of Steno's Cartesian developments, to ultimately show that he was firmly a Cartesian mechanist when discovering that the heart is a muscle.

2. The *Chaos Manuscript,* Schools, and Cartesian Circles

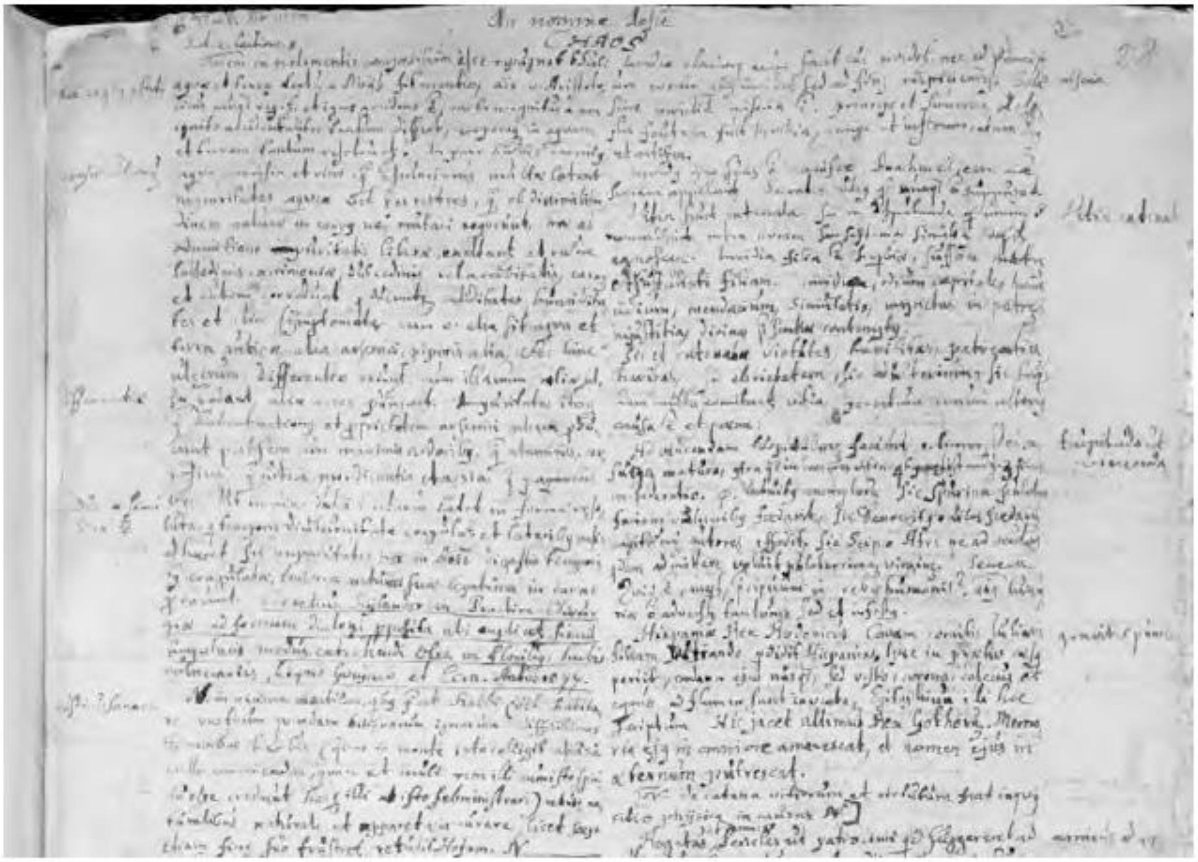


Figure 13: "*Chaos-manuscript*…upper half of first folio page" (From Kardel and Maquet 2018)

2.1. Descartes in the Script (1656-1659)

Born January 1st 1638 in Copenhagen Denmark, Steno clearly had a remarkable childhood and exceptional resources. Kardel and Maquet tell us that that Steno labored in his father's goldsmith workshop at a young age, and this may be where he gained his steady hand and scientific curiosity. Using that workshop "he built a hydraulic machine," "possessed thermoscopes," "fixed the lenses of a telescope to a stick and with them he measured refraction." He even had a microscope (Kardel and Maquet 2018, p. 51). Looking to foster such exploratory proclivity, Steno entered the academic scene at nineteen enrolling at the University of Copenhagen to study medicine. He studied and took notes from 1656 to 1659, and this produced what scholars now call the *Chaos Manuscript*.[51] An incredible breadth of philosophers and schools of thought passed through the grey matter of the budding anatomist, and we thankfully still know how he reacted to most of them.

Whether as a comparative gloss or a lengthy quarry, Steno was clearly quite taken with Descartes' published works during his university years. Kardel and Maquet explain that he even had a particular focus in Descartes: "above all his methods of obtaining certain knowledge." They recount one instance where,

> the student speaks of exhalations passing through the skins and muscles, he says: "This should be investigated more carefully and systematically according to Descartes' method, or by considering directly what enters the pores of the blood, what its particles are, how they move, what is expelled from there and how. Thus, by asking all similar questions that can be thought of and by collating them and doing experiments about it." (Kardel and Maquet 2018, p. 54)

Steno clearly draws his affinity for applying the Cartesian method from reading the *Discourse* and its essays, which he cites several times (Kardel and Maquet 2018, p. 55). In other places he also cites Descartes' *Principles*, showing his interest in the grander system and conception of nature derived from the method (Kardel and Maquet 2018, p. 54). Steno seems to summarize his interest in the two works with a twist when he states at the end of the *Chaos Manuscript*: "In

[51] For *Chaos Manuscript* citations, see referenced page numbers in Kardel and Maquet 2018.

physical science we know nothing beyond experiments and observations and that which is deduced from them according to metaphysical and mechanical principles" (Kardel and Maquet 2018, p. 56). An amalgam of other philosophical influences (not always conciliatory with Descartes) are present in the young Steno's notes, but none seem possibly as fundamental as the Cartesian ideas.

Such an odd pairing of interests is then represented by Steno's affection for iatrochemistry and iatrophysics, manifested by his commentary on Paracelsus (Kardel and Maquet 2018, pp. 49-50). In lieu of good evidence I didn't discuss Paracelsus in relation to William Harvey, but the wandering chemist definitely was a strong shaping force on Harvey's good friend and intellectual ally, Robert Fludd. One thing that Steno likely drew from Paracelsus at this time was microcosmic language, which I discuss later.

