The Place of Religion within Philosophy of Science: An Exploration and Assessment

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Introduction

The relationship between science and religion is one of the more contentious topics in contemporary philosophy. Much has been written and suggested within both philosophy of science and philosophy of religion concerning the best way to relate the two fields. One possibility is that the two fields are simply separate and have nothing to say to one another. Stephen Jay Gould has referred to this as non-overlapping magisteria (NOMA), which he describes in this way:

> The net, or magisterium, of science covers the empirical realm: what is the universe made of (fact) and why does it work this way (theory). The magisterium of religion extends over questions of ultimate meaning and moral value. These two magisteria do not overlap. . .[1]

Two additional views which conceive of the fields as independent from one another are existentialism and the notion of science and religion as separate "language games."[2] Existentialism draws a sharp distinction between the subjective and the objective, with religion being in the realm of the subjective and impressionable, while science is the province of the objective and rational. As described by Wittgenstein and other linguistic analysts, "language games" are fields or areas of study or interaction which can be identified according to the linguistic rules which they follow. In this analysis, the language game of science would be concerned with precise descriptions of phenomena and events related to the natural world and understood empirically, while the language

[1] Stephen Jay Gould; *Rocks of Ages: Science and Religion in the Fullness of Life*; New York: Ballantine; 1999, as cited in Richard Dawkins; *The God Delusion*; New York: Houghton Mifflin; 2006, p 55

[2] Ian G. Barbour; *Religion and Science: Historical and Contemporary Issues*; New York: HarperCollins; 1997, pp 85-89

game of religion is concerned with personal relationships to life and God or ultimate reality and the meanings to be found therein. While the two language games may share vocabulary, the meanings assigned to the words differ from one language game to the next, which makes communication between the two language games difficult or impossible.

These positions are largely unsatisfactory, however. Although religion is clearly concerned with issues that go beyond the empirical questions dealt with by science, it is unrealistic to say that religious thought does not need to take into account information about how we relate to the world provided by science. While science itself may strive to be objective in its description of the universe and processes around us, that objectivity does not of necessity mean that the universe and its processes are devoid of meaning. And while science as a discipline needs to be guided by rationality, it is nonetheless practiced by human beings, who may welcome insights from religion as guidance in regards to how they practice that discipline.

Although a great deal has been written by scientists, philosophers, and theologians concerning the impact of science on religion, and many theologians have attempted to show how religion can speak to science, little attention seems to have been paid to whether or not a religious proposition can ever be adopted as a scientific premise. In this paper I will seek to determine what room, if any, science may allow for ideas from the field of religion. I will begin by discussing logical positivism, the philosophical position most laypersons and many scientists associate with science, if they think of philosophy of science at all. From there I will look at questions which have been raised

about the approach of logical positivism, and go on to examine where religion might fit into the field of science. The work of Stephen Toulmin, Thomas Kuhn, and Paul Feyerabend, all scientists and philosophers of science, reveals some of the weaknesses of logical positivism, and begins to suggest where science may relate to other fields. Holmes Rolston III, a scientist, philosopher of science and theologian, and Nancey Murphy, a philosopher of science and philosopher of religion, have both suggested that religion itself is a science. Paul Davies is a scientist who has suggested that scientific knowledge points to the existence of a god or ultimate reality.[3] Finally, I will look at the work of Arthur Peacocke and John Polkinghorne, two scientists and theologians who have tried to construct theologies in which the description of God is shaped by a scientific understanding of how the universe works. The work of all these scientists, philosophers, and theologians suggests that there remains a lack of clarity about exactly what is and is not a science, and that the resolution of that question may leave some small space for religious ideas to be regarded as scientific propositions. Even if a clear line can be drawn marking the limits of science, science itself cannot be isolated from other fields of intellectual inquiry, and the effect of those fields on science marks a second place in which religion can influence science, even if that influence is indirect.

[3] Throughout this paper I will use the terms God, god, and ultimate reality in referring to the central proposition of most religions: the existence of some deity or force larger than the normal forces of the universe which exercises some degree of influence or control on a universal scale. I will use God when referring to the concept of a personal deity as is usually described within western monotheism. I will use god when the deity being referred to is less personal, but still seen as possessing unique attributes which are independent of the universe, at least to a degree. The term ultimate reality refers to an impersonal force which is seen as integral to the universe, but which does not have an independent relationship with the universe, as is often found in eastern traditions. In describing my own ideas and thoughts I generally have used the phrase "God or ultimate reality;" when describing the ideas of other scholars I have tried to use either their own terminology or have selected the term which seems to best represent their views from the three terms described above.

Logical Positivism

As mentioned above, logical positivism is the philosophical position most people, including many scientists, associate with science. Logical positivism seeks to describe the natural world (and sometimes human societies) as consisting of systems which are governed by facts, laws, and theories.[4] Facts are events and pieces of information about the world around us which can be obtained through observation. Observation in science refers not just to things that can be experienced or confirmed with the senses but also to events and information which can be measured or otherwise quantified. Facts also are subject to confirmation through additional observation and especially through experiments. Knowledge of facts is used to make predictions, formulate laws, and create hypotheses and theories which account for facts, laws, and the relationships those facts and laws have with one another. In short, science is empirically based, according to logical positivism. It should be noted, however, that the stereotypic idea of a scientist as someone in a long white lab coat mixing chemicals in a laboratory somewhere hardly encompasses all of science, and most of the logical positivists take pains to make this clear.

Confirmation or corroboration of facts is extremely important to logical positivism, and it should be noted that the more general or all-encompassing a fact is, the

[4] This description of logical positivism is based on Rudolph Carnap, *Philosophical Foundations of Physics: An Introduction to the Philosophy of Science*; New York: Basic Books; 1966 as excerpted in Timothy McGrew, Marc Alspector-Kelly and Fritz Allhoff, eds.; *Philosophy of Science: An Historical Anthology*; Malen, MA: Wiley-Blackwell; 2009, pp 329-43; Carl Hempel; *Philosophy of Natural Science*; Upper Saddle River, NJ: Prentice-Hall; 1966; and Karl Popper; *The Logic of Scientific Discovery*; London: Routledge; 2002

more difficult it is to confirm or corroborate. For instance, the statement or fact "Some swans are white," is very easy to confirm – one needs only locate two or more white swans. However, this fact would be of little use to logical positivists, since it does not offer much specific information about the next swan we may see – that swan could be either white or any other color and still agree with the fact. On the other hand, the general statement or fact that "All swans are white" is very difficult to confirm – a single black (or any other color that is not white) swan demonstrates that the fact is false. In order to confirm the fact, we really would need to survey all the swans in existence and verify that all were, in fact, white. Because of this, many logical positivists think of the process of confirming or corroborating a fact as an attempt to prove it false. Karl Popper views all of science as consisting of the effort to prove facts and theories false, requiring that any valid scientific fact or theory be constructed in such a way that it is falsifiable (can be demonstrated to be false). Another way of presenting the fact about swans would be to say "All swans which have been observed until now are white," but this is again of limited use to science, since it fails to say much about the swans we have not observed. After observing a great many swans, we might feel confident to state the fact as "All swans are white," thus making a universal prediction about the nature of swans. Notice that the statement is also falsifiable. (And in fact has been proven false by the existence of black swans in Australia.)

