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Chapter Six

Not Dead Yet: Teleology and the "Scientific Revolution"

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6.1. Introduction

In 1897, James Ross Clemens became seriously ill. He didn't die. Not then at least. Nonetheless, rumors swarmed throughout London that his cousin, Samuel Clemens, had passed away. Samuel Clemens–Mark Twain–was bemused, famously quipping that reports of his death had been greatly exaggerated. To be sure, something had happened, perhaps something important, but nothing as definitive as what was rumored.

It has similarly been thought that the concept of teleology met its fate in the seventeenth and eighteenth centuries with the rise of early modern science. Francis Bacon famously derided the use of final causes in physics as being akin to vestal virgins dedicated to God and accomplishing nothing.[1] It is easy to see in Bacon's quip the suggestion that natural philosophers in the early modern period came to see appeals to final causes as unhelpful or simply not explanatory. René Descartes implied that the pursuit of final causes in physics is presumptuous

[1] Francis Bacon, "*De augmentis scientiarum*," in *Works*, Volume 1, ed. James Spedding, Robert Leslie Ellis, and Douglas Denon Heath (London: Longman, 1858, Facs. repr. Stuttgart-Bad Cannstatt: Friedrich Frommann, 1963), 571, but for a fuller picture see also 570.

and promised to forego them in his own investigations of the physical world.[2] It is easy to see in his remarks a slightly different concern–the thought that even if there are final causes in the world, we have no reliable, scientific way of investigating them. Finally, Baruch Spinoza boldly denied that God acts for the sake of ends and suggested that final causes are nothing more than "human fictions" that "turn the order of nature completely upside down."[3] It is easy to imagine that Spinoza's first denial marks a decisive break between a medieval worldview infused with divine purposes and an early modern worldview that became increasingly naturalistic. It is easy to imagine that Spinoza's second denial signals a deep skepticism about the very coherence of final causation and foreshadows a general shift from a focus on final causation in the medieval period to a focus on efficient causation in the early modern era.

Scholars of early modern philosophy have—not unreasonably—devoted much effort to exploring attacks (or apparent attacks) on teleology at the dawn of modern science.[4] It remains a

[2] René Descartes, *Oeuvres de Descartes*, ed. Charles Adam and Paul Tannery (Paris: Vrin, 1978), vol. 9 pt. 2, 15-16; see also vol. 7, 53–63.

[3] Benedictus Spinoza, *Opera*, ed. Carl Gebhardt (Heidelberg: C. Winter, 1925), vol. 2, 80. For discussion, see Yitzhak Melamed's chapter on Jewish philosophy in this volume.

[4] For extended discussions of teleology in the early modern era, see Vincent Carraud, *Causa sive Ratio: La Raison de la Cause, de Suarez à Leibniz* (Paris: Presses Universitaires de France, 2002), Dennis Des Chene, *Physiologia: Natural Philosophy in Late Aristotelianism and Cartesian Thought* (Ithaca, NY: Cornell University Press, 1996), and Stephan Schmid, *Finalursachen in der Frühen Neuzeit* (New York: De Gruyter, 2011). Among much-discussed early modern philosophers, Gottfried Leibniz stands out as a recognized proponent of final

stubborn fact, however, that most natural philosophers in the early modern period remained deeply committed to teleology. Because they are numerous rather than few, it is impossible to relate their story here in the same detail that has been afforded to their more skeptical-sounding counterparts. The three sections that follow will, however, attempt to correct, at least in a small measure, the persistent impression that teleology was simply undermined by the so-called scientific revolution. It will do so by looking at three areas in which teleology was upheld and developed by three pioneers of early modern science. The next section will show how teleological reasoning is woven into the very fabric of William Harvey's revolutionary work in biology. Section 6.3 will take up Robert Boyle's explicit and systematic defense of teleology and especially his effort to reconcile the methods and commitments of the new science with a deep-seated commitment to divine teleology. Finally, section 6.4 will explore Pierre Maupertuis's bold attempt to find a place for teleology in the heart of modern, mathematical physics.

As we will see, in the early modern period, much happened to the concept of teleology. Much that was no doubt important. And yet, like James Ross Clemens, teleology didn't just die. Not in the early modern era at least. As with Clemens's hale and hearty cousin, rumors of teleology's early demise have been greatly exaggerated.

6.2. William Harvey and Biological Teleology

causes. For an attempt to situate his views on teleology in the larger landscape of the early modern era, see Jeffrey K. McDonough, "The Heyday of Teleology and Early Modern Philosophy," in *Early Modern Philosophy Reconsidered*, ed. John Carriero, *Midwest Studies in Philosophy* (35) 2011: 179–204.

Born between Bacon and Descartes in 1578, William Harvey rose from a yeoman's background to become the leading anatomist and physiologist of the early modern era. His accomplishments were many. After attending Cambridge, he earned a medical degree at the University of Padua, where he worked closely with the pioneering anatomist and surgeon Hieronymus Fabricius. At the age of twenty-nine, he joined the Royal College of Physicians and soon after was put in charge of St. Bartholomew's Hospital. Later, he would be appointed to the office of Lumleian lecturer and would eventually become "Physician Extraordinary" to King James I. A leading figure of early modern science, Harvey is best known today for his discoveries concerning the heart and the circulation of blood as set out in his masterpiece *Anatomical Exercises Concerning the Motion of the Heart and Blood in Animals (Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus,* hereafter *de Motu Cordis*).[5] A closer look

[5] William Harvey, *Exercitatio Anatomica de motu cordis et sanguines in animalibus* (Frankfurt 1628). I have generally followed the English translation in William Harvey, *An anatomical Disputation Concerning the Movement of the Heart and Blood in Living Creatures*, trans. Gweneth Witteridge (London: Blackwell Scientific Publications, 1976). All references are to the English translation. In spite of being a major figure in the scientific revolution, Harvey has long been relatively neglected by historians of philosophy. That tide may, however, finally be turning. For recent work on Harvey and teleology, see, for starters, Peter Distelzweig, "'*Meam de motu & usu cordis, & circuitu sanguinis sententiam*': Teleology in William Harvey's *De motu cordis*," *Gesnerus Swiss Journal of the History of Medicine and Sciences* 71:2 (2014): 258–270; Benjamin Goldberg, "William Harvey on Anatomy and Experience," *Perspectives on Science*

at his work quickly reveals that teleology plays important roles in Harvey's pioneering discoveries; that he draws explicitly teleological conclusions from those discoveries; and that, collectively, his efforts provide a powerful response to the charge that the investigation of final causes must be useless, brash, or both.