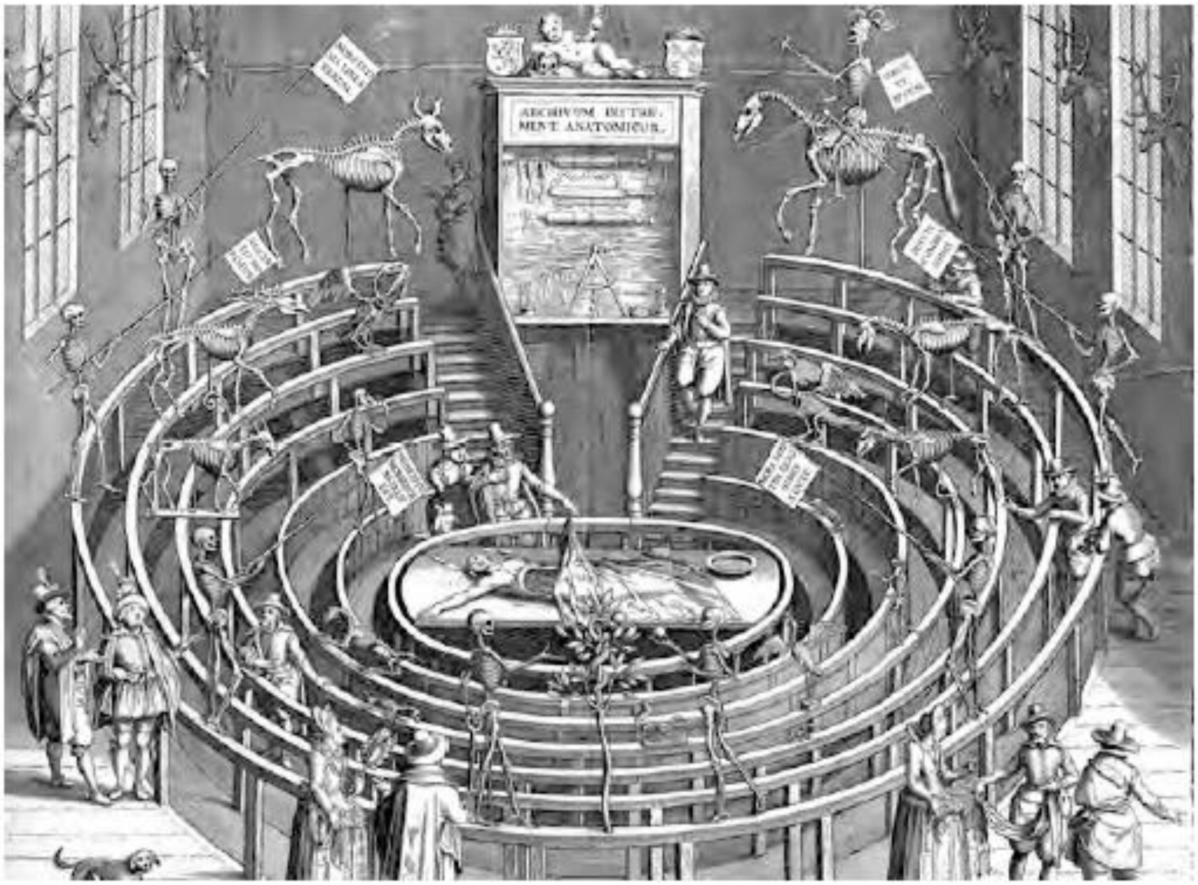


Figure 14:

"Leiden's anatomical theatre, drawing by J.C. Woudanus, W. Swanenburgh (etching), A. Cloucq (publ.) 1610" (From Kardel and Maquet 2018).

2.2. Some Observations from Leiden (1660-1663)

After his time studying at Copenhagen, Steno moved on to two more years of university study at Leiden. Accounts show the period of time was marked with a mix of Steno tightening and loosening his grip on different parts of Cartesianism. Kardel and Maquet state that,

> Stensen was certainly also impressed by the struggle for such universal mathematical rules which Descartes wanted to set as the basis of the complete explanation and

> domination of nature…. All phenomena in nature should be explained by extension and movement and the whole understanding of nature become geometry. In the strife for reliability Stensen willingly accepted the methodical doubt and Descartes' picture of two mechanics, God who produced the machine of the world and gave it movement the laws of which we study, and man who is provided with thinking and uses the particular machine of the human body while the beasts on the whole are machines. (Kardel and Maquet 2018, p. 88)

While at Leiden, it seems Steno reinforced his appreciation for Descartes' mechanics, but then grew skeptical of the Cartesian theory that animals are soulless machines.

For instance, his earlier adoption of Cartesian mechanics appears after he left Copenhagen and attended meetings on Descartes *De homine*. Kardel and Maquet recount that when "in the year 1662 the professor of philosophy Florentius Schuyl published in Leiden the Latin edition of *De homine* by Descartes, Stensen attended the discussion with lively interest, particularly in the physics and the anatomical lessons of that script" (Kardel and Maquet 2018, p. 88).[52]

But during this time, he also practiced his skills in dissection. When studying "the lymph," one account describes how he kept a dog alive for three hours during a vivisection. One experiment wasn't enough to establish the needed evidence, so he opened another dog (Kardel

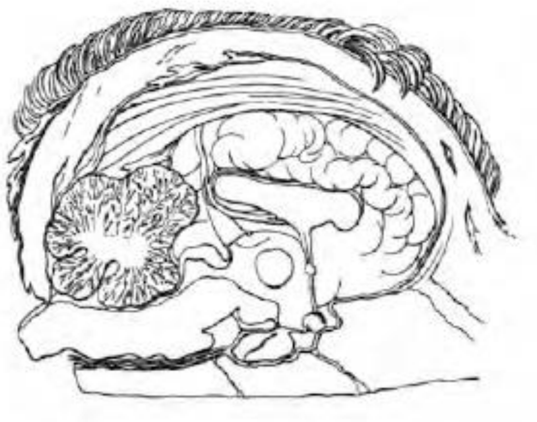
[52] Throughout his medical works Steno always seems fond of Descartes' *L'homme*. In a letter from August 26th 1662 he tells Thomas Bartholin where he encountered the work: "*Descartes*' *Tractatus de Homine* appeared these days published together with figures by *Florens Schuyl*, Senator of the renowned city of s'Hertogenbosch and professor of philosophy there. In this book there are some not inelegant figures" (Kardel and Maquet 2018, p. 433).

