

## OVERVIEW OF THE STRUCTURE OF A SCIENTIFIC WORLDVIEW

*by John J. Carvalho IV*

**Abstract.** Understanding the structure of a scientific worldview is important for the dialogue between science and religion. In this essay, I define *comprehensive worldview* and distinguish it from the more focused *noncomprehensive worldview*. I explain that scientists and the public at large agree that modern research works in a scientific as opposed to nonscientific worldview. I give some of the essential elements of any scientific worldview that differentiate it from nonscientific ones. These elements are the general presuppositions of science, the methods of science, and the articles of justification for the conclusions science puts forward. I question whether a scientific worldview can allow philosophical and theological tenets, which might appear to stand opposed to scientific paradigms, and conclude that the answer lies in the scope of its comprehensiveness.

**Keywords:** comprehensive worldviews; contingent truth; critical realism; evolutionary biology; hypothetico-deductive method; inductivism; justification in science; methods of science; noncomprehensive worldviews; philosophy and theology; presuppositions of science; science and religion; scientific worldview; statistical-relevance method; theological worldview.

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### COMPREHENSIVE AND NONCOMPREHENSIVE WORLDVIEWS

I define *worldview* as a belief system concerning the nature of reality and how one acts as a subject in reality. The scope of a worldview I designate as its *comprehensiveness*. With regard to the questions proposed and answered, some worldviews are focused, and others are broad-based and far-reaching in their aims. For example, a worldview in a particular area of scholarship,

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such as nineteenth-century history, may be concerned only with a subset of questions, such as how the industrial revolution affected societies of the 1800s. Other worldviews attempt to provide a complete understanding for the subject's known world and try to introduce ways of living that encompass every aspect of life, including one's religious and ethical perspective as well as social associations. For example, Roman Catholicism proposes a particular theological perspective that addresses nature and a person's activities as a member of society. Those worldviews that are more focused I call *noncomprehensive* worldviews, and those that attempt to act as all-encompassing I designate as *comprehensive*. I make these distinctions with the intent of introducing into the science-and-religion dialogue the idea that the particular comprehensiveness of a worldview determines its structure, content, and relevance to other worldviews and the ultimate truth of reality.

#### SCIENCE DEMARCATED FROM PHILOSOPHY AND THEOLOGY

In order to promote progress in the science-religion dialogue, it is important to identify the essential components of a scientific worldview, determine the criteria for judging whether a worldview is scientific or nonscientific, and recognize what would disqualify a worldview from being scientific. These points are significant because worldviews change over time, and one needs to determine if such changes are scientific in content. In addition, theists and nontheists disagree over what a scientific worldview would state about the nature of our universe and whether or not a divine reality exists behind it. Indeed, theists who hold that science coheres with religion are able to incorporate the scientific worldview into a much larger theological one. Such a theological worldview answers a more diverse array of philosophical, ethical, and religious questions that science alone cannot solve. Such a worldview suggests a greater purpose to the sum of reality.

A discussion of what constitutes the nature of a scientific worldview must begin with the recognition that science is profoundly different from philosophy and theology. Originally, the ancient Greeks put science and philosophy under a larger umbrella of "philosophical investigation," which permitted the use of many methods for the acquisition of knowledge. Aristotle, in his *De Anima*, was fond of saying that "knowledge of any kind is a thing to be honored and prized" (Aristotle [384–322 B.C.E.] 1947, 145). Indeed, it could be argued that knowledge closest to the "truth" is the most prized knowledge of all, and both science and philosophy are rational enterprises that attempt to discover and understand this truth. Given that many theological systems employ philosophical reasoning, theology itself can be considered a rational enterprise. Nevertheless, since the Enlightenment there seems to be a clear distinction between the disci-

plines of science, philosophy, and theology. These distinctions appear to rely on a general understanding that science finds the truth in certain ways, employing certain methods and drawing certain refined conclusions. Philosophy and theology use a separate and unique set of methods, procedures, and sources to discover truth. These distinctions, however, do not imply that a scientific worldview is bereft of any elements of philosophy. A number of scholars have concluded that science—and I would therefore argue any scientific worldview—must contain some essential, underlying, foundational tenets that are philosophical, as opposed to strictly scientific, in nature. Ian Barbour and Stanley Jaki are influential thinkers in this regard (Jaki 1974; Barbour 1990, 90–93). Jaki departs from Barbour’s position by asserting that without Christianity the philosophical presuppositions of science would not have been formulated (Jaki 1974). He explores numerous other cultures and finds that none of them discovered the key ideas in Christian thought that led to the beginnings of science.

