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ON THE RELATION BETWEEN SCIENCE AND THE SCIENTIFIC WORLDVIEW

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It has been widely believed since the nineteenth century that modern science provides a serious challenge to religion, but less agreement as to the reason. One main complication is that whenever there has been broad consensus for a scientific theory that challenges traditional religious doctrines, one finds religious believers endorsing the theory or even formulating it. As a result, atheists who argue for the incompatibility of science and religion often go beyond the religious implications of individual scientific theories, arguing that the sciences taken together provide a comprehensive challenge to religious belief. Scientific theories, on this view, can be integrated to form a general vision of humans and our place in nature, one that excludes the existence of supernatural phenomena to which many religious traditions refer. The most common name given to this general vision is the scientific worldview.

The purpose of my paper is to argue that the relation of a worldview to science is more complex and ambiguous than this position allows, drawing upon recent work in the history and philosophy of science. While there are other ways to complicate the picture, this paper will focus on differing views that scientists and philosophers have on the proper scope and limits of scientific inquiry. I will identify two different types of science – Baconian and Cartesian – that have different ambitions with respect to scientific theories, and thus different answers about the possibility of a scientific worldview. The paper will conclude by showing how their differing intuitions about scientific inquiry are evident in contemporary debates about reductionism, drawing upon the work of two physicists, Steven Weinberg and John Polkinghorne. History is more complex than this simple schema allows, of course, but these types provide a useful first approximation into the ambiguities of modern science.

I. CARTESIAN SCIENCE

Francis Bacon (1561–1626) and Rene Descartes (1596–1650) were among the earliest and most eloquent advocates of new strategies for gaining knowledge of nature and both have often been celebrated by proponents of the Scientific Revolution. For example, Jean le Rond d'Alembert in his entry on 'Experimental' in the famous *Encyclopedie* said that Bacon and Descartes put an end to the 'vague and obscure method of philosophizing' that was characteristic of Aristotelianism.[1] Contemporary accounts of scientific methodology often take as a starting point the work of the 'two greatest philosophers of the scientific revolution'.[2] A prominent view was that they laid down the novel methods of the new science, whereas Galileo and Newton put their methods into practice.[3] Whether or not their work deserves all the adulation that has been attributed to them, I will argue that both of their basic positions are evident in modern science, even though they cannot be easily reconciled. In order to facilitate a comparison between their views, I will identify three central characteristics of each. I identify them as Cartesian and Baconian positions, respectively, because my description also reflects the way their immediate followers appropriated their work.

In contemporary philosophy classrooms and textbooks, Descartes is most known for his method of bridging the gap that unmitigated skepticism opens between the mind and the world. He is confident that we can know that our ideas represent a world external to the mind because the belief in one's personal existence and the existence and goodness of God survive radical doubt. As recent historians have shown, however, this reading of Descartes as an epistemologist focused on method must be subordinated to Descartes the natural philosopher.[4] Placed in his historical context, Descartes was offering nothing less than a system of the world, one meant to replace the scholastic system of Aristotelianism. Descartes' cosmological system provided the first complete alternative to that of Aristotle.[5] The eager use of natural philosophical reasoning for constructing a worldview is the first and central characteristic of Cartesian science. The goal of the study of nature is to provide an integrated picture of nature and its relation to humankind.

Descartes' ambition is hardly novel in the Western tradition. Aristotle's work framed debates about the natural world from the rediscovery of his texts at the end of the twelfth century until the seventeenth, the traditional date given for the start of the scientific revolution. One attractive feature of Aristotle's natural philosophy was that nothing in the natural world escaped its explanatory grasp.[6] But this virtue became a vice as one rejected explanation implied another. For instance, Tycho Brahe observed comets in the superlunary realm, which indicated it was subject to change and corruption. Galileo's science of motion made it impossible to infer the nature of a body from its motions, which made Aristotle's essentialist method of explanation problematic.[7] Faced with such difficulties, the options were to either mend the standard Aristotelian model or to articulate an alternative natural philosophy that could better accommodate new discoveries. The major new natural philosophy of the seventeenth century became known, following Robert Boyle, as the 'mechanical philosophy' and Rene Descartes offered one of the most influential versions of it.[8]

The features of Descartes' system of the world are best explained with reference to the second characteristic of Cartesian science: confidence in the adequacy of theoretical reason to discern the hidden structure of reality, even when one's explanations are at variance with everyday experience. A common characteristic of the various mechanical philosophies in the seventeenth century is the reformulation of what counts as a proper explanation, which reflects new ontological assumptions. Because there is only one kind of matter underlying physical processes, phenomena were to be explained in terms of the discipline of mechanics: the shape, size, quantity, and motion of particles of matter.[9]