Laws are used to explain facts and to make predictions of facts which have not yet been observed. It should be noted that laws generally apply to facts that go beyond those obtained through simple empirical observations like the facts about swans used in the

description above. Laws are used to explain facts gained through experimentation, such as the speed at which a falling body will accelerate, not just simple observations. Laws can be modified or discarded if additional information shows that the law does not adequately account for all the circumstances to which it can be applied.

A theory is a system which encompasses a number of laws and their associated facts and is used to explain why those laws and facts work together the way that they do. Again, the greater the number of laws and facts encompassed by the theory, the greater the value it has to science. Theories, like laws, are used to predict what will occur in events and circumstances of which we do not yet have direct knowledge. Like laws, they are subject to confirmation and corroboration, and are vulnerable to falsification. Theories are rarely accepted as factual, they are simply regarded as confirmed or corroborated to a greater or lesser degree. The more instances have been located, or the more experiments carried out which match the predictions of the theory, the greater the degree to which the theory can be regarded as confirmed.

Most logical positivists have felt that one begins with facts and laws and examines and tests them carefully, eventually arriving at a hypothesis – an explanation for the facts and laws. A hypothesis, once confirmed or corroborated strongly enough, may become a theory, which will gain a general acceptance throughout one's field of science as the explanation of the set of facts and laws. Popper, however, suggested that it is more appropriate to propose a hypothesis early on, and then to look for facts and experiments which might be used to attempt to falsify the hypothesis. Once the

hypothesis has stood up to enough facts and experiments and is shown to be a valid explanation of the circumstances, it may be accepted as a theory, although it can never be conclusively confirmed or corroborated.

This approach is also referred to as "hypothetico-deductive" since one is forming a hypothesis based on deductions made from facts gathered through observation and experimentation. A key assumption being made by this approach is that the universe *is* intelligible. The basis of science is the belief that we can, in fact, explain how the universe works. This presupposes that facts are consistent throughout the universe, and can be explained by laws and theories. Thus, if the facts we obtain through observation and experimentation are inconsistent with one another or with our laws and theories, the assumption is that something is wrong with the laws and theories. The solution is to continue to gather information until we are able to modify the law or theory in a way that is consistent with the facts we have obtained or until we can formulate a new law or theory to replace the one which is no longer adequate. If we were to allow for the possibility that the universe itself may simply not be consistent, and that relationships and events are random and without cause, science itself would collapse. If the universe is unintelligible, no consistent explanation of events and relationships in the physical world is possible.

On the other hand, if the universe *is* intelligible (and there seems to be no reason to think it is not), the possibility is raised that science may ultimately be capable of explaining everything which happens in the universe. Science should be capable of producing a theory which would explain all behaviors on all levels of physical existence

in a way which is consistent across all the disciplines of science. Such a unifying theory of everything is currently the focus of a number of physicists, and is an important influence on the work of Paul Davies to be discussed below. Logical positivism, then, seeks to describe all that we know, and eventually all that we can know, in a consistent, intelligible fashion.

At this point, a word should be said about reductionism. Reductionism is the philosophical belief that all events on a certain level can be explained by events and relationships at a lower level, and thus reduced to the simplest level possible. It is often associated with science, particularly with a logical positivist approach to science. When a scientist such as Richard Dawkins suggests that all of biological behavior, including human behavior, can be understood by the interactions of our genes and our body chemistry, he is taking a reductionist approach to biology in which activity on the biological level is reduced to causes on the chemical level. While a reductionist approach is clearly compatible with logical positivism, logical positivism does not require that all of science be reduced to the simplest levels; rather, it is looking for a consistent explanation of empirical data. Reductionism will be discussed further in the conclusion of this paper.

Stephen Toulmin

We may now turn to the question of whether or not logical positivism represents the fullest or best approach to science by looking at the work of some philosophers of science who have questioned the assumptions of logical positivism, beginning with

Stephen Toulmin. Toulmin disputes the logical positivists' emphasis on the role of prediction (which he calls "the 'predictivist' account") in the purpose of science. In his exploration of the purpose of science, *Foresight and Understanding*, Toulmin argues that the focus of science is in explaining particular phenomenon, especially in a way that is consistent across broad fields of knowledge.[5] The goal of science is to provide the best explanation for sets of facts – prediction and confirmation are only a part of that purpose. Agreeing with Popper, Toulmin believes there is much more to science than simply describing natural phenomenon and then confirming or falsifying that description. Toulmin believes that individual and corporate beliefs about the nature of what is being studied play an important role in the way science is carried out, suggesting that many of the great advances in science have occurred when a scientist or group of scientists have rethought an idea or assumption which was already widely accepted. Toulmin offers Copernicus' description of the solar system and Galileo's and Newton's revisions of the understanding of motion as examples of new ideas which replaced older established understandings in order to allow science to better explain facts and observations.[6]

Where logical positivism suggests that scientific knowledge is gained through a rather basic accumulation of facts and observations which lead to falsifiable hypotheses and theories, Toulmin believes there is no final account to be given of the aims of science. Those aims are partly arrived at by the goals and motivations of scientists themselves, and so they shift as new scientists enter the field and develop new methods,

[5] Stephen Toulmin; *Foresight and Understanding: An Enquiry into the Aims of Science*; Indiana: Indiana University Press; 1961

[6] *Ibid.*, pp 39-42, 53-58

approaches, and explanations.[7] Toulmin compares scientific knowledge to the evolution of plant and animal species: as new ideas and explanations arrive, they replace older understandings – good scientific explanations adapt and survive, while inadequate explanations are discarded.[8]

Thomas Kuhn

Logical positivism believes that scientific hypotheses and theories are shaped by a largely accurate understanding of nature obtained through the accumulation of data and observation. It also assumes that scientific progress proceeds at a fairly constant and steady rate as data is accumulated, questions are asked, hypotheses are formulated, tested, and corroborated or falsified, modified, and ultimately integrated into theories. Thomas Kuhn calls both these beliefs into question in *The Structure of Scientific Revolutions*.