In Harvey's day, physiology—the study of the use and function of parts of the body—was still dominated by the second century work of Galen of Pergamon.[6] Galen sees the heart as standing at the juncture of two otherwise autonomous vascular systems. One system, anchored in the stomach and liver, produces purple, nutritive blood that slowly ebbs and flows through the venal system to the body's extremities, replenishing muscles and bones. The other system is anchored in the lungs and heart. Galen conjectures that some nutritive blood from the venal system is drawn into the right side of the heart, where it seeps through invisible pores in the septum into the left ventricle of the heart. There venal blood is mixed with a vital spirit drawn from the lungs in a process called "concoction." The process of concoction transforms the venal system's purple, nutritive blood into bright red, vivifying arterial blood. Once concocted, arterial blood ebbs and flows from the left ventricle of the heart through the arterial system to the organs where it is consumed (with any remainder evaporating). For Galen, then, the vascular system is really two vascular systems. Blood gently sloshes through both systems and is continuously produced and consumed. The heart plays a significant but not central role.

24:3 (2016): 305–323; James Lennox, "The Comparative Study of Animal Development: William Harvey's Aristotelianism," in *The Problem of Animal Generation in Early Modern Philosophy*, ed. Justin E. H. Smith (New York: Cambridge University Press, 2006), 21–46.

[6] On Galen's relation to teleology, see Patricia Marechal's essay in this volume.

Harvey was led to a radically different understanding of the "motions of the heart and blood in animals" by two principal clues, both of which make explicit appeal to teleological reasoning. The first such clue draws on assumptions about the teleological functions of animal parts. Earlier anatomists had discovered that veins contain numerous valves. Galen's followers had supposed that the function of venal valves is to counteract the force of gravity. As venal blood slowly ebbs and flows through the venal system, valves, they supposed, are needed to prevent it from pooling in the lowest extremities of the body. This Galenic account, however, struck Harvey as untenable. It was known, for example, that valves in the jugular vein are—in a person standing—oriented down, not up. They thus seem to guarantee that blood flows with gravity, not against it. Reflecting on orientation of jugular valves, Harvey concludes, "The discoverer of these valves did not rightly understand their use […] For their use is not to prevent the whole mass of the blood from falling downwards by its own weight into the lower parts of the body."[7] To this negative assessment, Harvey adds a positive discovery. He notes that venal valves are in general oriented in such a way as to guarantee the flow of blood towards the heart and away from the body's extremities. After conducting numerous investigations, including dissections of a wide variety of animal species, he concludes that venal "valves were made entirely lest the blood … should not go from the center of the body to the extremities, but rather from the extremities to the center."[8] Venal valves, in Harvey's opinion, don't function to counteract gravity, they function to ensure that blood in the veins always flows towards the heart.

[7] *de Motu Cordis*, 101.

[8] *de Motu Cordis*, 104, 102.

Harvey's second clue appeals to quantitative results backed up by teleological considerations –considerations invoking the purposes for which bodily parts were formed or created. Having witnessed countless vivisections and butcherings, Harvey was struck by the sheer quantity of blood that must pass through a beating heart. On the basis of rough calculations, he reckons, for example, that if it is supposed, conservatively, that "in a man there is sent forth at every beat of the heart … one dram which cannot possibly return to the heart by reason of the hindrance of the valves," and that "[t]he heart in one half hour makes above a thousand pulses," it can be deduced that in a half hour a "quantity of blood, is passed through the heart into the arteries, that is, always in a greater quantity than can be found in the whole of the body."[9] These quantitative estimates are supported, according to Harvey, by physiological—that is teleological—considerations. Harvey argues that the "abundance of blood passing through the heart out the veins into the arteries" is witnessed by "the symmetry and great size of the ventricles of the heart and of the vessels which go into it and go out from it (for Nature who makes nothing in vain would not have allotted to those vessels so comparatively large a size to no purpose)."[10] Harvey is using teleological considerations – what the ventricles of the heart are good for, their purpose—to support his quantitative estimations. Those quantitative estimations, Harvey concludes are, in turn, inconsistent with Galenic theory, according to which blood is continuously produced and consumed.[11] For Harvey, this is all more evidence that a new theory

[9] *de Motu Cordis*, 79, see also 105.

[10] *de Motu Cordis*, 74–75.

[11] *de Motu Cordis*, 80.

is needed, a theory according to which blood is not constantly generated and destroyed but rather recycled.

Spurred by physiological and quantitative clues, and assured by innumerable dissections, observations and experiments, Harvey accordingly first formulated, then confirmed to his own satisfaction, just such a new theory. Putting his "trust in the love of truth and in the integrity of learned minds," Harvey dares to put forward his "opinion concerning the circulation of the blood and to state it formally to all men:"

> [T]he blood passes through the lungs and heart by the pulse of the ventricles, and is driven in and sent into the whole body and there creeps into the veins and porosities of the flesh, and through the veins themselves returns from all parts, from the circumference to the centre, out of the tiny veins into the greater, and from thence comes into the vena cava and at last into the auricle of the heart, and in so great abundance, with so great an outflowing and inflowing, from hence through the arteries thither, from thence through the veins hither back again … it must of necessity be concluded that the blood is driven into a round by a circular motion in living creatures, and that it moves perpetually.[12]

Details remained to be worked out. What is the exact function of the blood itself? What is the exact mechanism by which it passes from the arteries to the veins? Nonetheless, Harvey's central thesis is of course correct: blood is forcefully circulated by the heart through a single circulatory system that includes both the veins and arteries. His understanding of the operations of the heart and circulatory system was a revolution in early modern science, comparable in its significance to Newton's theories in mechanics. Indeed, insofar as it eventually helped to loosen the grip of

[12] *de Motu Cordis*, 74, 107.

Galen's influence on biology and medicine, its practical implications were perhaps even greater. Newton's discoveries quickly led to improvements in astronomy and mechanics. Harvey's, however, spurred the advancement of modern medicine and public health.