In Aristotelian natural philosophy, matter never occurs without form and form endows objects with their essential nature.[10] Living things have particular forms that separate them from nonliving things and even plants show life in that they can grow and generate. Humans share forms with plants and animals, but also have a rational part of the soul that allows them to make judgments and have volitions. Because there is an entire hierarchy of forms between mutable prime matter and the immutable, the job of an Aristotelian natural philosopher is to classify, to understand a particular form's place on the scale of being.[11] The assumed heterogeneity of nature, along with Aristotle's robust notion of causality, gave medieval natural philosophers wide latitude in accounting for their sense experience.

By contrast, Cartesians reject all explanations for natural phenomena that do not fit with their explanatory principles.[12] This restriction had dramatic consequences for natural inquiry. What for the Aristotelian scholastic were real qualities of the world became merely secondary qualities, or effects of the particles on the senses, thus expunging properties associated with the mind from nature. Though animals may show the outward manifestations of being in pain, only those creatures with a soul can have the mental experiences associated with it. The actions of one's pet are not, in principle, different from the action of a magnet. Many natural philosophers found mechanistic explanations so intuitive that it became the dominant system of nature in the early modern period despite its puzzling consequences for the biological realm. Micromechanical accounts of reality, it was believed, should take precedence over common experience because the latter is not a reliable guide for how the world really is.[13]

The final characteristic of Cartesian science is the aspiration for scientific explanations that are timeless, universal, and necessarily certain, and so in general tend to prefer mathematical explanations for natural phenomena. In Aristotelian natural philosophy, explanation was couched in terms of local causes; the job of the medieval natural philosopher was to discern the particular essence of the phenomenon in question. Moreover, mathematics was seen as unhelpful for discerning the essential nature of objects, for it substitutes abstract mathematical models in place of nature itself. The general Aristotelian position was that the study of nature cannot be pursued mathematically, just as the study of mathematics cannot be pursued through physical means.[14] Mathematical practitioners in medieval Europe were thus seen as a craft tradition; they were useful for making calendars and predicting planet orbits, but not helpful for explaining nature.[15]

Once a Cartesian conception of matter is accepted, by contrast, it has direct consequences for how to study the natural world, including that mechanical philosophers had theoretical justification for applying mathematical reasoning directly to the natural world. Because Descartes confined the properties of matter to quantitative attributes like weight and velocity, he argued against the Aristotelian demarcation between natural philosophy and mathematics, calling his area of inquiry: 'physico-mathematics.'[16] In practice, Descartes' approach was to offer a macroscopic geometrical account, and then attempt to redescribe it in terms of an underlying micro-corpuscular picture of physical behavior. If matter is extended in three dimensions, Descartes believed that physics can be reduced to geometry, and thus physics can have the same deductive certainty.[17]

Despite Descartes' mathematical ability, his ambitions for a fully-realized mathematical system of nature remained well beyond his reach. He was unable to provide the same type of mathematical formulas for nature as Galileo, Christian Huygens, or Newton did and often settled for hypothetical explanations about underlying mechanisms.[18] Nevertheless, the ambition for a complete quantitative natural philosophy shaped many mechanist projects in the seventeenth century, though many questions remained about the relevance of the practical-mathematical tradition for natural-philosophical enquiry.[19] Eventually, the mechanical philosophy was replaced by what might be called the 'mathematical philosophy' for many scientists, in which finding the equations that control phenomenon is considered the real goal of science.[20] The open question is now, as I discuss below, whether mathematics can provide a complete and exhaustive account of the physical world, and Cartesian scientists answer in the affirmative.

In summary, an advocate of Cartesian science wants to construct a system of the world, has confidence in theoretical reason along with a tightly constrained view about what counts as a proper scientific explanation, and desires universal explanations of nature. An advocate of Baconian science, I will argue, differs on each of these three points.

II. BACONIAN SCIENCE

One of the most significant developments in the early modern period was a restructuring of natural philosophy into an enterprise centered on usefulness of natural knowledge, overcoming the separation of theoretical and practical knowledge that had characterized its Aristotelian predecessor.[21] Francis Bacon was a key figure in the transition because he forcefully articulated a broad new vision for a natural philosophy that emphasized the practical utility of natural knowledge. Bacon's vision for natural philosophy became popular after his death and provided the ideology for new movements and emerging scientific academies. Above all, it was the English Royal Society that tried most to put his vision into practice, albeit with modifications.