Kuhn suggests that much of science takes place in periods of what he calls "normal science," which are times when all of the scientists in a given field are operating under the same paradigm – a shared understanding of the systems and theories of that particular field of science.[9] During normal science, much of what is being done is testing and confirmation of how the existing paradigm works in an effort to extend the reach of the paradigm. As this takes place, various anomalies – questions or situations which cannot be answered or explained under the paradigm -- arise. At first, these generally get noted and pushed aside as problems to be returned to later. Eventually, however, the

[7] *Ibid*., p 15
[8] *Ibid*., pp 113ff
[9] Thomas S. Kuhn; *The Structure of Scientific Revolutions*, 3rd Edition; Chicago: University of Chicago Press; 1996 I know, I know . . . we're not supposed to reference Kuhn!

anomalies become so great that they require the attention and energy of more and more of the scientists within the field.

At some point a new paradigm arises. The new paradigm represents a new way of looking at and understanding basic principles within that field of science and generally results in the revision or replacement of most of the theories and hypotheses in the field. The new paradigm is usually presented by a younger scientist who is less invested in the old paradigm, and who sometimes may be a bit of an outsider to that particular field. The shift to the new paradigm takes place over an extended period of time, and may require nearly the length of a career to be accepted, as sometimes it takes the death and retirement of most of the advocates of the old paradigm before the new one can fully take its place. Thus for Kuhn the history of science is a history of periods of "normal science" interspersed between relatively rapid periods of paradigm shift.

In describing the paradigm, Kuhn differs with the logical positivists by suggesting that the paradigm is not so much designed to fit the facts of nature as that the facts of nature are understood and interpreted by scientists in a fashion which fits the paradigm. Where the logical positivists see science as progressing forward towards an eventual understanding of truth, Kuhn believes science's progress is not towards truth. Truth is something external, which can never be fully grasped. For Kuhn, science does make progress, but the progress is towards a better paradigm – a paradigm which gives a more complete description of nature. Since no paradigm can ever fully describe nature, the description of the natural world provided by science always falls short of what actually exists.

Kuhn makes a distinction between the fields of science and other fields in regards to the question of progress.[10] He suggests that the sciences are unique in that during times of "normal science" all of the scientists in a given field are operating under the same paradigm. Here Kuhn draws a further distinction between the natural sciences and the social sciences. Only in the natural sciences do we generally find a single unifying paradigm. In the social sciences multiple paradigms can exist within a single field at the same time. Likewise, in such fields as theology and philosophy, various schools may each operate under only a single paradigm, but multiple paradigms exist within the field as a whole. For example, some philosophers may still work from the Aristotelian paradigm, but it would be unheard of in the natural sciences for an astronomer to operate under a Ptolemaic paradigm or a physicist under a pre-Newtonian one.

Kuhn argues that this effect comes from the fact that scientific fields or communities are more focused in their education than other fields. Students of science are not encouraged to see things from various viewpoints, or to weigh multiple, conflicting approaches – rather, everything they are taught comes out of the prevailing paradigm. Kuhn believes that this separates the natural sciences not just from other disciplines within western culture, but from all other disciplines in any culture as well. To Kuhn, science has arisen strictly as a western discipline.[11]

One problem with Kuhn's description of science is this very narrowness. While the various social sciences often use methodologies which may be shared with or similar to those used by the natural sciences, Kuhn believes that their lack of a uniform paradigm

[10] *Ibid.*, Chapter 13
[11] *Ibid.*, pp 165-68

hinders their progress and prevents them from being described as "true" sciences in the same sense as the natural sciences. At the same time, it can be called into question whether operating out of a single paradigm is as unique as Kuhn seems to believe. While it may well be true that only in the natural sciences does one find cases of an entire field of study which operates almost exclusively under a single paradigm, one may well find other fields in which a substantial majority of the field operates under the same paradigm at any given time. And while some fields may have centuries-old paradigms which are still considered viable within the field, certainly there are many fields in which older paradigms are regularly discredited and discarded in much the same way that they are in the natural sciences.

Paul Feyerabend

Although Kuhn's view of science differs from the picture of slow, steady progress with fairly clear goals and methodologies offered by the logical positivists, it nonetheless suggests that such a description is generally accurate except during periods of paradigm shift. This leaves Kuhn (as well as the logical positivists) open to the challenge that science simply does not operate as neatly and cleanly as that. One philosopher of science who differs with Kuhn in such fashion is Paul Feyerabend.[12]

Feyerabend argues that there is no such thing as "normal science" as described by Kuhn.[13] For Feyerabend, there are always unanswered questions and "loose ends" in

[12] The discussion of Feyerabend's ideas which follows is based upon Paul Feyerabend; *Against Method*, 3rd Edition; New York: Verso; 1993 and "How to Defend Society Against Science" in E.D. Klemke, Robert Hollinger, and A. David Kline, eds.; *Introductory Readings in the Philosophy of Science*, revised edition; Buffalo, NY: Prometheus Books; 1988, pp 34-44

[13] Feyerabend; "How to Defend Society…," p 39

science. While he agrees with the logical positivists that good theories will be in line with known facts, he challenges the notion that new theories can be arrived at in a relatively straight-forward fashion. Feyerabend thinks that science should always have alternative theories, provided that they offer explanations which fit with established facts. Multiple theories offer a better chance of finding the best explanation for facts and events.