Teleology thus played a central role in the discovery of one of the most important and far-reaching theories of early modern science. In Harvey's work, however, teleology is not limited to the process of discovery. Rather, he also aims to draw conclusions that are themselves teleological. Some of these conclusions assign teleological functions to animal parts and processes. They specify the purposes of animal parts and activities. So, for example, in the second chapter of *de Motu Cordis*, Harvey tells us that "the *proper* movement of the heart is not the diastole but systole," that is, that its proper, essential function is to pump blood out rather than to draw blood in.[13] The fifth chapter of *de Motu Cordis* is entitled "Of the action and function of the movement of the heart." In it, Harvey tells us "one of the [characteristic] actions of the heart is the very transmission of the blood and its propulsion to the extremities by the intermediacy of the arteries."[14] Again, the thought is teleological: one of the functions of the heart is to push the blood through the arteries into the extremities of the body. In the eighth chapter, he describes the heart as "this familiar household god" and attributes to it the functions of "nourishing, cherishing and quickening."[15] In the thirteenth chapter, he discusses of the "uses" of the valves. In the fourteenth, he declares that driving the blood in a circular motion is "the

[13] *de Motu Cordis*, 34, emphasis added.

[14] *de Motu Cordis*, 51–52.

[15] *de Motu Cordis*, 76.

action or function of the heart, which by pulsation it performs."[16] In such passages, we see Harvey drawing explicitly teleological conclusions. We see him assigning proper functions to animal parts and processes.

Other conclusions draw by Harvey assign teleological origins to animal parts and processes. They specify why animals have the particular parts and processes that they do have. In the final chapter of *de Motu Cordis*, he argues that "because more perfected creatures need a more perfected aliment and a more abundant innate heat … it was fitting and reasonable that these animals should have lungs and a second ventricle."[17] He tells us, for example, "Nature being perfect and divine and making nothing in vain, neither gave a heart to any animal where there was no need, nor made it before it could be of any use."[18] He argues, "since Nature who is perfect makes nothing in vain and in all her works suffices every need, the nearer the arteries are to the heart, the more they differ from veins in their constitution."[19] Finally, he concludes that "it were very hard for anyone to explain by any other way than I have done for what cause all these things were so made and appointed."[20] For Harvey, biological parts and operations not only have teleological functions, they also have teleological origins. The heart, for example, not only has a purpose, namely, circulating the blood: it is present in cordate creatures because of its purpose.

[16] *de Motu Cordis*, 107.

[17] *de Motu Cordis*, 122.

[18] *de Motu Cordis*, 128.

[19] *de Motu Cordis*, 130.

[20] *de Motu Cordis*, 133.

Hearts are for the sake of circulating blood, and creatures have hearts because they are for the sake of circulating blood.

The roles of teleological reasoning in Harvey's discovery of the circulation of the blood as well as the teleological conclusions he drew from his momentous discovery, provide the basis for a powerful reply to the charges raised against teleology by Bacon and Descartes. One distillation of Bacon's quip about vestal virgins is that teleology—like a virgin dedicated to God—is useless. It is easy to be sympathetic with Bacon's complaint. When we are told that bones are for the sake of supporting the body and that the earth is for the sake of supporting creatures, we seem to learn nothing and to gain no advantage.[21] Harvey, however, has a powerful reply. For surely a response to Bacon's charge does not require one to show that *every* appeal to final causes is useful. And, indeed, in his "introductory discourse" to *de Motu cordis*, Harvey savages the teleological conclusions of many of his predecessors. No, a proper reply to Bacon's charge only requires producing evidence that teleological reasoning can be useful in some cases, that it can, in some cases, get results. And that is exactly what Harvey does in his *de Motu cordis*. We've seen already how considerations of function played a role in the two major clues leading to Harvey's discovery of the circulation of blood. But even those clues don't tell the whole story. Harvey's masterpiece is laced through with teleological hypotheses and principles. Hypotheses, for example, concerning the function of the valves of the heart, the thickness of the arteries near the heart, and the thinness or arteries at the body's periphery. Principles, for example, such as the maxim that similar structures should be presumed to have similar functions

[21] Bacon, *De augmentis scientiarum, 569.*

and that nature does nothing in vain.[22] If Bacon's charge is that teleological reasoning cannot be *useful* in the pursuit of science, Harvey's work provides a devastating rebuttal.

Harvey's work also represents a powerful response to the central thrust of Descartes' criticism of final causes, namely, that it would be presumptuous to speculate concerning them. Again, it is easy to be sympathetic with the charge. Granted that our bones prop up our bodies, how do we know that that is their function? Granted that the earth supports the creatures living on it, how do we know that it even has a function? Again, however, we should be clear about the rules of the game. Surely, the defender of teleology needn't rebut the radical skeptic. In order to defend teleology, she needn't refute general arguments intended to show that we have no knowledge or justified beliefs at all. Rather her goal – qua defender of teleology – must be to show that evidence can be amassed for teleological conclusions in essentially the same way that it can be amassed for non-teleological conclusions. In the context of early modern science, that means above all showing how evidence in the form of observations and experiments can be marshaled in support of an interlinked set of hypotheses some of which are teleological in nature.

With his *de Motu cordis*, Harvey again rises to the challenge. His account of the motion of the heart and blood contains a complex web of interlinked hypotheses, including, for example, that the chief action of the heart occurs during contraction, that the function of the mitral valves of the heart is to prevent the backflow of blood driven out of the heart during contraction, and that arteries are thickest near the heart in order to prevent their being ruptured when engorged with blood surging out the mitral valves. Harvey understood all of these hypotheses as involving appeals to final causes, and—with the possible exception of the hypothesis concerning the chief

[22] *de Motu Cordis*, 16–17, 128.

action of the heart—we should too. Can evidence be marshaled in their favor? Of course. The thickness of the arteries near the heart is evident to the naked eye and can be compared directly with their relative thinness at the body's extremities. Harvey convincingly argues that the function of the mitral valves can be confirmed by experiment – for example by probing the valves or trying to force water against their closure. The chief action of the heart is—Harvey acknowledges—difficult to discern because the hearts of warm-blooded animals beat so quickly. But the lion's tail can be twisted here as well, in part, for example, by observing hearts just before they expire, by looking at the hearts of cold-blooded animals, which generally beat more slowly, and by making inferences from the nature of the muscle fibers constituting the heart.[23] None of this evidence, of course, is absolutely conclusive. Real evidence seldom is. But Harvey is nonetheless surely right to see it as evidence for his teleological hypotheses nonetheless. Indeed, it is as good or better than most of the evidence for any interesting hypothesis in early modern science.