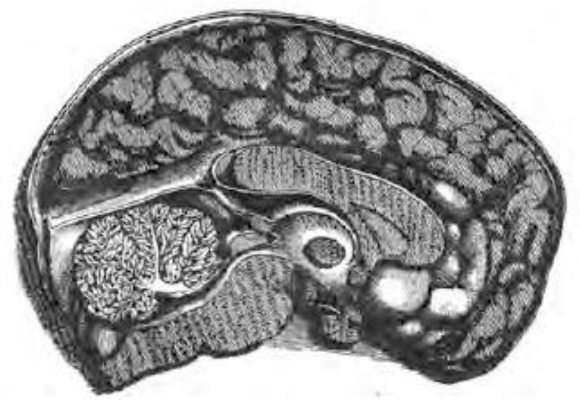
and Maquet 2018, p. 90). Holding the Cartesian theory of animal machines in his mind doesn't seem to have sufficiently quelled his emotions. He writes:

> I must admit that I did not subject them so long to torments without being filled with horror. The Cartesians glorified themselves so much of the certainty of their philosophy, I would wish they should convince me for certain as they are convinced themselves, that the animals have no mind and that it does not make any difference whether one touches, divides or burns the nerves of a living animal or does that to the strings of a self-acting machine. (Kardel and Maquet 2018, p. 90)

No one would rightfully blame Steno for questioning the theory under such conditions. But his doubt regarded Descartes' philosophy about souls and not the general conception of nature being mechanical. In fact, the nerves he separated and burned in live dogs seem to still have been understood according to Descartes principles of motion.

In 1663 Steno writes to Thomas Bartholin and in part compares his findings from brain dissection with those of Descartes: "Certainly, the more I open brains, either of other animals or of birds of various kinds, the less the structure of the brain of animals thought out by the noble *Descartes*, most ingenious and very appropriate otherwise to explain animal actions" (Kardel and Maquet 2018, p. 445). So, his skepticism of animal machines doesn't appear to have cut much deeper into his Cartesian views in physiology and mechanics. Again, the year before on May 21st 1662 he communicates a theory to Bartholin about why tobacco powder can clear up the eyes, offering an explanation for something physiological by calling on Descartes: "What about the fact that also the very intelligent *Descartes* wrote in his *De homine tractatu*…it would not be absurd to attribute the faculty of penetrating the cornea to the subtlest particles of drugs, above all since there is no membrane so dense that it is not perforated by almost infinitely many pores." (Kardel and Maquet 2018, p. 427) This letter is especially instructive since it shows Steno utilizing Descartes' concept of imperceptible particles. Early on Steno wasn't just interested in Cartesian physiology, but also the mechanistic Cartesian universe.





Steno's Drawing of the Cartesian Brain   Steno's Drawing of a New Model

Figures 15 & 16: Derived from a 1665 Lecture in Paris (In Kardel and Maquet 2018)

2.3. Cartesian Circles (1664-1665)

It's well known that Steno was friends with Baruch Spinoza, but the initial source of their connection is hazy. Kardel and Maquet conjecture that one of Steno's teachers, Ole Borch, may have brought the two together through a circle of other Spinozan associates in Amsterdam. Borch writes in his diary about Amsterdam, saying: "There are here atheists, mostly Cartesians" (Kardel and Maquet 2018, p. 91). Of course, he meant that when they talked about God they were talking about nature. But Steno's relationship to Cartesian circles wasn't limited to Amsterdam and Spinoza.

In 1664 Steno went to Paris where he would soon reconnect with Borch and meet many of his teacher's friends. Steno's first Parisian residence was in the home of Melchisédech Thévenot in the Marais quarter, where he met the mathematician of famous stature, Pierre Petit. And in November of 1664 Borch and Steno together spent time with Claude Morel who introduced them to the "Paris of the physicians" (Kardel and Maquet 2018, pp. 118, 121).

At this time in Paris Cartesian science enjoyed a dubious reputation, and the academic scene still taught the ancients in medicine. Thus, the conversation and practice of Cartesian science occurred in private circles. Kardel and Maquet explain that during the first half of the 17th Century several groups formed the foundation for the *Académie Royale des Sciences*. "The conferences connected with the names Mersenne, Montmort and Thévenot." Henri-Louis de Montmort "himself an enthusiastic supporter of Descartes, drew into his circle such determined Cartesians as Clerselier, Rohault and Cordemoy." But they also note that Montmort's circle became disrupted with dispute and was only held together by Thévenot, who continued inviting a condensed group to his home where Steno took up temporary residence (Kardel and Maquet 2018, pp. 122-23).[53] Borch, who also attended meetings, recorded in his diary various dates for the circles assemblies that spilled into the following year. "On March 31, Borch received the whole circle in his lodging and, among those absent, Stensen is expressly named" (Kardel and Maquet 2018, p. 123). Further evidence of Steno's affect on the Cartesian community is reflected in a letter from Petit to Christiaan Huygens who explains that "Thévenot's circle had become deeply involved in anatomical investigations immediately after the arrival of Stensen" (Kardel and Maquet 2018, p. 124).

Two relevant events can be noted here regarding Steno's research activities with Thévenot's Cartesian circle. The first was the circle's discussion of topics clearly stemming from Steno's handy work. Kardel and Maquet report that "On December 9, 1664 the following points of discussion of this *conventus eruditorum* in the home of Thévenot point at Stensen: 1. The course of the muscle fibres in the left ventricle of the heart. 2. Oval vesicles in the heart of a man

[53] One wealthy member of the group was Jean Chapelain, who wrote to Steno offering his help in whatever (presumably financial) capacity he could offer. Steno would eventually send him a copy of his *Myology* manuscript (Kardel and Maquet 2018, p. 123).

at the Hôtel-Dieu. 3 A new-born is dissected" (Kardel and Maquet 2018, pp. 123-24). With Steno's history of canine disturbance, we can presume and hope that (3) wasn't a vivisection.[54] What's significant otherwise is that the group of Cartesians discussed *muscle* fibers of the heart. The second relevant event that occurred with the circle was Steno's *Discours sur l'anatomie du cerveau*—a lecture on the anatomy of the brain—delivered at the Thévenot's in the spring of 1665" (Kardel and Maquet 2018, p. 125).[55] The published text of what Steno demonstrated during the lecture refutes Descartes' model of the brain, but never fails to praise the philosopher as ingenious and ahead of his time.