While he seems to accept the notion that each scientist operates out of a particular paradigm, he rejects the narrowness of Kuhn's description of fields of science. Different viewpoints suggesting different solutions or possibilities to a given field are an asset to Feyerabend, not a hindrance as Kuhn's description of "normal science" would seem to suggest. Further, he rejects Kuhn's notion that science can best be understood as a western endeavor. Feyerabend finds value in such non-western approaches to knowledge as ancient mythology and traditional Asian medicine,[14] although he acknowledges they can be difficult to integrate into contemporary scientific theory. Such challenges to science serve to create possibilities for new and potentially fertile hypotheses and theories. Feyerabend also viewed the introduction of students from non-traditional backgrounds into American science education in the 1960s as an opportunity to introduce new voices and viewpoints to scientific disciplines. He felt he and other science educators had as much to learn from these students as the students had to learn from their teachers.[15]

While Feyerabend's view is refreshingly open to new and unconventional

[14] Feyerabend; *Against Method*, pp 35-36n, 37
[15] *Ibid.*, pp 263-64

approaches, it raises the question of where the line between what is science and what is not science is to be drawn. Certainly there is a need for science to draw on resources from other disciplines, and outsiders and unconventional thinkers have clearly played key roles in the history of science. On the other hand, in addition to seeing possibility in ancient astronomy and Asian medicine, Feyerabend has also suggested that such ideas as telepathy and telekinesis be taken seriously by science,[16] a notion which most scientists find wildly preposterous. It is not clear what distinction, if any, Feyerabend is making between what constitutes science and what does not.

Holmes Rolston III

I have now examined the logical positivist position as well as some of the weaknesses of logical positivism discussed in the work of Toulmin, Kuhn and Feyerabend. Kuhn and Feyerabend, in particular, suggest that science may not be able to fully describe the natural world, and may have much to gain from insights brought to it from other fields of intellectual inquiry. It is time to turn to the question of whether religious propositions may have a place in science, looking first at the work of the scientist, philosopher and theologian Holmes Rolston III.

In contrast to Feyerabend, Rolston clearly finds a distinction between what is science and what is not. While he recognizes science as a field which is different from other fields of study, Rolston finds the distinctions between various fields markedly less sharp and well-defined than Kuhn, however.[17] Rolston argues that the relationship

[16] Feyerabend; "How to Defend Society…," p 40

[17] Holmes Rolston III; *Science and Religion: A Critical Survey*; New York: Random House; 1987, Chapter 1

between the natural sciences, the social sciences, and religion (which for Rolston is generally exemplified by theology) should be understood more as being on a spectrum with a methodology shared across the fields rather than sharply divided fields each with a distinct paradigm.[18] Rolston sees a parallel between the way theories in science are subject to verification and falsification and the function of creeds and doctrines within religion. Religious beliefs and practices can be affirmed or challenged by doctrinal statements, which cause some beliefs and practices to be discarded while others are encouraged, which he compares to the falsifying and confirming of scientific theories.[19] Rolston argues that doctrine is arrived at through religious experience, including subjective experience, and suggests that this parallels the empiricism utilized by science. At the same time, he acknowledges that knowledge gained through experience is not the same as data gathered through observation and experimentation.

He adopts Kuhn's idea of a paradigm as the primary means by which we interpret experience and observation. Just as the sciences have a paradigm which shapes the interpretation of facts and theories, so religions have paradigms which influence the interpretation of religious experiences and scriptures. Religious paradigms are created by creedal statements, doctrinal formulations and theological writings. They can be challenged by anomalous information in the same way that scientific paradigms are challenged by anomalous data. For example, a teaching of Jesus which runs counter to the prevailing Christian paradigm can suggest a problem with the paradigm. If enough

[18] Rolston himself does not use "spectrum" in his description; however, I think it is a fairly accurate interpretation of what he has in mind.
[19] Rolston, *op. cit.*, pp 4-8

such anomalous teachings can be identified, it may become necessary to switch paradigms, just as paradigms shift within science as described by Kuhn.[20]

Rolston understands both science and religion to be ways of ordering the facts and experiences which nature and life bring to us. In this he again parallels Kuhn. For Kuhn, nature is external to science, which seeks to understand and explain natural forces and processes, but which can never hope to fully describe them. In a similar fashion, Rolston sees God or ultimate reality as something external to religion, which religion seeks to explain or describe, but which can never be fully grasped or understood.[21]

The distinction he makes between science and religion lies in the focus of their paradigms. The focus is on causality and meaning, respectively. Rolston argues that scientific paradigms try to explain nature and our experiences in terms of causality, while religions try to understand ultimate reality and human experiences in terms of meaning. He believes that part of the confusion over whether the social sciences are true sciences or not comes from their occupying a middle ground between the natural sciences and religions on Rolston's spectrum. While the social sciences operate from within a paradigm which focuses on causality, they are frequently engaged in describing human experiences which imply or search for meaning. Although the social sciences themselves do not seek to ascertain meaning, they may look for the causes which lead people to adopt certain meanings. By contrast, the focus of religious paradigms is clearly on bringing meaning to human experience – any causal descriptions are incidental.[22]

[20] *Ibid.*, pp 8-15
[21] *Ibid.*, pp 16-22
[22] *Ibid.*, pp 22-31

If Kuhn may be too narrow in describing science as unique among fields of study, Rolston may be too generous in ascribing scientific methodology to religion. In science, once a theory or idea is falsified, it is discarded by the scientists. Even under Kuhn's paradigm shifts, out-moded theories and paradigms remain for only a generation until they are fully replaced. Rolston sees religion as making progress in the same kind of sense that Kuhn sees science progressing. However, religious ideas do not always get discarded in the same way that scientific ideas are discarded. Rolston is correct in suggesting that some ideas – such as witchcraft and astrology – have been discredited and cast off in most religious traditions.[23] But many more persist, even though there may be strong doctrinal arguments in favor of discarding them. In other cases, competing ideas continue to exist in a tension, rather than leading to a paradigm shift as happens in science.

If Rolston's ideas are correct, it would seem to suggest that the Reformation of the sixteenth century represented a moment of crisis in Christianity comparable to the conflict between the Ptolemaic model of the solar system and the Copernican one. It should be expected then, that the ideas of the reformers would demonstrate superiority to existing doctrine, which would then be replaced in a paradigm shift. Instead, what occurred was a schism in the church, which led to the rise of several Protestant denominations while the Catholic church continued as well. Although the Counter Reformation eventually lead to a revision of Catholic doctrine in which some of the ideas of Protestant doctrine were adopted, there remain significant differences between

[23] *Ibid.*, p 7

Catholic doctrine and the doctrines of various Protestant churches. Rather than one paradigm replacing another, the original paradigm persisted, while several additional paradigms developed. It is as though in astronomy the Ptolemaic school continued to exist, with significant modifications to the theory, alongside the newer school of Copernican astronomy.