Harvey's *de Motu cordis* thus represents an ambitious defense of teleology along two main fronts. First, and perhaps foremost, it is ambitious in its conclusion. Above all, Harvey's efforts radically reshaped our understanding of the physiology of the central components of the cardiovascular system. The structure and location of the parts of the cardiovascular system were, in general, already well known. Harvey didn't discover the general structure or location of the heart, liver, lungs, arteries, veins, etc. He didn't even discover the presence of valves or blood in the arteries. What he offered was a better understanding of the *function* of all these parts, of *why* they are so structured and located. Second, Harvey's *de Motu cordis* is ambitious in its efforts to

[23] *de Motu Cordis*, 86–87, 129.

combine the full rigor of the new science with the ancient investigation of ends and functions. Although not alone in this endeavor, Harvey helped to popularize and reinforce techniques in the investigation of ends and functions of animal parts that seem obvious only in hindsight: careful observation, comparative study, experimental variation. In doing so, he married early modern physiology to the methods of the new science. In spite of occasional reservations—such as those of Bacon and Descartes—it has, in fact, been a long and happy union.[24]

6.3. Robert Boyle and Divine Teleology

Robert Boyle, the father of modern chemistry, was as much a leading figure of the "scientific revolution" as William Harvey. Born in Ireland in 1627, Boyle received a privileged education at the hands of private tutors and at Eton College. After his father passed, Boyle devoted himself to scientific research. In 1654, he set up shop at Oxford and, with the aid of Robert Hooke, began experimenting with air pumps. In the course of defending his work, Boyle articulated the law that still bears his name, that is, "Boyle's law." Many additional discoveries followed, and Boyle became a recognized spokesperson for the new mechanical philosophy. Like most natural philosophers in the early modern era, however, Boyle's commitment to religion remained broad and deep. He contributed funds to missionary work and translations of the bible. Having helped to found the Royal Society, he turned down its presidency on theological grounds. In his will, he endowed a series of lectures—now known as the Boyle

[24] On the place of teleology in modern science, see Patrick's Forber's essay in this volume.

lectures—to defend the Christian religion against "notorious infidels, namely, atheists, deists, pagans, Jews and Muslims." No one might be more aptly described as a man of the science *and* religion of his day than Boyle.

In 1688, Boyle published what is perhaps the most important, explicit treatment of teleology by a leading figure of the scientific revolution: *A Disquisition about the Final Causes of Natural Things: Wherein it is inquired, Whether, and (if at all) with what Cautions, a Naturalist should admit them?* (hereafter *Disquisition*).[25] The defense it mounts, Boyle tells us, is "now the more seasonable" because "two of the chief sects of the modern philosophizers do both of them, upon differing grounds, deny, that the naturalist ought at all to trouble or busy himself about final causes."[26] The two sects Boyle has in mind are Epicureans and Cartesians. Epicureans "banish the consideration of the ends of things; because the world being, according to them, made by chance, no ends of any thing can be supposed to have been intended."[27]

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[25] Robert Boyle, *The Works of the Honorable Robert Boyle*, ed. Thomas Birch, new edition, 6 vols. (London, 1772; reprinted Hildesheim: Georg Olms, 1966), 392–444. For recent work on Boyle and teleology, see, for starters, Laurence Carlin, "The Importance of Teleology to Boyle's Natural Philosophy," *British Journal for the History of Philosophy* 19:4 (2011): 665–682; James G. Lennox, "Robert Boyle's Defense of Teleological Inference in Experimental Science," *Isis* 74:1 (1983): 38-52; Timothy Shanahan, "Teleological Reasoning in Boyle's Disquisition about Final Causes," in *Robert Boyle Reconsidered*, ed. Michael Hunter (New York: Cambridge University Press, 1994), 177–192.

[26] *Disquisition*, 393.

[27] *Disquisition*, 393.

Cartesians, in contrast, allow that the earth has not been made by chance, but nonetheless "suppose all the ends of God in things corporeal to be so sublime, that it were presumption in man to think his reason can extend to discover them."[28] One sect, Boyle declares, thinks it is "impertinent for us to seek after final causes," the other "presumptuous to think we might find them."[29]

In responding, Boyle draws a distinction between two kinds of teleological reasoning. What he calls *physical reasoning* begins with ends and draws conclusions about the natures of the things that have those ends. In cases of physical reasoning, Boyle tells us, "upon the supposed ends of things men ground arguments, both affirmative and negative, about the peculiar nature of things themselves; and conclude, that this affection of a natural body or part ought to be granted or that to be denied, because by this, and not by that, or by this more than by that, the end, designed by nature, may be best and most conveniently attained."[30] Physical reasoning, in short, moves from the fitness of creatures (or parts of creatures) to conclusions about their natures and ends. Ears are for the sake of hearing, so the tiny bones of the ear must have a function that promotes hearing. What Boyle calls *metaphysical reasoning* begins with the fitness of things to certain ends and draws conclusions concerning God's intentions in creating those beings. In this case, Boyle tells us, "from the uses of things men draw arguments, that relate to the Author of nature, and from the general ends He is supposed to have intended in things corporeal: as when from the manifest usefulness of the eye, and all its parts, to the

[28] *Disquisition*, 393.

[29] *Disquisition*, 393.

[30] *Disquisition*, 420.

function of seeing, men infer, that at the beginning of things the eye was framed by a very intelligent Being, that had a particular care, that animals, especially men, should be furnished with the fittest organ of so necessary a sense as that of sight."[31] Metaphysical reasoning, in short, moves from the fitness of creatures (or parts of creatures) to the divine reasons for their existence. Ears are good for hearing, so God gave us ears for sake of hearing.