The first characteristic of Baconian science is, as just mentioned, that scientific knowledge should provide one with direct control over natural processes. Natural philosophers should not sit back and contemplate the system of nature but actively try to interfere with it in order to find applications that might benefit humanity.[22] Bacon went so far as to deny that there could be knowledge for its own sake, or truth that does not result in action. He argued, 'In religion we are taught that faith is shown by works; and the same principle is well applied to a philosophy, that it be judged by its fruits and, if sterile, held useless'.[23] In other words, the way to judge whether something is true is whether it yields operative knowledge of nature. The 'experimental philosophy' of the Royal Society reflects the Baconian belief that the study of nature cannot be conducted from an armchair but requires experimental interventions to discern its workings.

A second characteristic of the Baconian approach to natural inquiry was a skeptical attitude towards theorizing because it blinds you to the obvious features of everyday experience. Bacon argued that the philosophy of the medieval schoolmen had an over-optimistic view of human nature, for the mind itself is prone to 'idols' through its tendency to anthropomorphize nature, become enslaved to systems of thought, and be misled by language.[24] The mind, no less than the heart, creates graven images of its own imagination in order to satisfy its own wicked desires. The problem with idolatry is not merely that one is mistaken in the object of worship, but also that idols cause their worshipers to cease their quest for the true object of worship.[25] Members of the Royal Society embraced Bacon on this point and consequently tended to eschew large-scale theories and speculations about worldview in favor of close examinations of discrete, historical events. Instead of offering universal generalizations for what must happen, they focused on what had happened in particular cases so as to avoid premature system building, metaphysical speculation, and the like. In this way, English experimentalists tried to restrict natural inquiry to those matters upon which there could be consensual inquiry, respecting the limits of human noetic abilities.[26] The experimental philosophy was an anti-systematic philosophy, one that wanted to avoid the mistake of bending reality to fit a theory of matter, for example.

Skepticism towards theory and an ambition to control nature inserted a strong pragmatic and experimental emphasis into natural inquiry. Western natural philosophers had typically shunned craft practitioners because they were said to force natural bodies into artificial motions, creating a social space between those taught in universities and manual laborers who 'got their hands dirty.' Seventeenth-century English natural philosophers began instead to advocate an experimental approach to the study of nature, emphasizing first-hand experience over reliance upon authoritative textbooks. A reorientation of the role of usefulness in discovering truth in turn led other disciplines, such as alchemy, natural magic, and medicine to slowly become assimilated into the field of natural philosophy. By tracing the effects of a new conception of useful knowledge on medieval natural philosophy, historians have helped to reveal the complex interface between theoretical and experimental practices in the Scientific Revolution.[27]

A final characteristic of Baconian science is the reliance upon particular experiences when making knowledge claims. Adaption of Baconian skepticism towards theorizing by the Royal Society led to its preoccupation with gathering 'matters of fact'. The legal system offered a promising way forward for English empiricists who wanted to show how the abandonment of the goal of certain knowledge does not lead to skepticism, for it taught that facts could be established with a high degree of certitude by witness testimony.[28] The members of the Royal Society promoted a philosophy that preferred facts over hypotheses, the former of which are adequately witnessed and theory-neutral statements of natural events, whereas the latter was conjecture, even if well-founded. After establishing the requisite number of facts, one might infer a general statement ('axiom') built upon those experimental particulars.[29]

The Royal Society's emphasis on the particulars of experience meant that mathematics was not always seen to have a place in natural inquiry. Royal Society members had a characteristic approach: members reported events that happened in particular times and places, explicitly avoiding generalizations about the course of nature.[30] Consequently, when Isaac Newton presented his famous papers on Optics in the *Philosophical Transactions*, he went out of his way to make it appear non-mathematical.[31] Newton did not include any geometrical diagrams in the preliminary discussion of the experiments, adapting to the historical form that his audience would expect. Only later would mathematics become a legitimate part of the Baconian enterprise because it effectively led to the control and prediction of natural phenomenon, even while many remained skeptical that mathematics could fully explain nature.

In summary, the Baconian tradition is characterized by its emphasis on experimental work, its concern for the particular over the general, and its avoidance of speculative hypotheses. It is more pragmatic when compared to its Cartesian rival: science should focus most on those domains that might prove useful for human existence, while always retaining a certain modesty about what we do not and cannot know.