My own position is that only from the foundational tenets do auxiliary scientific tenets arise that make a scientific worldview depart from a strictly philosophical one. When I use the term *scientific* worldview I am referring to the modernist, mechanicalist, naturalistic worldview that had its birth in the Enlightenment. I contend that modern science, especially biology and biomedicine, gravitates toward a critical realist perspective, which believes that experimental and empirical activity can lead us to truths about nature. (For a general introduction to critical realism see Southgate et al. 1999, 17–19.) The correlation between scientific conclusions in this perspective and fundamental reality may not be exact, but science leads us in the “proper direction” and, arguably, is the best way of getting there. One may criticize my position, but the empirical sciences have dominantly held the critical realist perspective in a vast majority of the world’s experimental research institutions, whether they be universities, government laboratories, or biotechnology companies in the private sector (see Barbour 1990 and his accompanying references). Thus, there emerges from this definition of science in the critical realist perspective essential, foundational components of a scientific worldview. I argue that these components are historically accurate and are actually “philosophical presuppositions” (in the words of Barbour and Jaki) of the experimental sciences.

So what are these philosophical presuppositions?

#### PHILOSOPHICAL PRESUPPOSITIONS OF SCIENCE THAT ACT AS FOUNDATIONAL COMPONENTS TO ANY SCIENTIFIC WORLDVIEW

1. The first philosophical presupposition is that the world is *ordered* and that such order is *detectable* and *explainable*. Additionally, the explanations of such order can be incorporated into a theory about nature. Belief in an orderly universe has its roots in the medieval scholastics and the

natural theologians that followed them, though ancient Greek philosophers such as Plato and Aristotle postulated a good, beautiful, and intelligent being or “agent intellect” as an architect of nature who was responsible for such order (Plato [427–347 B.C.E.] 1999; Aristotle [384–322 B.C.E.] 1947). Faith in the rationality of the world can be found in the writings of Albert the Great ([1206–1280] 1890–1899), Francis Bacon [1561–1626] 1952), G. W. Leibniz ([1646–1652] 1991), William Paley (1802), and a host of others in the Christian perspective. The contribution of these thinkers was profound, because, in a universe lacking a benevolent God, one could have no faith in its order and rationale and thus would be unable to perform experiments and produce theories that explained how the world behaves. Because an undecieving God did exist in the minds of these thinkers, it became possible to explore the world with confidence that it would make sense. In fact, the philosopher Leibniz went so far as to say that we live “in the best of all possible worlds” and even put forward arguments demonstrating the importance of final causality (a concept originally proposed by Aristotle) because of the place of teleology in his thinking.

As a corollary to this first philosophical tenet, I argue that the order in the universe, beyond the realm of quantum mechanics, is *continual and consistent* in such a way that experimental investigation can yield reproducible results whenever the conditions are met. This element of reproducibility is one of the ideas incorporated into the justification of a scientific worldview (discussed below). Without consistency and repetition, it would be difficult to discover truths about the known world. Consistency allowed Bacon to champion the method of inductivism, which rested on observation. David Hume questioned the consistency of our universe in his defense of “constant correlation” over “causal connections” (Hume [1779] 1988), but many philosophers of science subsequently have argued for the validity of causality (for an excellent review see Salmon et al. 1992). The vast majority of modern scientists endorse the critical realist perspective that there indeed exists causal relevance for the occurrences they measure in their laboratories. Nowhere can the importance of causal relevance, and therefore consistency, be more obvious than in medical research, where vaccines have helped to eradicate certain diseases.

2. The second philosophical presupposition is *faith in sense perception* and in the human intellectual capacity to know the world. Aristotle, using his method of simple enumeration to acquire facts about nature, was arguably the most influential philosopher for this idea. Subsequently, during the Enlightenment, René Descartes used a method of “radical doubt” to differentiate his position from Aristotle’s and arrive at his famous *Cogito ergo sum*, “I think therefore I am” (Descartes [1596–1650] 1989). A critical analysis of Descartes’ philosophy is beyond the scope of this essay. Suffice it to say that in the empirical sciences such as biology, observation and the interpretation of observation require a belief in the reality being ob-

served. Essentially, critical realists hold that there exists an absolute truth to the universe that explains its nature, and we, as human experimenters, can gain at least a probabilistic, if not deductive and definite, insight into this truth. Faith in sense perception and in the human intellectual capacity to know the world appears to be the dominant position in the empirical sciences today, for the vast majority of laboratories have scientists who consciously or subconsciously perform their experiments accordingly.