Boyle draws a further distinction between two kinds of physical reasoning, namely, positive and negative physical reasoning. He maintains that both are permissible. As an example of a positive physical reasoning, Boyle offers Harvey's own work as an example. Boyle had met Harvey not long before the elder man's death and asked him what had put him on to the idea of the circulation of the blood. On the basis of their conversation, Boyle reports:

> [W]hen he [Harvey] took notice, that the valves in the veins of so many parts of the body were so placed, that they gave free passage to the blood towards the heart, but opposed the passage of the venal blood the contrary way; he was invited to imagine, that so provident a cause as nature had not so placed so many valves, without design; and no design seemed more probable, than that since the blood could not well, because of the interposing valves, be sent by the veins to the limbs, it should be sent through the arteries, and return through the veins, whose valves did not oppose its course that way.[32]

Harvey's report provides Boyle with a prime example of what he sees as positive physical teleological reasoning. On Boyle's rendering, Harvey was led to positively attribute a particular function to the venal valves on the assumption that the human body is well-designed. The venal

[31] *Disquisition*, 420.

[32] *Disquisition*, 427.

valves are so well-suited to directing the flow of blood from the limbs to the heart that it may be surmised that it is indeed the nature of venal valves to have precisely that end. The inference here is from positive suitability to positive purpose.

Boyle also provides an example of negative physical reasoning. Earlier physiologists had supposed that the seat of vision is to be found in the crystalline humor (that is, the lens) of the eye. Boyle suggests that the physiologist Christof Scheiner was able to refute this view by arguing that the crystalline humor is not well suited to perform the requisite functions of the eye and that furthermore the retina is so suited:

> Thus, though anatomical and optical writers, as well as the schools, did for many ages unanimously conclude the crystalline humour to be the principal seat of vision; yet the industrious Scheiner, in his useful tract, intitluled Oculus, does justly enough reject that received opinion, by shewing, that it suits not with the skill and providence of nature, to make that part the seat (or chief organ) of vision, for which it wants divers requisite qualifications, especially most of these being to be found in the retina.[33]

Whereas Harvey had moved from the fitness of the valves to a conclusion concerning their positive function, Scheiner, on Boyle's telling, moves from the lack of fitness of the crystalline humor, and the greater fitness of the retina, to the conclusion that the crystalline humor does not have the function of serving as the seat of vision. Whereas Harvey's inference was from suitability to purpose, Scheiner's inference is from lack of suitability to lack of purpose.

Although Boyle defends physical reasoning at some length, his principal aim in the *Disquisition* is to champion the legitimacy of metaphysical reasoning about ends. In setting out

[33] *Disquisition*, 427.

the conditions under which metaphysical teleological reasoning may be pursued, Boyle distinguishes four kinds of ends. (1) *Universal ends* concern the creation of the universe as a whole. These are, Boyle tells us, the "grand and general ends of the whole world, such as the exercising and displaying the Creator's immense power and admirable wisdom, the communication of his goodness, and the admiration and thanks due to Him from his intelligent creatures, for these his divine excellences, whose productions manifest his glory."[34] (2) *Cosmic ends* concern the movement and apparent design of celestial bodies. These are "ends designed in the number, fabric, placing, and ways of moving the great masses of matter, that, for their bulks or qualities, are considerable parts of the world … so framed and placed, as not only to be capable of persevering in their own present state, but also as was most conducive to the universal ends of the creation, and the good of the whole world, whereof they are notable parts."[35] (3) *Animal ends*, which—as the label suggests—"concern the parts of animals, (and probably plants too) which are those, that the particular parts of animals are destinated to, and for the welfare of the whole animal himself, as he is an entire and distinct system of organized parts, destinated to preserve himself and propagate his species, upon such a theatre (as the land, water, or air) as his structure and circumstances determine him to act his part on."[36] (4) Finally, *human ends* concern the ends of nature occurring specifically for the sake of human beings, that is, the ends "that are aimed at by nature, where she is said to frame animals and vegetables, and other of her

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[34] *Disquisition*, 395-6.

[35] *Disquisition*, 396.

[36] *Disquisition*, 396.

productions, for the use of man."[37] Such human ends, Boyle tells us, may themselves be distinguished into two kinds. On the one side, ends that are for the sake of our minds, that is, ends that increase our awe, wonder, and appreciation of the divine. On the other side, ends that are for the sake of our bodies, that is, ends that contribute to our preservation and propagation.[38]

Boyle maintains that metaphysical reasoning can legitimately be applied with respect to all four kinds of ends. As an example of metaphysical reasoning applied to cosmological ends, Boyle maintains that "the sun, moon, and other celestial bodies, excellently declare the power and glory of God."[39] Boyle's favorite examples of metaphysical reasoning, however, involves animal ends, and in particular the eye. In a characteristic passage, he writes:

> The eye (to single out again that part for an instance) is so little fitted for almost any other use in the body, and is so exquisitely adapted for the use of seeing, and that use is so necessary for the welfare of the animal, that it may well be doubted, whether any considering man can really think, that it was not destinated to that use.[40]

The passage underscores a difference in aim between Harvey's *de motu cordis* and Boyle's *Disquisition*. Although Harvey believes in divine teleology, his principal aim in *de motu cordis* is to establish the ends of bodily parts such as the heart, valves and veins. He aims, for example, to show that the function of the heart is to circulate blood. Boyle, conversely, believes in physical teleology—he agrees that the function of the heart is to circulate blood. His principal aim in the

[37] *Disquisition*, 396.

[38] *Disquisition*, 396.

[39] *Disquisition*, 444.

[40] *Disquisition*, 425.

Disquisition, however, is to defend metaphysical reasoning—to argue, for example, that the eye not only has the function of seeing, but that it was indeed designed in order to see. The divine teleology largely in the background in Harvey's *de motu cordis* takes center stage in Boyle's *Disquisition.*

Boyle's extended defense of metaphysical reasoning may serve as a reminder that the vast majority of the proponents of the new mechanical science saw it as thoroughly consistent with the postulation of divine teleology. It is possible today to imagine the mechanist's universe as an impersonal, autonomous world. A world of billiard-ball-like interactions: the movement of one lifeless part mechanically, efficiently causing the movement of another lifeless part. A world with no need nor place for God. To the early modern mind, however, things were likely to seem very different. The thought of the world as a grand machine—one with obvious efficiencies and countless intricacies—naturally conjured the further thought of a grand designer. If the world is like a wondrous clock, surely there must be a wondrous clock maker. Thus, where we might be tempted to see mechanism as a step in the direction of a secular worldview, early modern naturalists like Boyle were more apt to see it as providing further reason for a providential worldview. For Boyle and his like, religion and science were mutually supportive. Religion leads us to expect a well-designed world with purposes hidden around every corner. Science shows that that expectation is met.