Rolston also sees a progression within religion in regards to discarding out-dated paradigms and doctrines which simply isn't there. He argues that a number of religious ideas have been almost completely disregarded by contemporary Christianity – among them a six-day creation, a literalistic reading of the fall of Adam and Eve, the doctrine of original sin, and the inerrancy of the Bible.[24] All of these ideas are still held by significant numbers of Christians, although their ranks may be diminished.

The issue of verification and falsification raises an additional challenge to Rolston's contention that religion and science share a methodology. Despite the recognition by such philosophers of science as Toulmin, Kuhn, and Feyerabend that the personal views and biases of scientists play an important role in the formulation of theories and paradigms, the underlying importance of ideas which can be tested and corroborated remains central to science. Religion, however, often deals with ideas which simply cannot be verified or falsified. How could one go about verifying the Christian claim that Jesus was God embodied in human form, for instance? It seems unlikely that we could find a means to duplicate the conditions under which Jesus appeared on earth in an attempt to see if God would become incarnate again. Likewise, the idea that one could

[24] *Ibid.*, p 9

somehow create an experiment to verify whether or not the *karma* accumulated during one's previous lifetime has any effect on one's current life seems equally absurd.

Comparing Rolston's ideas to Kuhn's suggests an interesting possibility. Kuhn views the natural sciences as separate disciplines (physics, biology, astronomy, etc.), each with its own paradigm, which fit together into one category. Following Rolston's description, we might describe this category as disciplines that share a methodology which is concerned with causation. In a parallel fashion we might group all religions as separate "disciplines" within the category of religion, which can be characterized as disciplines that share a methodology which is concerned with meaning. The problem would arise, though, of the relationship between the individual religions or disciplines. In the natural sciences, while the paradigms may vary from one discipline to another, they do not contradict one another to any significant degree. The theories that govern cellular behavior in biology, for example, do not contradict the theories of sub-atomic physics. Whether or not various religious beliefs can be reconciled with one another is a matter which has long been the subject of dispute. Is the "hypothesis" that ultimate reality is an impersonal force which connects everything in the universe, including human beings, as is taught by some schools of Hinduism and Buddhism, compatible with the hypothesis that God is a personal entity who can relate directly to human beings taught by most schools of the western monotheistic religions (Judaism, Christianity, and Islam)? The model is further complicated by the fact that many individual disciplines (religions) are divided into competing schools with separate paradigms as discussed above, so that most individual disciplines would not be governed by a single paradigm in the way that each of

the natural sciences are.

Nancey Murphy

Like Holmes Rolston, Nancey Murphy believes that theology should be considered a science.[25] Instead of a spectrum based on methodology and aims, however, Murphy proposes a hierarchical arrangement of the sciences:

Theology

Ethics

Cosmology Social Sciences

Psychology

Biology

Chemistry

Physics

She bases this hierarchy on the understanding that each science is built upon the one below it. Physics describes the basic "building blocks" of the universe – atoms, protons, neutrons, quarks and other sub-atomic particles. Chemistry studies how these particles are arranged to form atoms and molecules, with much of its work based in knowledge gained from physics. In turn, much of biology is based on understanding how chemistry works in living organisms. In addition, Murphy believes that many lower level processes

[25] Nancey Murphy; *Reconciling Theology and Science: A Radical Reformation Perspective*; Kitchener, Ontario: Pandora Press; 1997

are constrained by the systems which operate at the level above. So each science may raise questions which can only be answered by information from the science above it in the hierarchy. Finally, as one moves up the hierarchy, each science is concerned with a more encompassing whole or a more complex system than the science below it.[26]

In some cases, this encompassing whole and the more complex system fit within the same science. Thus, chemistry fits above physics in that it encompasses all of physics, as well as containing the next most complex system (molecules) above the system dealt with in physics (atoms and sub-atomic particles). When we reach biology, however, the hierarchy branches. In terms of an encompassing whole, cosmology, as the study of the universe, is the whole which would encompass all of the natural sciences. If we see the universe as a system, it can also be understood as a more complex system than the organisms studied in biology. However, relationships and societies are also complex systems which display a greater complexity than the individual organisms studied within biology. Thus, psychology and the social sciences can be understood as sciences which belong above biology in the hierarchy, on the grounds that they study more complex systems – societies and relationships.[27]

Murphy places theology at the top of her hierarchy on the grounds that the study of God and God's relationship to people and the universe is the study of the most all-encompassing system possible.[28] She argues that theology relates to cosmology in that it

[26] *Ibid.*, pp 12-16
[27] *Ibid.*, p 16
[28] *Ibid.*, p 17 It should be noted that Murphy, as a Christian philosopher, sees theology as the discipline at the top of the sciences. If we consider that religions see God or ultimate reality as encompassing or having power over the entire universe (a description which holds true of most religions), religion can be easily substituted for theology in Murphy's hierarchy.

provides a means to evaluate hypotheses about the fine-tuned nature of the universe.[29] (The fine-tuning of the universe and its implications will be discussed in more detail below.) Murphy adds ethics to her hierarchy because she finds that the social sciences pose questions about the nature of what is good for human beings which can only be answered by an appeal to ethics. In turn, theology provides the universal understanding necessary to resolve ethical dilemmas.[30]

In common with Rolston, Murphy suggests that theology uses the same methodology as that employed by science – the hypothetico-deductive method of logical positivism. Murphy argues that the data used by theologians include Christian experience, church practices, and historical events, and that much of this data is drawn from Christian scripture.[31] This last point is likely to be problematic with philosophers of science. The strength of the data used here to support the hypothesis – the existence of God as an organizing system of the universe – seem to rest in part on the authority of scripture and legitimacy of Christian practice, which in turn seems to rest on the assumption that God exists. While Popper, Kuhn, and Feyerabend make clear that the hypothesis influences the way in which we interpret facts, they all agree that the basic facts must have a large degree of acceptance even beyond their role as supporting data for the hypothesis.

In addition, if we try to extend Murphy's hierarchy by substituting religion for theology, we encounter the same difficulties presented by Rolston's system. If one of the

[29] *Ibid.*, Chapter 3
[30] *Ibid.*, pp 80ff
[31] *Ibid.*, pp 22-32

requirements for a field to be considered a science is a unifying paradigm, religion clearly lacks such a paradigm, even if sketched in the broadest terms possible. If we accept Murphy's hierarchy as she has presented it, and restrict the top-most science to Christian theology, there remains so much diversity within Christianity that it is difficult to identify a unifying paradigm in any but the broadest terms.