3. The third philosophical presupposition is that the world is *contingent* in its character regardless of its primary, underlying rationale and relative consistency with respect to experimental observations (whenever the conditions are met). This contingent character of the world entices scientists to perform experiments and make observations in order to determine underlying principles and the exceptions and varieties of it. Evolutionary biologist Ernst Mayr has argued that contingency in the biological realm is what allows biology to proceed by way of *concepts* as opposed to strict *laws* during the process of biological theory construction (Mayr 1982, 75–76; 1988). Even though some basic laws in biology may exist (see Hull 1974), a biological worldview must incorporate concepts that have exceptions. In the physicochemical sciences, experimenters appear to be driven more by laws than by concepts (Mayr 1982; Rosenberg 1985). Nevertheless, these laws rest on observation of a contingent world that can be grasped by principles that explain its contingency in a meaningful way. The world is not a complete chaos but rather ordered and changing within the boundaries of that order.

The philosophical presuppositions of science reveal that there exist two forms of truth that scientists try to discover, and these forms of truth are also embedded in the concept of a scientific worldview. The first is the truth, or underlying laws and principles, of the universe and the entities it regulates, as well as the complete history of the universe and its processes. This truth of the universe may be considered its absolute truth, its complete story and the rationale behind it. It is the ongoing challenge of science to discover this truth, and scholars might argue that the complete acquisition of it is so challenging that it is unlikely. This fact is most evident in the science of evolutionary biology, where historical information is so critical that without it a full accounting of how organisms have changed over time and how the forces of selection have worked on the various levels of life's hierarchy is virtually impossible (Mayr 1982; 1988; Gould 2002). A more likely scenario is that science can discover partial truths about the universe whenever the conditions of scientific experiments are met. The parameters for acquiring contingent truth would thus be the attainment of the previous experimental conditions and the logical robustness of the experimental method used. Hence, the philosophical presuppositions of science reveal that science, as a rational enterprise, can gain knowledge about the universe in a systematic, progressive, and meaningful

way by acquiring contingent, partial truths the sum total of which provide a reasonable idea of how nature works.

THE UNIQUE METHODS OF SCIENCE AND HOW THEY STAND  
AS ADDITIONAL ESSENTIAL COMPONENTS OF ANY SCIENTIFIC  
WORLDVIEW

Scientists are concerned with whether the theories of science (or philosophy, for that matter) can *explain* the reality “out there” or merely map onto reality in such a way as to make reality understandable without really elucidating its nature (Losee 1993, 45–53). In other words, they are concerned with science as explanation, not as representation. Unfortunately, mapping (science as representation) is more inaccurate and may involve greater subjectivity on the part of the investigator. Certainly modern science has been criticized for being too subjective, to the point where some view it as a mere social construction devoid of any objectivity in its process of theory building. For example, the Strong Program in the Sociology of Knowledge contends that the facts of science are socially made and that social theory adequately describes both the production of science and the product of science (Collins and Pinch 1993). Science, arguably, does proceed with at least some social construction, but I maintain that such construction is based on the contingent truths that science acquires. In addition, science puts forward certain methods that are more capable of discovering contingent truth. These methods, like the philosophical presuppositions mentioned earlier, are also essential components of any scientific worldview, because they provide the means to ascertain the conclusions a scientific worldview encompasses and promotes.

Throughout the history of philosophical investigation, numerous methods have been introduced to acquire information about the known world as well as to ascertain the content of prior knowledge. Bacon was a strong champion of strict inductivism, Aristotle was an advocate of the method of simple enumeration, and Socrates and his disciple Plato used the dialectic. There are weaknesses to these methods, and most philosophers of science agree that there now exist some dominant methods that are used extensively and specifically with regard to science which appear more robust against the logical errors of past methods. This is important, because the methods by which scientists acquire knowledge for their worldview allow them to introduce propositions about the world that may or may not be true.

Two dominant methods have evolved for the present scientific worldview in the critical realist perspective. They are the Hypothetico-Deductive (H-D) method and the Statistical-Relevance (S-R) method (for a review see Salmon et al. 1992). These methods are so tightly linked as components of the present scientific worldview that without them it is not clear this worldview would be possible in its present structure, if at all.