Steno's acceptance into Thévenot's Cartesian circle is truly significant, since the group was already reduced from a larger Cartesian audience that couldn't seem to agree on Descartes' philosophy; it was selective and likely inhospitable to opponents of Cartesian philosophy.[56] Thus, Kardel and Maquet's wonderfully full historical account matches with Vasiliki Grigoropoulou's assessment, who explains that even when Steno refuted the Cartesian model of the brain, he still did so from a mechanistic Cartesian perspective. The application of his new anatomical method during the 1665 lecture in Paris wasn't a wholesale rejection of Descartes' system (Grigoropoulou 2018, p. 114). Presumably the same applied when he published "*De musculis & glandulis observationum specimen*" in 1664. This work is the first published

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[54] Still it seems that Steno wasn't done torturing man's best friend since at a meeting held March 3rd 1665 "the experiment with the paralysis of the hind legs of a dog by ligation of the aorta was publicly carried out by Stensen" (Kardel and Maquet 2018, p. 124).

[55] Although given as lecture in 1665, the *Discours sur l'anatomie du cerveau* was published in 1669 by the printer Robert de Ninville; upon leaving Paris Steno "transmitted the manuscript to his protector Thévenot" who took care of the publication. This was followed by a "Latin translation published in Leiden" as early as 1671 (Kardel and Maquet 2018, p. 130).

[56] Steno also attended a meeting with Rohault on March 25th 1665, and one with Clerselier on April 13th 1665 (Kardel and Maquet 2018, p. 124).

declaration that the heart is muscle, and it appears Steno formulated his defense of the notion while doing dissections with Thévenot's Cartesian circle.

3. The Heart Becomes Muscle

During his time at Leiden Steno met Thomas Bartholin. He went on to collaborate with Bartholin on several anatomical projects, and even acted as editor for Bartholin's *Acta Medica et Philosophica Hafniensia*. It is in a letter to Bartholin in which Steno first describes the anatomical experiment that lead him to his discovery. The letter, dated April 30th 1663, shows Steno explaining the experiment:

> as to the substance of the heart, I think I am able to prove that there exists nothing in the heart that is not found also in a muscle, and that there is nothing missing in the heart which one finds in a muscle. Happening to have a dead rabbit at hand, I laid hold of its legs and separated its muscles. It was immediately clear in the first muscle and by the first cut that there was no fundamental difference between heart and muscle tissues. (Tubbs et al. 2010)

Of course, the contribution that Steno makes to physiology here is that the heart is a muscle, nothing more nothing less. When he recounts the discovery to Bartholin, he doesn't explicitly suggest anything about the heart's principle of motion, and it definitely doesn't mark Descartes' physiology as a target. This perhaps changed after Steno's conversion, and we can recognize that this obviously isn't a fermentation model. By calling the heart a muscle, Steno places himself in agreement with Harvey about the order of systole and diastole.

When Bartholin responds, he doesn't seem interested either in the implications of solving the heartbeat controversy between Descartes and Harvey. In a letter back to Steno on August 4th 1663, Bartholin stated

> Certainly your observations of the muscles and the heart are excellent and worthy of publication. The spirit of Hippocrates will applaud you, because you, through your outstanding observations, revive his view of the heart which we have moved away from, and provide clear evidence of the fact that the heart really is a muscle. Galenos and his successors will thank you because you have established the fibers of the heart are of one and the same kind. (Tubbs et al. 2010)

Bartholin notes the affinities of Steno's discovery with the ancient theories of Hippocrates, and the confirmation of the Galenist theory that the heart's fibers are homogenous. But Steno's discovery truly did have implications for Descartes' physiology and the larger heartbeat controversy.

Regarding the physiology, Kardel states that "Steno's findings on muscle were incompatible with the loco-motor system of Descartes which had been constructed on ancient concepts" (Kardel 2018, p. 142). He again compares Steno's model to Descartes' remarking that Steno "replaced the notion that the action of muscles was explicable by an inflation brought about by an influx of animal spirits. He suggested instead that it resulted from a shortening of the muscles' fibres in pennate structures" (Kardel 2018, p.143). Kardel is clearly correct about

Steno's refutation of Descartes' physiology. It's fair to conjecture that, had Descartes seen Steno's dissections with his own eyes, he may have been swayed. It would be a large revision to Cartesian physiology to change the specific mechanisms responsible for muscle motion, but it wouldn't have been necessary to discard the principles behind it. It's notable that the contraction demonstrated by Steno is not contrary to Descartes' larger mechanistic system, and in fact, it seems likely that the system is what allowed Steno's to make his discovery in the first place.

It's important to note the date of Steno's discovery. In 1663 he was still finishing his studies at Leiden where he developed a distaste for vivisection and the Cartesian doctrine of animal machines. However, we also saw that his acceptance of Cartesian mechanistic physics remained steadfast. 1663 was also one year before Steno would spend a large portion of time closely working amongst the strongest Cartesian proponents in Paris. Thus, Steno's discovery that the heart is a muscle is a rejection of Descartes' cardiac physiology, but not a rejection of Descartes system. In fact, since the *Chaos Manuscript* shows evidence that Steno adopted Descartes' method with open embrace, we can judge that his discovery of the heart's muscle was the product of a Cartesian paradigm.