III. THE AMBIGUITIES OF MODERN SCIENCE

The remaining portion of the paper will argue that these two types of scientific inquiry are evident in contemporary debates about science and its implications for religious belief. I will do this by comparing the work of two scientists, Steven Weinberg and John Polkinghorne. They were chosen because they are both particle physicists and both have worked hard to understand and convey the philosophical implications of their discipline to the wider public. They illustrate that the tension between Cartesian and Baconian science can be found at the core of modern science and often underlie disputes over reductionism.

Steven Weinberg

Weinberg won the Nobel Prize for Physics in 1979 and has published over 300 articles and numerous books on particle physics. Moreover, through popular books, lectures, and articles in magazines such as the *New York Review of Books*, he has gained the status as a public intellectual.

Weinberg fits quite neatly into the category of a Cartesian scientist, as set forth above. For one reason, he accepts the restricted explanatory principles of the mechanical philosophy, and so labels himself a reductionist. As we discover more about the universe, he says, we find that all scientific explanations flow downward in levels of nature, until at last we reach the bottom. Sciences such as biology, chemistry, and psychology will be shown to rest on the deeper laws of particle physics, even if they operate relatively independently today because of our relative lack of knowledge. Of course, Weinberg would wish to modify aspects of Descartes' mechanical philosophy in light of current knowledge, not least because of the quantum revolution in twentieth-century physics. Nevertheless, Weinberg says that even after the rise of quantum mechanics, 'there is still a sense in which the behavior of any physical system is completely determined by its initial conditions and the laws of nature'.[32] True to the Cartesian legacy, Weinberg is confident that laws that apply to the micro-world can explain the macro-world in its entirety, even if we currently lack any way to make good on such a claim.

Weinberg also accepts the Cartesian ideal that a complete science should provide explanations that are universal and timeless. He has written at length of his belief that scientists should strive for and will likely obtain a 'final theory', a theory of 'unlimited validity and entirely satisfying in its completeness and consistency.'[33] Such a theory would consist of the complete laws of nature, the fundamental principles that govern natural phenomenon and apply everywhere and throughout time. A final theory would not end scientific research; it would only end the search for principles that cannot be explained in terms of deeper principles. He says it is this dream, which started with the ancient Greeks, that inspires much work in high-energy physics.

Finally, Weinberg champions the Cartesian view that it is possible to establish a system of the world, or worldview, using science alone. The success of science and the universal scope of its claims allow one to draw religious conclusions from scientific theories. He has written: 'One of the great achievements of science has been, if not to make it impossible for intelligent people to be religious, then at least to make it possible for them not to be religious.'[34] The primary reason that science undercuts religious belief is that the latter was often invoked to explain earthquakes, diseases, etc., phenomena that no longer seem so mysterious. Moreover, he believes science casts doubt on the special role of humankind in creation.

Weinberg recognizes that the 'worldview of science' is 'chilling'. There is no objective basis for our moral actions, no deeper purpose for the existence of humanity, and the whole universe seems 'pointless'. Science shows us that 'the emotions that we most treasure, our love for our wives and husbands and children, are made possible by chemical processes in our brains that are what they are as a result of natural selection acting on chance mutations over millions of years'.[35] The only redeemable aspect of our experience is that we, because of scientific discoveries, can know the truth of our predicament. The Cartesian system of nature, shorn of its references to supernatural realities, is at once both an object of scientific awe and existential fear.

John Polkinghorne

Polkinghorne also has had a distinguished career as a scientist, being a Fellow of the Royal Society and former chair in mathematical physics at Cambridge University. He is most widely known these days for his second career: he is an ordained Anglican priest who has published numerous books on the relationship between Christianity and science.

Using the criterion outlined above, Polkinghorne is an advocate of Baconian science. Polkinghorne, for example, argues that science has consistently revealed the limits of theoretical reason. The most consistent way that Polkinghorne characterizes his own approach is as a bottom-up thinker; a habit of thought that he says is a 'natural stance for a scientist to adapt'.[36] A bottom-up thinker, says Polkinghorne, starts first with experimental data before moving to theory. Because reality is abundantly more surprising that we are able to imagine, we should recognize the inherent limits on our ability to rationally deduce the way things must be. Scientific education, he says, produces a certain cautiousness that other forms of inquiry would be wise to embrace.[37]

The cautiousness that Polkinghorne attributes to bottom-up thinking flows directly from his experience with experimental science. Because scientists spend most of their time trying to extend and develop models to cover new domains, they are keenly aware of the way that even the best models fall short. Science is a tough and frustrating process, where much of laboratory work bears little tangible results. Polkinghorne thus says, 'Philosophers find it difficult to recognize how resistant nature is to yielding up its secrets, how very hard it is to discover a theory possessing economy, plausibility, and widespread empirical adequacy.'[38] When philosophers focus on the implications of scientific theories in isolation from their use in the laboratory, they often miss or underplay their known limitations when applied to the real world.