Boyle's defense of final causes goes beyond Harvey's in several respects. It goes beyond it in its focus. Teleology per se is not a topic of Harvey's *de motu cordis*. Harvey's work draws teleological conclusions, but its central topic is the movement of the heart and blood. In contrast, teleology per se is the central topic of Boyle's *Disquisition*. Its central aim is to categorize teleological reasoning and explicitly defend its legitimacy as far as possible. Boyle's work also goes beyond Harvey's in the scope of the teleological reasoning it defends. In *de motu cordis*, Harvey is almost exclusively concerned with the functions of animal parts and organs. As we've seen, Boyle cites Harvey's own work as part of his defense of what he calls physical reasoning, and his favorite examples of teleology similarly involve animal parts and organs. In keeping with his aim of defending teleology per se, however, Boyle offers a much wider range of cases, and moves beyond animal parts and organs to treat universal and cosmological ends as well. Finally, and most importantly, Boyle explicitly defends not just physical reasoning but also what he calls metaphysical reasoning about final causes. The divine teleology that hums in background Harvey's *de motu cordis* becomes a central theme in Boyle's *Disquisition*. Where Harvey generally takes divine teleology for granted, Boyle gives it a rigorous, sustained defense.

6.4. Pierre Louis Maupertuis and Formal Teleology

Born seventy-one years after Boyle, in Saint-Malo France, Pierre Louis Maupertuis rose to become the foremost French proponent of Netwonianism in the eighteenth century. Good, but not brilliant, at mathematics, Maupertuis cultivated his native talents and social position well enough to secure an adjunct position at the Academy of Sciences in Paris in 1723. Thirteen years later, he led a daring expedition to Lapland to verify the Newtonian view that the Earth is flattened at the poles. The wild success of his expedition gained him favor with Frederick the Great, and he was appointed to serve as the president of the Berlin Academy of Sciences from 1745 to 1753. His most daring adventures behind him, and his pioneering work on genetics still ahead, in 1746, Maupertuis published a short work in the *History of the Royal Academy of*

Sciences and Belles Lettres entitled *Les Loix du mouvement et du repos déduites d'un principe metaphysique* (*The Laws of Motion and Rest Deduced from a Metaphysical Principle*, hereafter *The Laws*).[41] He described the piece to Leonard Euler, his colleague at the Berlin Academy, as "a dissertation on final causes and the abuse that some physicists have made of them."[42] It represents yet another surprising twist in the long history of the concept of teleology.

The Laws begins with a critique of earlier attempts to defend final causes. Maupertuis makes a show of not criticizing arguments by figures such as Cicero and Aristotle, "drawn from the beauty, order, and understanding of the universe." Given the science of their time, such historical figures are, in Maupertuis's opinion, "too little acquainted with Nature, to be entitled to

[41] Pierre Maupertuis, "*Les loix du movement et du repos, déduites d'un principe de métaphysique*," in *Histoire de l'Académie Royale des Sciences et Belles-Lettres*, Berlin 1746 [1748], 267–94. For recent work on Maupertuis and teleology, see for starters, J. Christiaan Boudri, *What Was Mechanical about Mechanics? The Concept of Force between Metaphysics and Mechanics from Newton to Lagrange* (Dordrecht: Kluwer, 2002); Helmute Pulte, *Das Prinzip der kleinsten Wirkung und die Kraftkonzeptionen der rationale Meckanik: Eine Untersuchung zur Grudlegungsproblematik bei Leonhard Euler, Pierre Louis oreau de Maupertuis und Joseph Louis Lagrange* (Stuttgart: Franz Steiner Verlag, 1989); Ansgar Lyssy, "L' Économie de la Nature – Maupertuis et Euler sur le Principe de Moindre Action," *Philosophiques* 42:1 (2015): 31–51.

[42] Letter from Maupertuis to Euler, 22 May [1746], *Archives de l'Académie Royale des Sciences*, Paris. Cited in Mary Terrall, *The Man Who Flattened the Earth* (Chicago: Chicago University Press 2002), 270.

admire" it.[43] Instead, Maupertuis sets his sights on the great Newton and the "crowd of physicists, after Newton, [who] have found God in the stars, in insects, in plants, in water."[44] His criticisms focus on two kinds of argument in particular, arguments that Boyle would have identified as metaphysical reasoning about cosmic ends and metaphysical reasoning about animal ends.

As an example of metaphysical reasoning about cosmic ends, Maupertuis highlights an argument suggested by Newton in the "queries" appended to his *Opticks*.[45] According to Maupertuis:

> This great man [Newton] believed that the motions of celestial bodies demonstrate well enough the existence of the One who governs them. Six planets, Mercury, Venus, the Earth, Mars, Jupiter and Saturn, revolve around the Sun. All move in the same direction, and describe nearly concentric orbs: while another species of celestial object, the Comets, describing very different orbits, move in all directions, and roam all regions of the sky. Newton believed that such uniformity could only be the effect of the will of a Supreme Being.[46]

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[43] *The Laws*, 269.

[44] *The Laws*, 270.

[45] See Query 31 in Isaac Newton, *Opticks, or A Treatise on the Reflections, Refractions, Inflections and Colours of Light*, with a forward by Albert Einstein, introduction by Sir Edmund Whittaker and preface by I. Bernard Cohen. Based on the 4th edition, London, 1730 (New York: Dover, 1952).

[46] *The Laws*, 269–270.

The form of the argument is familiar. The movement of the six planets seems too uniform and harmonious to be due to chance alone. The effect appears designed and the most reasonable conclusion is that it is the intended end of a cosmic designer. To this familiar, intuitive argument, Maupertuis adds a touch of mathematical sophistication. Anticipating the feel of contemporary fine-tuning arguments, he suggests that the plane in which the planets move is so narrow that the probability that all the planets should be contained in it is 1,419,856 to 1![47] The implication, of course, is that it is all but certain that the orbits of the planets have a cosmic end.