This story would of course develop a different flavor when Steno recounted it after his conversion. In 1677 Steno wrote of the heart muscle discovery to Leibniz. This letter provides a bit of additional information about the experiments on the rabbit leg communicated to Bartholin above. Kardel and Maquet provide interesting context, noting that "the German philosopher had ironically asked whether Stensen had perhaps found the Catholic truth in the marrow of the bones." I give Steno's reply at length:

> I can tell you that, in that country of freedom (Holland), I associated with people of a very free understanding, I read all kinds of books and had a very high regard for the philosophy of Descartes and for everybody who was praised for his understanding of Descartes. Then a friend from Sweden brought me the lungs of a deer with the heart attached, to investigate the pulmonary substance. As we had dissected the lungs, we were inspired to boil the heart in order to see whether the substance was musculous or not. Having boiled it and removing its membrane, the first fibres of the heart which I touched, led me to the lower tip and from the tip upwards again, a truth explaining the whole structure of the heart which up to that moment neither I nor anybody else had ever known. This was in complete contradiction to anything the greatest and altogether most dangerous philosophers held for so obvious a truth that they even had the assertion that those who did not share their point of view on the heart did not understand anything in mechanics. A short time later, an afternoon, I got the desire to compare the structure of the heart to that of the muscles. As far as these were concerned, I considered the system of Mr Descartes as infallible. To this end I chose a leg of a little rabbit which I had dissected a short time before. The first muscle which I tested revealed to me the first step of the structure of the muscle which so far nobody had known and which demolished the whole system of Mr Descartes. (Kardel and Maquet 2018, pp. 93-4)

If we take the post-conversion Steno at his word here, it’s difficult to imagine just how twisted his young mind was when an infallible belief was disproven by his own eyes. Steno does faithfully report what we saw in Descartes’ own words to Mersenne regarding the heartbeat. To reiterate Gorham’s well paraphrased preface to Descartes’ statement: “if his theory of the heart’s motion was false and Harvey's true, then Descartes was willing to 'concede that the rest of my philosophy comes to nothing'" (Gorham 1994, p 234). What was at stake for Descartes in cardiac physiology was his mechanistic physics. But I think I've already sufficiently shown in Chapter Three that knowing the heart is a muscle and explaining its motion as such could have fit into that framework. Why then could Steno have possibly thought that his discovery "demolished the whole system of Mr Descartes?" I think this was a post-conversion misrepresentation, a commiserating exaggeration to another formerly Cartesian supporter, Leibniz.[57] The only clarification I can offer for whether or not Steno was earnest with Leibniz is from "*De musculis et glandulis*" (1664). The was published the year after Steno's discovery and when he was actively involved with the Cartesian circles.

Along with his first public assertion that the heart is a muscle he notes how the heart's motion has been interpreted in the past. Steno remarks, "the heart has been made the residence of the innate heat, the throne of the soul, even the soul itself by some. The heart has been greeted as being the sun, the king whereas, if you examine it properly, you will find that it is nothing else than a *muscle*" (Kardel and Maquet 2018, p. 466). He was clearly aware of the long debate over the heartbeat and the microcosmic scheme used by many parties to explain it. Following this statement Steno promptly returns to anatomical description, only speaking of observable structures. Several pages later he interrupts his structural description to once again briefly discuss the cause of the heartbeat, which he is now certain is nothing more than the contraction of the heart's muscle fibers. He states,

[57] Leibniz made his own sojourn to Paris, and his interaction with the philosophical community seems to be the primary impetus for a shift away from Cartesianism. When Leibniz returned to Hanover in 1676 he began plotting moves against the newly perceived danger of Descartes' system. A year later he received the letter from Steno recounting the discovery of the heart muscle.

> How this contraction occurs is difficult to determine. Many attribute it to a filling in of the fibres, some to their emptying and some to both. I should be bold if I arbitrated between them. Therefore, I publicly proclaim that the causes and ways of action *are not obvious* and, since an explication through analogies greatly pleases many people, I will present here something which is not completely foreign to the purpose. Those who drive posts and palisades into the ground for foundations use an engine by which several men raise a ram by way of cables, each of them pulled by a single hand. Not inconveniently this machine can be compared with a muscle divided transversely through the middle of the flesh. The ropes indeed represent the tendons. They are longer and longer depending on the distance the men are at. The weight hooked to the ropes represents the mobile part and the men themselves represent the fleshy fibres. By shortening while together they pull their ropes, the men indeed move the weight. Similarly, the contracting fleshy fibres, while they pull the fibres of the tendon move the mobile part. This being only a comparison, I shall insist no further on this. (Kardel and Maquet 2018, p. 473)

Steno doesn't seem eager to depart from his role as anatomist, and as such he emphasizes that the causes for the heart muscles' contraction (and thus of the heartbeat) "*are not obvious*." Noting Kardel's earlier description of Descartes' explanation of muscle movement, we can assume that this is the position vaguely referenced at the beginning of Steno's explanation. What follows is a mechanical analogy leaving much to be desired. Regardless, the mechanical explanation is itself credit to his Cartesian commitments. We can tell that Steno distrusts those that make the heart into a sun and source of innate heat, but it doesn't seem as though he's worked out a model to replace it in 1664. This would explain his concluding emphasis on analogy and his quick termination of the topic.

4. Steno's Microcosm and the Synthesis of Themes

We already saw that Steno showed skepticism toward microcosmic ideas when discussing past theories of the heartbeat. In his "*De musculis et glandulis*" (1664) he quickly dismisses the notion that the heart is like the sun of the microcosm. But the microcosmic theme pops up again in at least three other instances of Steno's writing. The first arises in a disputation defended during his time at Leiden (1661), the second appears in a story from Steno's time in Paris (1664-1665), and the third occurs in his final tract on the muscles during the year of his conversion (1667).

Steno's first two years at Leiden were marked by controversy as he studied glands. While his professors Johannes van Horne and Franciscus Sylvius were demonstrating "the parotid glands of an ill woman," they publicly announced Steno's discovery of the *ductus Stenonianus*. An Amsterdam professor Jan Blasius was outraged with the announcement, as he himself laid claim to the discovery. With van Horne presiding, Steno formulated and defended a disputation for the discovery on July 6th 1661 (See Kardel and Maquet 2018, pp. 68-74). Titled *Anatomica de glandulis oris, & nuper observatis inde prodeuntibus vasis,* Steno opens the dissertation with a caricature, perhaps of Blasius. The caricature represents an unnamed scientist who in old age directs his attention away from the natural universe to look inward, "inside a sphere of such small capacity, inside his skull." Steno describes the old man's internal journey glibly. He first, "flying up to the heavenly bodies will explain to us the constant order of the fixed stars, the undeceiving wanderings of the planets, the excursions of the comets deprived of any law." Next, "sliding down he will range in a moment through the air and will depict nice varieties of colours," while yet again the hypothetical old man condenses his view "descending to the earth" to "reveal the concealed mysteries of minerals." Steno tops the story off remarking "Another one has all these ideas submitted to his will as if the included macrocosm were hidden from the microcosm" (Kardel and Maquet 2018, p. 360). Thus, while still steadfastly Cartesian, Steno presents the microcosm-macrocosm scheme with skepticism.