Although it does not have a direct bearing on the relationship between religion and science, it should be noted that Murphy's hierarchy appears to be incomplete. Several sciences seem to be missing. Ecology, for instance, would seem to belong somewhere in the hierarchy as the science which includes the systems within which organisms live and evolve. Other sciences, such as geology, are also missing, perhaps because they are not concerned with living organisms. While their omission likely does not change Murphy's argument to a significant degree, the relationship of the sciences with one another does seem to be more complex than her hierarchy indicates.[32]

Paul Davies

In his book *The Mind of God,* physicist Paul Davies assesses the capacity of science to understand what he sees as an orderly and organized universe. Davies argues that physics is able to describe the universe because it assumes that the universe is governed by a set of physical laws which are transcendent – they exist outside of the existence of the universe itself. If the laws are not transcendent, there is no possibility of

[32] In a more recent version of her hierarchy, Murphy has added astrophysics, ecology, and cognitive science to the hierarchy and removed ethics. Geology remains absent. See Jeffrey Schloss and Michael Murray, eds.: *The Believing Primate: Scientific, Philosophical, and Theological Reflections on the Origin of Religion*; New York: Oxford University Press; 2009, p 269

explaining how it is that the universe itself exists.[33] Many of these laws of physics which were once believed to be independent of one another are now seen to be linked together, leading many physicists to see a chain of contingency among the various laws. According to Davies, many scientists believe that this linkage implies that a theory explaining *all* of the laws may some day be possible. Such a theory, however, would have to explain not just how the universe came into being, but also why the universe has this set of laws and no other.[34] The problem is that there seems to be no reason why the laws of physics should be the *particular* set of laws that governs our universe, when other laws of physics might well be possible. However, a different set of laws would necessitate a different kind of universe – one in which life (or even the elements which we know) might not be possible.[35] Thus, the universe appears to somehow be fine-tuned to operate according to laws which make the evolution of life possible.

This fine-tuning of the universe is often called the anthropic principle, and raises the question of why a universe fully suited for human life would arise if other universes would be possible. One possible answer is that multiple universes exist, and we just happen to be in one which is suited for life. Another possibility is that new universes form repeatedly, either in succession or from within other universes, and we inhabit one suited for life. Davies examines these possibilities and concludes that the science involved is either problematic or overly complex.[36]

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[33] Paul Davies; *The Mind of God: The Scientific Basis for a Rational World*; New York: Simon and Schuster; 1992, Chapters 2 and 3

[34] *Ibid.*, p 167

[35] *Ibid.*, Chapters 7 and 8

[36] *Ibid.*, Chapter 8 Nancey Murphy has also examined these theories and rejected them for similar reasons (Muphy, *op. cit.*, Chapter 3), while Richard Dawkins finds the multiple universe theories less improbable than the idea that some sort of designer is behind the fine-tuning (Dawkins, *op. cit.*, p 147).

Davies' conclusion is that since the universe is contingent – dependent on laws of physics – and can only exist as we know it under a precise set of conditions (laws) there must be a designer or creator who set down those conditions at the point when the universe came into being. It should be noted that Davies is explicit in saying that this creator would *not* necessarily be a personal god.[37] However, such a designer must not be contingent upon any other conditions, or we simply continue the chain of contingency. At the same time, Davies finds it contradictory to suggest that a necessary being or force would produce a contingent universe, or any universe at all. In the end, he suggests that process philosophy describes the kind of god which could resolve this contradiction. Such a god produces the conditions necessary to the universe, thus establishing the potentialities of the universe. After that, however, this god is participatory in the universe, affecting its potentiality, but also being effected by the realization of potentialities in the universe. At the same time, the basic nature of this god remains unchanged. Davies compares the nature and activities of this god with quantum theory, where the behavior of an electron can be described according to a set of possibilities, but the actual behavior remains indeterminate until a measurement is taken.[38]

Although Davies believes that science points us towards the possibility of a designer, Davies ends his book by arguing that there is a limit to what science can understand. Reason itself cannot in the end resolve all questions, and the cause of its failure lies in the nature of rationality itself. In the end, there can be no rational explanation for everything, since such an explanation would necessarily include itself – a

[37] Davies, *op. cit.*, p191
[38] *Ibid.*, pp 183-84

logical impossibility. Davies believes that if we are ever to gain an understanding of the ultimate reality underlying the universe, it will come through mysticism, rather than rational science.[39]

Davies makes an impressive argument, utilizing far more details and examples than I have given here, that science suggests an orderly and rational nature to the universe which implies a designer. It is notable, however, that he relies on philosophy (citing Plato, Anselm and a number of other philosophers in addition to Whitehead's process philosophy) to suggest and assess his descriptions of the designer. While science may provide evidence that suggests a god, science itself is apparently not capable of describing that god.

It is also not clear if Davies' arguments concerning the relationship between a contingent universe and a necessary creator and the impossibility of a rational explanation for everything represent sound conclusions or are more a matter of semantics. Again, these questions would fall into the area of philosophy rather than science.

Arthur Peacocke and John Polkinghorne

As scientists and theologians, Arthur Peacocke and John Polkinghorne have each sought to describe God in a way that is consistent with contemporary science, particularly

[39] *Ibid.*, Chapter 9

physics.[40] Like Davies, both find a contradiction in the contingent nature of the universe and the necessary nature of God, as God is generally conceived. They take similar approaches to the resolution of the problem, but arrive at somewhat different conclusions regarding the nature of God, however.

Peacocke sees the world as a series of levels made up of organized systems, with each level and its systems made up of parts drawn from the level below. The lowest level is the sub-atomic particles and energy studied by physicists, which combine to form the systems of the next level and so on. Peacocke's levels of organization coincide roughly with the systems studied by the various sciences in Nancey Murphy's hierarchy of sciences.[41] Peacocke adds that relationships of parts to wholes can be viewed both by looking up and down the levels of complexity as well as back and forth across records of history. Furthermore, all *properties* of these systems, no matter what level they exist on, may be accounted for using the basic forces and laws of physics.[42]

However, as one moves up the levels of complexity, one finds that not all of the *relationships* between the parts and the wholes within the systems are explicable according to the laws of physics. Increasing levels of complexity possess a "reality" which cannot be explained by reference to the parts below, a phenomenon which Peacocke describes as "emergence." The consequence of this is that causality can flow

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[40] Arthur Peacocke; *All that is: A Naturalistic Faith for the Twenty-First Century*, Philip Clayton, ed.; Minneapolis: Fortress Press; 2007; John Polkinghorne; *Science and Creation: The Search for Understanding*; Philadelphia: Templeton Foundation Press; 2006; John Polkinghorne; "The Metaphysics of Divine Action" in Robert John Russell, Nancey Murphy, and Arthur R. Peacocke, eds.; *Chaos and Complexity: Scientific Perspectives on Divine Action*, 2nd edition; Vatican City: Vatican Observatory Publications; 1997

[41] In fact, Murphy credits her description of the hierarchy of the sciences to her understanding of Peacocke's work (Murphy, *op. cit.*, p 17).