The H-D method generally constructs a hypothesis to be evaluated and then attempts to deduce an observational consequence of that hypothesis. Observation then determines whether the deduced observational consequence is true or false, hence, proving or disproving the hypothesis. The H-D method can be represented in the following schematic:

- Hypothesis
- + Auxiliary Hypothesis (which may or may not be needed)
- + initial conditions of the experiment  
yields a deduced observational consequence or prediction  
which is tested in an experiment
- = conclusion proving or disproving initial hypothesis.

The validity of the H-D method rests on clearly defined initial conditions of the experiment. Indeed, this is why scientists are so concerned about laboratory records. Any experiment must be repeatable, but for such repetition to occur the initial conditions must be met.

In the vast majority of cases, an experiment needs auxiliary hypotheses in addition to the initial conditions and the hypothesis. For example, in a biological experiment testing growth parameters for bacteria there must be certain equipment (such as microscopes and optical spectrophotometers) and procedures (such as time point harvesting protocols) that, in themselves, must be valid. Consequently, there must be an auxiliary hypothesis for each of these parameters. Intriguingly, these auxiliary hypotheses are usually products of the H-D method in prior, supporting experiments. If one of the auxiliary hypotheses is false, an experiment under the H-D method could provide a negative observation, which normally would invalidate a hypothesis under test, even if that hypothesis is actually true.

The strength of the H-D method is that under very controlled experiments, where only one condition is under investigation, in the hypothesis under test, there is good causal relevance between the observational prediction and the condition in the main hypothesis. However, some hypotheses may be true only most of the time, not all of the time, because of something embedded in the logic of the hypothesis. This is especially true in biology, which deals with life forms that are more probabilistic in nature because of their complexity (Mayr 1982). As a result, the H-D method could sometimes confirm the hypothesis and sometimes not confirm it through the use of the exact same procedure in the experimental design. A statistical-relevance approach therefore is needed to determine whether the probability of the hypothesis being true is relevant.

For example, it is known in the biomedical sciences that vaccines can prevent viral infections or pathological effects post-infection if the vaccine is effective to certain strains of virus, such as influenza. Clinical vaccine trials, such as those occurring at the National Institutes of Health, could be structured by the S-R method as follows:

$\Pr(R/P)$ : probability of recovery (R) of patient (P) without vaccine administered (considered the prior probability)

$\Pr(R/P-V)$ : probability of recovery (R) of patient (P) with vaccine administered (V) (considered the posterior probability)

Such that when:

$\Pr(R/P) > \Pr(R/P-V)$ , the vaccine is positively relevant

$\Pr(R/P) < \Pr(R/P-V)$ , the vaccine is negatively relevant

$\Pr(R/P) = \Pr(R/P-V)$ , the vaccine is irrelevant

Hence, depending on the statistical readouts of the clinical trials, experimenters can determine the efficacy of their vaccine for influenza.

From my years in biomedical research, it appears that most scientists use a combination of H-D and S-R methods to perform experiments and draw conclusions from them. In addition, the content of science can change over time, but the methods used to change that content seem to be the H-D and S-R choices. Certainly, any scientific worldview needs to address scientific change over time. Some experimental programs may be modeled on the philosophies of Imre Lakatos's "progressive research programs" (1970) or Thomas Kuhn's "scientific revolutions" (1970; 1977). Nevertheless, these experimental programs seem to employ the above methods to attain the content that leads to the change in science. Hence, a key component of a scientific worldview, I would argue, requires these two dominant methods. Abolishing these methods would end the empirical sciences as we know them and probably place us in a philosophical as opposed to empirical-scientific worldview in our modern, critical-realist perspective. There are other empirical approaches (simple enumeration, for example), but it appears that if modern scientists use these approaches, they incorporate them under a larger umbrella method of either H-D or S-R. In addition, I am concerned in this essay with scientific worldviews in the critical-realist perspective employing empirical activity rather than strictly theoretical reasoning, and some forms of mathematical research may lie outside of this perspective.

It is important to understand that auxiliary tenets of any scientific worldview that are purely scientific as opposed to philosophical in nature are derived from the initial tenets and the actual experiments performed using the above scientific methods. There are many examples of auxiliary tenets in modern science. Mendelian laws of genetics are one such case. These laws themselves were never embedded in the underlying foundational components of science but were derived from the scientific methods being used by an experimenter, in this case Gregor Mendel.<sup>1</sup> Hence, in the scientific worldview, these tenets are auxiliary to the foundational components, but they still can be used for the acquisition of new knowledge.