The second characteristic of Baconian science that Polkinghorne endorses is recognition of the importance of the particular in scientific knowledge. This emphasis comes from the work of Polkinghorne's favorite philosopher of science, Michael Polanyi, who has most clearly shown the important role of tacit knowledge in scientific inquiry. Whereas philosophers of science have typically stressed the objective elements to scientific work, Polanyi argued that these capacities depended crucially on the more basic abilities of a trained observer to assess the situation. As Polkinghorne summarizes his view: 'Polanyi's central thesis is that. . .Scientific knowledge is *personal* knowledge, because it is inescapably based on acts of personal judgement and its pursuit requires a personal commitment to a point of view, even though scientific corrigibility means that that point of view could conceivably be false.'[39] Scientists are not passive observers of nature, but rather have undergone intensive training that allows them to make complex discriminations at all levels of the scientific process: which problems and observations are significant, which theories are relevant, and how to employ a multitude of instruments in a satisfactory manner. Without the existence of this personal dimension, which is easy for outsiders to miss because it is difficult to convey in words, science would be impossible. One must always be careful in abstracting knowledge too quickly from their source because scientific ideas have their most salient contact with reality through their connection with particular persons.

The final characteristic of Baconian science that Polkinghorne affirms is that proper science cannot provide a system of the world, or worldview. A bottom-up thinker recognizes the multi-level character of the world in human experience, that there are many windows 'through which we may look out onto the world of which we are inhabitants'.[40] There can be no complete representation of reality, no Archimedean points from which reality can be surveyed with complete neutrality.[41] Despite the remarkable successes of particle physics, for example, it would be both imperialistic and wrong to think that it could incorporate the perspectives of other disciplines into a 'Theory of Everything'.[42] Tidy schemes that oversimplify the complexities of our reality are simply not of any value, and so a bottom-up thinker values piecemeal achievements in science over the ambitions of global theories of knowledge.[43] Scientists should be seen as something like cartographers, producing true and useful representations of a complex and often hidden landscape, without imagining that their maps are exhaustive or complete. Science offers a perspective that must be taken seriously, while recognizing its inherent limitations. This philosophy is what has guided Polkinghorne's work in science and religion: Baconian science can inform your worldview, but it cannot become your worldview.

IV. CONCLUSION

In conclusion, a description of the differing perspectives of Baconian and Cartesian science helps one to better understand debates over the scientific worldview. From the beginnings of early modern science there has been uncertainty concerning the proper limits and scope of scientific theories, which I illustrated by comparing two traditions of science that developed in the Scientific Revolution. The Cartesian tradition offered a sweeping mechanistic philosophy of nature, full of inert particles that can be mathematically described with perfect precision. The Baconian tradition (as realized in the English Royal Society) eschewed large- scale theories and speculations about worldview in favor of close examinations of discrete, historical events.

Both traditions make valid points about the process of scientific inquiry. The anti-worldview orientation of Baconian philosophy of science more closely resembles the *modus operandi* of many types of science. Because science is now a professionalized activity that requires extensive training over narrow domains, most scientists do not have the luxury to engage in philosophical system-building. The governments and companies that fund most of science want more tangible results than philosophy provides. As Steven Shapin says, 'The conceptual unification of all the sciences on a hard and rigorous base of materialist reductionism . . . may be somebody's dream, but it's hardly anybody's work'.[44]

Nevertheless, there is a continual demand to understand the implications of science for nature and human existence. This is why scientific popularizers like Weinberg and Richard Dawkins are in demand, for they, like Descartes, offer a complete system of nature that answers the questions of human existence. Nevertheless, as soon as one sets forth a candidate for the scientific worldview, one can raise legitimate questions as to whether he or she is substituting their own religious or philosophical interpretation of nature for a scientific one, stepping into the realm of speculative hypotheses and away from matters of fact. That these debates about the proper scope of scientific inquiry remain unsettled after three hundred years suggests that debates on the topic of 'science and religion' have a long future.

Notes

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