[42] Peacocke, *op. cit.*, pp 12-13

both ways across the levels. Lower level parts and systems can have a "bottom-up" effect on the systems above them, but the higher-level systems also have a causal effect on the systems below. The constituent parts below behave differently than they would if they were not part of the more complex, higher-level systems.[43]

Peacocke describes God's relationship with the world as panentheistic. His system requires that all causation be from within the system, therefore, God must be part of the system. Peacocke's suggestion is that the universe is part of God, but is not the whole of God. The universe is within God, but God has an existence which is not limited to the universe.[44] In this model, God has an awareness of the interconnectedness of the parts and systems which make up the universe, and is able to effect the universe through those patterns. God would be able to exercise God's will in the universe without violating any of the laws of the universe. Since the universe is part of God, God is able to be present everywhere in the universe and act at any level. Peacocke suggests that God acts to both influence the universe at a whole, as well as being able to act on the human level through God's influence on the parts and systems which make up human beings and human society.[45]

Polkinghorne understands the nature of the universe in a fashion similar to Peacocke, suggesting that it is made up of systems and open to both bottom up and top down causality.[46] Unlike Peacocke, however, he does not believe that God is embodied in the universe. Polkinghorne uses human nature to help understand the nature of God.

[43] *Ibid.*, pp 13-16
[44] *Ibid.*, pp 21-22
[45] *Ibid.*, Chapter 9
[46] Polkinghorne, "The Metaphysics of . . .," pp 150-51, 155-56

He sees human beings as possessing a dual nature – we are creatures of matter, but nonetheless also possess a mind, which is something more than and other than matter. The mind is concerned with the organization and manipulation of information, which can affect the universe of matter. Polkinghorne's suggestion is that God can affect the universe purely through information, and does not need to be embodied in the universe. In Polkinghorne's system, God is a being of pure spirit, able to act in a universe of pure matter. There is a clear difference between what is God and what is the universe, while human beings represent "mind/matter amphibians" who are neither pure matter nor pure spirit.[47]

In contrast to Paul Davies, Polkinghorne is not satisfied with an impersonal god who is not affected by the life forms which inhabit the universe. No one prays to a "necessary being," Polkinghorne insists.[48] Natural theology, which relies on science and the observable universe, is not enough to fully describe God. That task must fall to theologians and is based on religious experience and revelation.[49]

What Peacocke and Polkinghorne have done goes a step beyond Davies' work. Where Davies used science to provide a description of god, Peacocke and Polkinghorne have begun with a scientific description of the universe and constructed theological descriptions of God which are informed by and compatible with that description of the universe. In common with Davies, both scientists find that in order to draw conclusions about the nature of God, it is necessary to utilize data from fields outside of what is

[47] Ibid., pp 154-56; also Polkinghorne, *Science and Creation*, Chapter 5
[48] Polkinghorne, *Science and Creation*, p 103
[49] *Ibid.*, pp 105ff

traditionally thought of as science – in Davies' case from philosophy, and in the case of Peacocke and Polkinghorne from Christian theology.

Conclusion

The issues surveyed here suggest two things. First, a tighter definition of what constitutes science may be needed to determine if religion can say anything at all which might be deemed "science." Second, philosophy of science should recognize that science cannot be separated from other intellectual and academic disciplines. Even if a precise definition of science can be arrived at and agreed upon by all or almost all philosophers of science and scientists, the practice of science will always be shaped and influenced by disciplines outside of science.

The work examined in this paper suggests that three things must be taken into account in attempting to determine the limits of the discipline of science – methodology, the existence of a uniform paradigm, and the aim or goal of the discipline. The methodology of science involves the gathering of facts and data which are used to formulate hypotheses and theories constructed in such a fashion as to be testable either through direct observation or by correlation with additional data. While there is some disagreement, even among logical positivists, as to exactly how the formulation of hypotheses and theories can be carried out and what consititutes an adequate test of a hypothesis or theory, this description would be generally agreeable to all scientists. All of the natural sciences share this methodology, as well as most, if not all, social sciences. Within the social sciences, there is some variation in what would be considered

appropriate data. Historical information, for instance, would be valuable data to a historian, but likely would not be considered useful data by most psychologists. But natural sciences make a similar discrimination of data across fields. While the social sciences may not always use terminology such as hypothesis and theory with the same precision as the natural sciences, or even use the same terminology at all, the methodology nonetheless is substantially the same as that of the natural sciences.

Both Holmes Rolston and Nancey Murphy argue that theology can be considered a science on the grounds that it utilizes the same methodology as the natural sciences. While this may not be the case for all theologies, certainly many of them take data (in the form of scriptural passages, creedal statements, and accounts of religious experiments) and use it to formulate conclusions and theological systems or doctrines which are then tested through comparison and corroboration with additional scriptural passages, creeds, and religious accounts. If the social sciences share a methodology with the natural sciences, this kind of theology would seem to as well. While much of religion could not be considered a science on this basis, it would seem that theology and similar intellectual religious systems might well be considered sciences due to shared methodology.

That the aim of science is to provide a causal description of or explanation for observable facts and phenomena is again a matter of general agreement. Clearly this is the primary undertaking of the natural sciences. Likewise, the social sciences are concerned with providing explanations or causes for the data and phenomena with which they deal. Rolston has suggested that theology be regarded as a science because of its methodology, but as a science which has a different aim – to bring meaning rather than to

describe causation. The problem is that other fields may share a methodology with science and also have the aim of finding meaning. Astrology, for instance, takes observable facts and data and interprets them in such a way that meaning is assigned to them. In this case, of course, many of the facts are being used to support hypotheses and theories which cannot be falsified or corroborated with any degree of authority. Similarly, the facts and data of religion are often used to support hypotheses and theories whose authority cannot be tested outside of the religious system within which they originate. It seems unwise to extend the definition of science to fields which bring meaning to data unless a robust system exists with which to test that meaning.