When Steno published *Canis carchariae dissectum caput*—a treatise about dissecting a shark head—a story from his time in the Cartesian circles of Paris appears. Although written in 1667, the events of the story must have occurred between 1664 and 1665. Steno tells us that:

Figure 17: Shark Head
(From Kardel and Maquet 2018)

> In Paris, in the Academy at the house of my great friend *Thévenot*, I have seen *Borel*, greatly skilled in chemistry, pour together two quite clear liquids which immediately became so solid that not even a drop left the glass container when it was inverted. Why then, may we not suspect that rain falling from the atmosphere at various times, and of varying composition, or perhaps juices and vapours of different kinds from the earth, when mixed with the waters, may sometimes precipitate bodies dissolved in

> them and at other times dissolve bodies that have been precipitated from them? This is evident in urine collected from one and the same person at different times, since a solid deposit laid down during the first days, and adhering most firmly to the base of the container, is very often dissolved, during subsequent days, by fresh urine from the same person, only to collect afresh, soon after, from the second urine. What varieties of diet accomplish in the humours of the microcosm, so alteration in the sun and moon and various other changes could produce in the humours of the earth. *Gassendi*, the "glory of France", supports this assertion with the clearest of examples in his learned work in which he explains the origin of stones. (Kardel and Maquet 2018, pp. 590-91)

It's interesting to see Steno utilize microcosmic language in the context of explaining a Cartesian experiment. He finds a correspondence between the behavior of rain and the condensation and evaporation of human urine samples. Further, he notes that his conclusions are supported by Gassendi's work on stones (presumably of the kidney and bladder). Gassendi was a devoted mechanist in physics like Descartes and Hobbes, and his mention here hints at the meaning of Steno's microcosmic language. Steno takes the interaction between celestial bodies and rain and compares it to human urine. However, this doesn't mean to Steno what it would have meant to Stephan Roderic de Castro, Robert Fludd, or William Harvey. For these three, their microcosmic ideas were interpreted in the framework of an Aristotelian cosmos, and Harvey himself had recommended Castro's book on the microcosm because it aided him in investigating kidney stones. I think I provided sufficient evidence for the position that Steno was a Cartesian mechanist during his time in Paris. Thus, when he uses microcosmic language to describe an experiment from that time, we can assume he simply meant that the same laws of nature determining the motion of the sun, moon, and particles in rain also determine the motion of particles in evaporating urine.

This interpretation is further justified by Steno's last microcosmic reference, written in his final treatise on the muscles: *Elementorum myologiæ specimen* (1667). He urges the necessity for myology to become a part of mathematics, or else "the parts of muscles cannot be distinctly designated nor can their movement be successfully studied. He continues with the statement: "why should we not give to the muscles what astronomers give to the sky, what geographers to the earth, and, to take an example from microcosm, what writers on optics concede to the eyes? These writers treat natural things mathematically so that they may be more clearly understood" (Kardel and Maquet 2018, p. 547). His emphasis on the application of mathematics to anatomy is telling, as he appears like a man after Descartes' own heart. But his further statement that mathematics would be useful in studying the movement of muscles (and thus their physiology) further elucidates his earlier mechanical analogy used to explain the cause of the heartbeat. Again, in "*De musculis et glandulis*" (1664), he admits that the causes behind the heartbeat are not obvious and he hesitates to explain them, implying that the topic needs further investigation. We can now see that even in 1667 he conceived of this investigation as a mathematical approach, and therefore as a study of mechanism. His subsequent reference to microcosmic writers on optics and the eyes is a reference to a mathematical approach.

So, we can see that Steno did find something of interest in microcosmic ideas, but that the microcosmic-macrocosmic scheme didn't reference an Aristotelian cosmos, but had been adapted to fit into a Cartesian universe. Wonderfully Steno resolves the heartbeat controversy of the first half of the 17th century in completeness: He mechanizes the microcosm. A consequence of discovering the heart is muscle was the clear dispensation of an Aristotelianism vestige in

Descartes' physiology (the fermentation heartbeat model), but Steno was only able to manifest such a consequence because of Descartes' method and mechanistic commitments.

CHAPTER SEVEN:

CONCLUSION

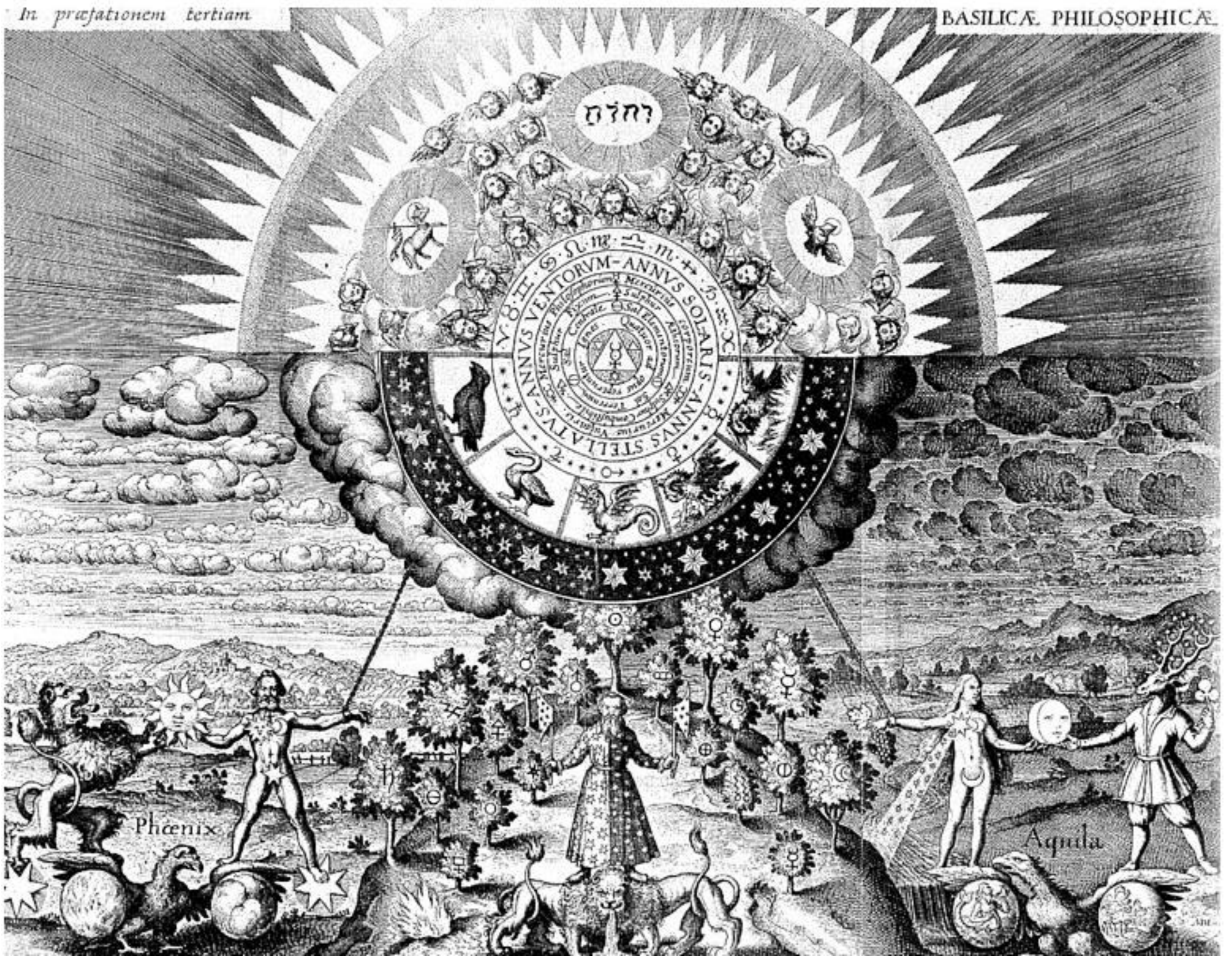
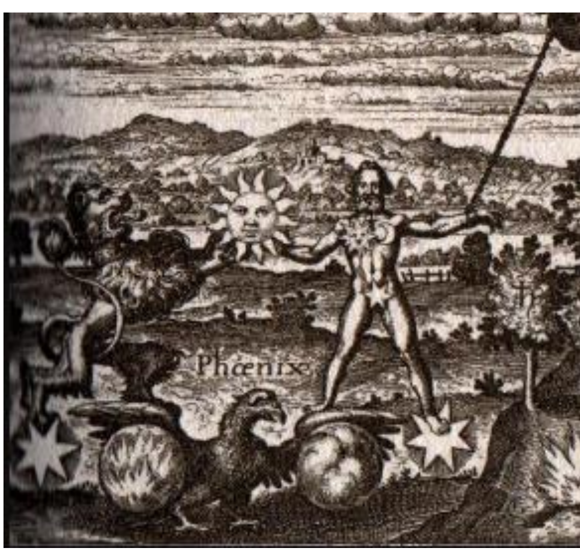
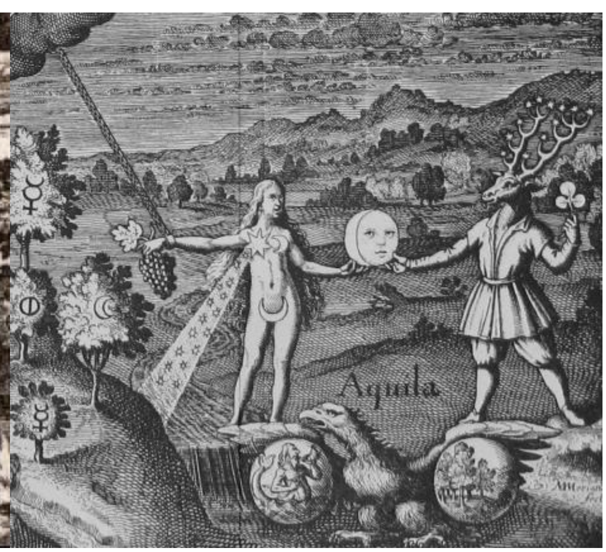


Figure 18: From Johann Daniel Mylius' *Opus Medico-Chymicum*, 1618.


Phœnix


Aquila

Viewed with the right kind of eyes, the historical narrative in this dissertation has symmetry. Roger Ariew explains how Martial Gueroult presents Descartes' *Meditations* "as a diptych, a work of art in two panels." Ariew continues:

> The first three Meditations as the first panel, ruled by the darkness of the principle of universal deception with a battle being fought against it by the truth of the existence of the self—a mere point of light—a narrow but piercing exception to the principle of doubt…The second panel is then ruled by the blinding light of God's absolute veracity—that is, the principle of universal truth—and fought against by the existence of error, a narrow point of darkness and seeming exception to that principle, puncturing the light of universal veracity in the same way that the existence of the self punctured the darkness of universal deception. (Ariew and Watkins 2000, p. 2)

A similar symmetry might be mapped to the heartbeat's historical development in the 17th Century. Standing in the present, viewing the story of how the heart became muscle, one might think of Harvey as the first panel. His acceptance of an Aristotelian cosmos and metaphysics spreads out as the darkness of a universal deception, only punctured by the mere point of light that was a correct ordering of systole and diastole. Descartes is the second panel. In bequeathing a method and mechanistic physics to future generations, his standards for truth might represent a blinding light of veracity—universal truth—only effaced with a narrow point of darkness, his erroneous acceptance of Aristotle's cardiac physiology. Alternatively, one could view Ross with a dot of Harvey and Descartes with a dot of Steno. The Aristotelianism represented by Ross is a decent vehicle of the Taoist yin, dark and degrading, yet it gave birth to the creative discovery of the blood's circulation through its interplay with Harvey's yang departure from tradition (his heartbeat model); The new system of physics produced by Descartes' striving is properly yang, light and creative, but from the principles of that system Stensen disproved the Cartesian cardiac model. None of these analogies are perfect, and I'm certainly no Ariew or Gueroult. But I hopefully showed that Harvey was "right" for the wrong reasons, while Descartes was "wrong" for the right reasons.