Maupertuis is willing to concede that, if Newton is right in assuming that "all the celestial bodies attracted towards the Sun, move in the void," then their current trajectories are highly improbable.[48] They are a long shot on a cosmic scale. He pauses to note, however, that even so, the probability of the coincidence is not nil. Even if Newton's assumptions are right, the coincidence of the trajectories of the planets might be due to chance, and so "it cannot be said that this uniformity is the necessary effect of choice."[49] But this is really just skirmishing—a prelude to Maupertuis's main point. For, he asserts, we simply do not know the true physical causes of the uniformity of the motions of the planets. Perhaps Newton is wrong on that front. Perhaps the planets are carried along in fluid vortices, as Descartes had previously suggested. In that case, "the uniformity of their trajectories does not seem inexplicable; it no longer requires this singular chance or choice; and proves no more the existence of God, than would any other

[47] For contemporary versions of the fine-tuning argument, see the essays in Neil Manson, *God and Design: The Teleological Argument and Modern Science* (New York: Routledge, 2003).

[48] *The Laws*, 271.

[49] *The Laws*, 271.

movement imparted to Matter."[50] The odds of the motions of the planets might be a million and half to one given Newton's assumptions. Nonetheless, they might be highly probable, or even necessary, if given their true causes.

Turning from planets to animals, Maupertuis allows that the "argument drawn from the suitability of the different parts of animals with their needs appears to be more solid."[51] Concerning animals, he asks, rhetorically, "are not their feet made for walking, their wings for flying, their eyes for seeing, their mouths for eating, other parts for reproducing their ilk?"[52] Even here, however, Maupertuis is ultimately critical. On defense, he offers clear anticipations of thoughts that would be worked out with much greater care by Darwin in the next century. Maupertuis asks if the following might not be the case:

> Hazard … had produced an innumerable multitude of individuals: a small number were found in such a manner that the parts of the animal could satisfy its wants; in an infinitely greater number, there was neither convenience nor order, all these perished: Animals without mouths could not live, others who lacked organs for generation could not perpetuate themselves; the only ones which have remained, are those in which order and convenience are found."[53]

On offense, Maupertuis takes a different tack, effectively accusing his opponents of cherry-picking their evidence. If the presence of thick skin on the rhinoceros is evidence *for* design, why

[50] *The Laws*, 271.

[51] *The Laws*, 271.

[52] *The Laws*, 271.

[53] *The Laws*, 272.

is its absence on the turtle not evidence *against* design?[54] Maupertuis suggests that we should grant that the serpent's being "covered with a hideous and scaly skin" helps it survive.[55] But how can this fact be admired as evidence of the design of a wise and benevolent creator when the snake's skin seems merely to preserve "an animals whose tooth kills man"?[56] Generalizing in a way that recalls modern-day attacks on the argument from design, Maupertuis concludes that "The evils of all kinds, the disorder, vice, grief" seem as prodigious as their contraries and are "difficult to reconcile with the empire of" "a wise and mighty Being."[57]

Having heaped abuse on his predecessors in the first part of his *The Laws*, Maupertuis turns, in the second part, to a positive defense of teleology rooted in his principle of least action. That principle states, "In collisions of bodies, motion is distributed in such a way that that the quantity of action, once the change has taken place, is as small as possible," and that "in a state of rest, bodies in equilibrium must be situated such that if they are given some small motion, the quantity of action will be a minimum."[58] Maupertuis's principle has the implication, for example, that a ray of sunshine will travel along the quickest path from the sun to a viewer's eye regardless of whether it travels straight through the air, is reflected by a flat mirror, or is refracted by a glass of water. It has the implication that the momentum of two lumps of clay will be the same before and after they collide. It has the implication that the kinetic energy of two

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[54] *The Laws*, 272-273.

[55] *The Laws*, 274.

[56] *The Laws*, 274.

[57] *The Laws*, 275.

[58] *The Laws*, 286.

billiard balls will be the same before and after they collide. It has the implication that two children of different weights will balance on a teeter-totter if they each sit at the right distance from its center. Maupertuis was justly proud of his articulation of the principle of least action. It was a bold and fruitful attempt to unify the laws of physics in a single, exceptionally elegant principle. But how does it lend support to teleological reasoning?

In *The Laws*, Maupertuis suggests that the principle of least action provides a new basis for an argument for divine teleology. As the new science revealed elegant, general laws of nature, it was an irresistible move by devout believers to suggest that those elegant, general laws provide evidence of God's wise design and governance of the world. Just as Boyle infers providential ends from the apparent design of animal parts, Maupertuis would infer providential ends from the elegance of the most basic law of nature. In pursuing this rather well-trodden line of thought, Maupertuis could see his principle of least action as providing two specific advantages over earlier efforts.

First, Maupertuis suggests that the principle of least action provides an improved foundation for supporting divine teleology because his principle far exceeds its rivals in unifying the laws of nature. He argues, for example, that within the domain of physics, his principle surpasses Descartes's laws in grounding accurate rules of collision, and that it surpasses Leibniz's laws in applying to both elastic and inelastic bodies.[59] Indeed, Maupertuis suggests that the principle of least action might be applied to all phenomena with full generality—not only to

[59] *The Laws*, 283–286.

colliding bodies and cases of equilibrium, but also to "the movement of animals, the vegetation of plants, the revolutions of the stars."[60]

Second, Maupertuis suggests that the principle of least action—presumably in contrast to other laws of nature—can be deduced directly "from the attributes of an all-powerful and all-wise being."[61] He doesn't, of course, show how such a deduction would go in detail. Perhaps, however, we can see the grounds for his optimism. Laws such as Galileo's law of falling bodies or Newton's second law of motion are elegant and powerful. But they suggest no intuitive connection in their content to the possible ends of a divine designer. Why should a wise designer seek to make bodies fall with constant acceleration or guarantee that the product of a body's mass and acceleration is directly proportional to the forces to which it subjected? The principle of least action, however, does, at least at a first pass, suggest just such an intuitive link. We can easily imagine that a wise designer would aim for the sort of universal efficiency seemingly promised by the content of Maupertuis's principle of least action.