The criterium of a unified paradigm is derived largely from the work of Thomas Kuhn, and is the most problematic of these three criteria. Kuhn uses it to suggest that science is unique among the disciplines in that its practitioners share a single paradigm. To do so creates a division between the natural sciences and the social sciences, which use the same methodology as the natural sciences but often lack a unified paradigm among practitioners. And the usefulness of using a unified paradigm as the identifying feature of science can be criticized on two fronts. First, it is not inconceivable that other fields possess a unified paradigm. Music, for instance, by virtue of possessing a common language -- musical notation – common concerns such as rhythm, tempo, etc., and a common aim – the production of a specific type of art – might be regarded as a field with a unified paradigm, although it is doubtful that many people would regard it as a science. Secondly, science does not always possess a unified paradigm. At the present, the field of physics is divided over questions such as the validity of string theory, which make it

difficult to perceive a unified paradigm, except in the most general terms. Although it could be suggested that this simply means that physics is undergoing a paradigm shift, as described by Kuhn, that would raise the further question of whether the lack of a unified paradigm at such a time means that a field has somehow ceased to be a science until a new paradigm emerges.

It appears then that the best way to define science would be as a field which utilizes a methodology based on the collection or study of particular data and phenomena resulting in the formulation of hypotheses and theories which may be corroborated or challenged through further study of the data and phenomena, and which has as its end a determination of causality for or an explanation of the data and phenomena and the systems in which they exist. This definition would encompass the natural sciences and social sciences. The description of science as having a unified paradigm raises more issues than it solves, and is not necessary to adequately define science. Portions of the broad field of Religious Studies would fit within this description, by virtue of being part of the social sciences. A sociologist studying the role of religion in society, for example, would use the methodology described above for the purpose of explaining or determining *causes* of religious belief or actions, as would a psychologist studying the psychology of religion. Religion as a discipline itself would be excluded, except for one relatively small exception. There is the possibility, exemplified here in the work of Paul Davies, that science can provide evidence supporting the idea of the existence of God or ultimate reality as a source of order or design in the universe, which is a hypothesis rooted in religion. However, this is as far as science may go. As seen with Davies' work, and that

of Peacocke and Polkinghorne as well, any further description of the actual nature of God or ultimate reality must rely on ideas from outside of science, not formulated by or corroborated by the methodology of science. The room for religion in science is extremely small, but not non-existent.

This leads us to the second point mentioned above: science cannot be fully isolated from other fields of intellectual inquiry. The division of fields of study into distinct disciplines is an artifact of the human mind, and reflects neither an actual order of reality nor the actual context in which those disciplines are practiced. As was illustrated in the work of Davies, Peacocke, and Polkinghorne, science can raise questions which can only be explored through other disciplines. The fact that philosophy and theology may be needed to answer the questions raised by science about God and ultimate reality does not mean that those disciplines are sciences, it merely means that there are questions which arise in science which cannot be fully answered by science itself.

In addition, and perhaps more importantly, the practitioners of science themselves are not isolated from other disciplines. The question of reductionism has already been mentioned. Nothing in science requires reductionism; rather, it is a philosophical position taken up by the scientist. That position will deeply affect the scientist's approach to his or her work, however, and will color the way he or she interprets it and applies the conclusions to larger issues. If the central aim of science is to determine causality and explain phenomena, any meaning to be found in those descriptions and explanations will come from outside of science. Davies, Peacocke and Polkinghorne, then, are simply drawing on resources from philosophy and theology to offer meaning for

a phenomenon suggested by scientific reasoning. Absent a unifying theory, it would seem that ultimate meanings will need to come from sources other than science itself.

Thus, even if a definition for science can be arrived at which satisfies most scientists and philosophers of science, the boundaries of science will remain blurred. On occasion resources from outside science, including resources from philosophy and religion, may be needed to illuminate issues raised through the practice of science. And all scientists are shaped by their own views of philosophy and religion, whether they acknowledge those influences or not.

Bibliography

Barbour, Ian G.; *Religion and Science: Historical and Contemporary Issues*; New York: HarperCollins; 1997

Davies, Paul; *The Mind of God: The Scientific Basis for a Rational World*; New York: Simon and Schuster; 1992

Dawkins, Richard; *The God Delusion*; New York: Houghton Mifflin; 2006

Feyerabend, Paul; *Against Method*, 3rd edition; New York: Verso; 1993

----------; "How to Defend Society Against Science" in E.D. Klemke, Robert Hollinger, and A. David Kline, eds.; *Introductory Readings in the Philosophy of Science*, revised edition; Buffalo, NY: Prometheus Books; 1988, pp 34-44

Hempel, Carl; *Philosophy of Natural Science*; Upper Saddle River, NJ: Prentice-Hall; 1966

Kuhn, Thomas S.; *The Structure of Scientific Revolutions*, 3rd edition; Chicago: University of Chicago Press; 1996

McGrew, Timothy, Marc Alspector-Kelly, and Fritz Allhoff, eds.; *Philosophy of Science: An Historical Anthology*; Malden, MA: Wiley-Blackwell; 2009

Murphy, Nancey; *Reconciling Theology and Science: A Radical Reformation Perspective*; Kitchener, Ontario: Pandora Press; 1997

Peacocke, Arthur; *All that is: A Naturalistic Faith for the Twenty-First Century*, Philip Clayton, ed.; Minneapolis: Fortress Press; 2007

Polkinghorne, John C.; *Science and Creation: The Search for Understanding*; Philadelphia: Templeton Foundation Press; 2006

----------; “The Metaphysics of Divine Action” in Robert John Russell, Nancey Murphy, and Arthur R. Peacocke, eds.; *Chaos and Complexity: Scientific Perspectives on Divine Action*, 2nd edition; Vatican City: Vatican Observatory Publications; 1997

Popper, Karl; *The Logic of Scientific Discovery*; London: Routledge; 2002

Rolston, Holmes, III; *Science and Religion: A Critical Survey*; New York: Random House; 1987

Toulmin, Stephen; *Foresight and Understanding: An Enquiry into the Aims of Science*; Indiana: Indiana University Press; 1961