Put differently, Harvey's physiology was correct while his supporting principles were "wrong," and Descartes' physiology was incorrect while his supporting principles were "right." Our assessment of Harvey and Descartes comes from the present, with all our historical and scientific knowledge in play. In some general ways we are still Cartesians, viewing the universe as passive matter that obeys laws and behaves like a mechanism. These were the very reasons that motivated Descartes to adopt the Aristotelian model for cardiac motion. So from our present perspective, he had the right reasons for a wrong conclusion that wrongly ordered systole and diastole. In comparison Harvey ordered the heart's motion correctly. But he chose to do so because it made sense within his Aristotelian conception of nature, which is completely foreign and incorrect by our present standards.

Geoffrey Gorham pointed out the different metaphysics and physics lurking behind Descartes and Harvey's explanations of Cardiac motion. What was at stake was whether or not a human organ—or any natural body for that matter—could be the source of its own motion. Harvey's belief that the heart could contract itself wasn't baseless, since to him the stars in circular orbits represented the same internal principle of movement. Descartes believed the heart could not move itself; its motion must have been a result of other motions.

Alexander Ross was a stone-cold Aristotelian and contemporary to Harvey and Descartes. Thus, he contained the Aristotelian elements of both Descartes and Harvey, albeit, different elements. Ross lays out the Aristotelian boiling model for the physiology of the heartbeat, where an innate heat vaporizes the blood that expands and pushes on the walls of the heart (diastole). Systole is a mere relaxation of the heart and not a constriction that pushes the blood. Ross' description helps us to see that Plempius was correct when he told Descartes he had seen his heartbeat physiology before in Aristotle. But Ross also presents the boiling model in the context of an Aristotelian cosmos, concentric layers of immaterial faculties and souls that lay behind and support the boiling model. Specifically, the cosmos is used to explain the source of innate heat in the heart, which Descartes alternatively explained with the mechanistic explanation of fermentation.

Ross like many others said there was a similarity between the innate heat in the heart and the heat in the celestial sun, and this formed the basis of Ross' microcosm-macrocosm scheme. In other words, the human heart is a smaller version of the sun because it acts from the same principles. Conceiving of the human body as a microcosm of the larger cosmos encouraged an easy acceptance of Harvey's theory for the circulation of the blood, since the circular motion of the blood could then be said to mirror the circular motion of the celestial bodies in orbit. Thus, when Ross published objections to Harvey's medical philosophy, he didn't object to the circulation, and he didn't object to the general microcosm-macrocosm scheme presented in *de generatione*. Ross splits hairs over whether it's the animal and vital spirits in the blood or the blood itself that is the proper instrument of the soul, and thus the source of innate heat and producer of circular motion. I then showed that Harvey didn't believe in animal and vital spirits (a position coincidently shared by Steno but for different reasons). Rather Harvey held that the blood simply is spirit, manifesting a particular set of qualities and behaviors. This notion of spirit only makes sense in a larger Aristotelian cosmology that he shared with Ross, along with the very functional idea that the human body is a microcosm. For Harvey, the cause of the heart's motion, its internal principle of movement, was possible because the blood mirrored the circular motion of celestial bodies.

Nicolas Steno marks the crossroad and resolution of Harvey, Descartes, and their differences. He thought of nature as a mechanistic Cartesian universe, but also demonstrated the correct order of systole and diastole. He determined that the heart is a muscle. Others before him like Hippocrates and Leonardo de Vinci made similar statements, but these early physicians didn't mean the same thing and didn't use the muscle to explain the heart's motion. This is because their conception of physics and the cosmos was still non-mechanistic. Steno on the other hand was able to call the heart a muscle and use it to explain the heartbeat (correctly ordering systole and diastole) because of his commitment to a mechanistic Cartesian physics. With Steno, we also saw the microcosmic ideas popular in the renaissance and first half of the 17th Century dissolve into the mechanistic Cartesian universe.

My narrative only focused on a select number of thinkers in a much larger group of active physicians and philosophers, each with their own idiosyncrasies. But I think I have selected the best representatives of the contrasting poles of opinion in the heartbeat debate, and that most of the other early moderns would fall in line behind them or somewhere on the spectrum between them. Although it's outside the domain of my research, there seems to be credence in the idea of Hisao Ishizuka, who explained that Harvey's research on muscles was a precursor to the discovery that the heart is muscle. Still it seems more likely that Harvey was much less of an influence on Steno than he was on Richard Lower in Britain, who made the same claim as Steno five years after in 1669 (Ishizuka 2006, p. 11). In fact, Harvey makes a sparse appearance in Steno's published works and isn't mentioned by Kardel and Maquet during their commentary of Steno's *Chaos Manuscript*.

In a similar vein, my narrative clearly avoids aiming for historical completeness, as cardiac physiology continued to develop into the 18th Century and beyond. Ishizuka's 2006 article cited above and in Chapter Two appears to pick up the thread where I left off, explaining how early 18th Century iatromechanists sought to provide an explanation for the cause of Cardiac motion after Steno established the heart was a muscle. It would be a considerable number of years still until an accepted theory of electricity was developed and implemented in physiology.

William Harvey's discovery of the blood's circulation is rightfully praised as a great scientific achievement to this day. But his recognition seems to overshadow so many other important scientists working at the time, and is rarely if not never accompanied by even a mention of his Aristotelian microcosmic ideas. If Harvey receives such historical emphasis for circulation, then perhaps shouldn't Nicolas Steno be more recognized for his cardiac discovery, along with the Cartesian mechanism behind it?

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figure number & title / caption Fig. 6.
The fifth table of the muscles from Vesalius’ *De humani corporis fabrica*. The artist has given immediacy to the historia of the muscles by placing the figure in a landscape…

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figure number & title / caption Fig. 4.
A pig prepared for vivisection, from Vesalius’ *De humani corporis fabrica*. The illustration is rather a celebration of Galen's vivisections in Rome than a report of those of Vesalius, who preferred to use dogs.

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St Thomas Aquinas, the Counter-Reformation ‘Sun of the Church,’ took his place on the title page of a number of books published in Louvain. Here (i) he appropriately decorates Plemp’s edition of book 1 of the Canon of Avicenna…

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