In *The Laws*, Maupertuis himself thus emphasizes how the principle of least action might lend support to divine teleology—to what Boyle calls *metaphysical* reasoning about ends. But Maupertuis's principle is striking in part because it might also seem to lend support to conjectures about ends falling within nature itself, to what Boyle calls *physical* reasoning about ends. Maupertuis closes *The Laws* by showing how the principle of least action could be applied to a small handful of elementary cases. With his unrivaled mathematical skills, Euler subsequently extended the principle's applications to a much wider range of examples. In doing

[60] *The Laws*, 286

[61] *The Laws*, 279

so, he became convinced that "nothing whatsoever takes place in the universe in which some relation of maximum and minimum [i.e. "least" in Maupertuis's sense] does not appear."[62] In this universal result, Euler saw conclusive evidence of teleology operating within the world itself. By Euler's lights, it is clear that natural phenomena develop in such a way as to realize maxima and minima—they unfold in order to realize determinate outcomes. Those outcomes may be taken to be the ends of the physical processes that lead to them. A ray of light may reflect at such and such an angle in order to travel along the quickest path. Two billiard balls might rebound in such and such a way in order to minimize their overall "action." Euler thus maintains that "there is absolutely no doubt that every effect in the universe can be explained as satisfactorily from final causes, by the aid of the method of maxima and minima, as it can from the efficient causes themselves."[63] This line of thought is distinct from the line attributed to Maupertuis just above. Whereas Maupertuis inferred the existence of divine ends from the principle of least action, Euler infers the existence of ends within nature itself. On Euler's view, it seems, any world governed by the principle of least action would have physical ends even if it were not the product of divine choice. The phenomena of such a world—of a world like ours—would be teleological in the sense that they would come about for the sake of precise, predictable ends. More than 2000 years after Aristotle's *Physics*, we seem to have returned to a kind of immanent teleology.[64]

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[62] Terrall, *The Man Who Flattened the Earth*, 278.

[63] Terrall, *The Man Who Flattened the Earth*, 278

[64] For discussion of Aristotle's views on teleology, see Mariska Leunissen's chapter in this volume.

Maupertuis's defense of final causes is no less ambitious than the defenses offered by Harvey and Boyle. As we've seen, *The Laws* begins with a critical, incisive attack on earlier attempts to defend teleological reasoning in the sciences. Maupertuis is openly dismissive of arguments that seek to support divine teleology by appeal to either cosmological phenomena or the functions of animal parts. Indeed, he even offers a prescient argument for how the apparent design of organisms might come about through a process of blind natural selection. And yet, it is clear that such criticisms are merely a propaedeutic to an even more audacious attempt to defend teleology on the basis of the principle of least action. Maupertuis saw his new principle as providing not only novel foundations for physics and natural philosophy more generally, but also as providing a novel basis for divine teleology. Surely such an elegant and universal principle could only be the product of a wise and benevolent designer. Furthermore, the principle itself suggested to many that teleology must operate within the order of nature. Just as I might go to the store in order to buy milk, or a dog might dig in the backyard to find a bone, so a physical particle might, it seems, follow a particular path in order to minimize or maximize its action. Maupertuis's principle thus held out the promise that a home might be found for teleological reasoning even in the heart of the mathematical physics of the new science.

6.5. Conclusion

Often portrayed as a victim of the scientific revolution, teleology was, in fact, widely upheld by leading figures of early modern science. As we've seen, Harvey championed teleology above all in the domain of biology. There he made a powerful case that the attributions of functions to animal parts and organs could not only be made rigorous but also prove fruitful in the pursuit of scientific discovery. Boyle defended the legitimacy of teleology above all in the domain of natural theology while making a systematic, positive assessment of the place of final causes in the worldview of early modern natural philosophy. Finally, Maupertuis, with Euler's assistance, made a surprisingly powerful pitch for locating teleology at the foundations of physics, setting the stage for novel arguments in support of both providential and natural ends. Despite rumors to the contrary, teleology was alive and well in the early modern period. Reservations expressed by the likes of Bacon, Descartes, and Spinoza converted few at the time, and primarily served to rally others to take up their quills in defense of teleological reasoning.

To say that teleology survived, even flourished, with the new science, however, is not to say that the concept did not evolve during the period. No universal assertions are warranted here. If we restrict ourselves to the English-inspired tradition to which Harvey, Boyle and—to a slightly lesser extent—Maupertuis belonged, two broad, general trends might nonetheless be noted. First, the investigation of final causes became increasingly continuous with the critical methodology of early modern natural philosophy. Harvey, Boyle and Maupertuis all thought that attributions of final causes could not rest with everyday experiences or commonsense. Harvey performed countless dissections, vivisections, and experiments to discover and test the functions he ascribes to animal parts and organs. Boyle cites, often in exhausting detail, studies drawn from throughout the full range of early modern science. Even while championing the legitimacy of final causes against Cartesians and Epicureans, he repeatedly cautions his fellow natural philosophers to shun arrogance, presumption and to "ground all things upon as solid reasons as may be had."[65] Finally, Maupertuis proved willing—even eager—to turn the critical reasoning so indicative of the new science against the teleological claims of his predecessors, even as he sought to provide new foundations for final causes in mathematical physics. Having developed a critical approach to the study of nature, early modern natural philosophers such as Harvey, Boyle and Maupertuis couldn't but help to apply the same standards of reasoning to their investigations of final causes.

Second, within the English-inspired tradition, focus shifted from perennial metaphysical debates surrounding final causes to their explanatory potential. The late scholastic philosopher and theologian Francisco Suárez overlapped with Harvey for almost four decades. A reader of his *Disputationes Metaphysicae* will be treated to discussions of, for example: "Whether the end is a true cause?" "What the nature of causing or the causality of the final cause is or consists in?" "What the proximate nature of causing in the final end is?"[66] Such foundational metaphysical questions are simply absent from Harvey's *de Motu*, Boyle's *Disquisition*, and Maupertuis's *The Laws*. In focusing their attention on whether and how attributions of final causes might be held to the rigors of the new science, the English-inspired tradition by and large simply ceased to discuss—perhaps ceased to worry—about the vast majority of metaphysical questions that had seemed so pressing to scholastic figures such as Suárez. It was progress in the spirit of Newtonian quietism—progress that delivered explanatory payoffs without fussing over their metaphysical foundations. It was also a development that almost begged for someone to make a

[65] *Disquisition*, 399.

[66] Francisco Suárez, *Disputationes Metaphysicae*. 2 vols. Reprint (Hildesheim, Germany: Georg Olms, 2009), Disputation 23.

clean break. That almost begged for someone to explicitly embrace the utility of teleological reasoning while denying that we can have any deep knowledge of the metaphysical basis of teleology itself. Having been raised in the very non-English tradition of Leibnizian metaphysics, Immanuel Kant would awake to that call and— as the next chapter will show—answer it with enormous implications for the historical development of the concept of teleology.

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