#### WHAT JUSTIFIES A WORLDVIEW AS SCIENTIFIC?

How do we determine whether a worldview is scientific? As already stated, empirical science is a methodological approach to discover the truths of an orderly, causally driven world that takes into account belief in an actual reality outside of the human mind and the ability of the human mind and human sense experience to grasp that reality.

In light of this, the first justification for any worldview's acting as a scientific one is that it must possess the essential components of a scientific worldview: philosophical presuppositions, scientific methods, and so on. If it does not, the worldview is automatically nonscientific.

Second, the worldview must contain auxiliary tenets with explanatory power and the ability to predict future events with accuracy. Explanatory power and accuracy are important because scientists desire that their conclusions do more than just produce representative models that map onto reality. In addition, the combination of accuracy and a causally ordered universe yields the ability to predict future events based on underlying laws and the initial conditions identified by scientific research. Worldviews that possess explanations about natural phenomena but lack predictive power are nonscientific.

All of these elements lead to a third justification, namely, coherency or consistency. Nowhere in the worldview should there remain gross contradictions that negate the entire system. The worldview must be logically and empirically robust. In the case of biology, where the theories involve concepts that have exceptions, these exceptions should not negate the entire worldview. In biology, theories are normally comprehensive and account for how exceptions arise. The theory of evolution, for example, must be applicable to all species of organisms, not only a small number of them (Mayr 1982; 1988; Gould 2002; Sober and Wilson 1998; Sterelny and Griffiths 1999).

A fourth justification for a scientific worldview is that the laws and theories in the worldview must be "compact," that is, devoid of superfluous explanatory components. In general, this is known as Ockham's razor, and it has been a good guide for the justification of auxiliary tenets in a scientific worldview. Indeed, Ockham's razor has helped to provide "elegance" to theories. The fundamental equations of physics are classic examples of theories that both are elegant and can lead to greater insights. Another example is the double-helix structure of DNA, a model so elegant that scientists immediately saw its potential of furthering hereditary research.

From the above points, it becomes clear that at least some justifications for a worldview being designated as scientific is that the *content* of the worldview itself be justifiable as scientific. There is, however, another justification, namely, a worldview's comprehensiveness; I discuss this in the conclusions that follow.

## CONCLUSIONS

The recurring question in the science-and-religion dialogue is whether any scientific worldview can contain elements of philosophy or theology. Indeed, if scientists, philosophers, and theologians are to reconcile the respective concerns that each possesses, this question must be resolved. As already proposed, any scientific worldview contains presuppositions that are strictly philosophical as opposed to scientific in nature. These philosophical presuppositions had their beginnings early in Judeo-Christian thought. The auxiliary scientific tenets that arise from scientific research are subsequent to these philosophical presuppositions. Thus, it is already obvious that any scientific worldview must possess tenets of philosophy. The question then becomes, Can any scientific worldview possess elements of theology, or, for that matter, resolutions to larger philosophical questions that are not immediately derivable from conclusions of scientific experiments? Scholars with theistic perspectives answer in the affirmative, while skeptics respond in the negative. Who is correct?

It is my opinion that we run into the problem of comprehensiveness here. That is, how comprehensive is our scientific worldview to be? What kinds of questions does it aim to address? Does it answer all of the philosophical, ethical, social, and religious questions that are important to human beings? Can it be an all-encompassing, comprehensive worldview, or must it be a more focused, noncomprehensive one? Scholars in the science-and-religion dialogue have proposed a variety of different answers, most of which regard how science relates to religion (see Barbour 1990; Gould 1999).

I argue that such comprehensiveness cannot be achieved by a strictly scientific worldview. Rather, such comprehensiveness needs a philosophical worldview that may have science as a component but not as the element whereby hierarchical tenets are formed. Rather, in such a worldview scientific information is used by philosophical theory construction to answer questions that science alone could not solve. The question then becomes whether a philosophical worldview is adequate to explain the sum total of reality or whether a theological perspective is required. This position, one that many nontheist scientists refuse to recognize, is actually the position that must be taken given the scope of any scientific worldview. The methods of science answer scientific questions, and the methods of philosophy and theology answer questions about the ethical implications of scientific information or what can be inferred from scientific information about nonscientific phenomena, such as the possible existence of a divine entity whose status is "supernatural" and therefore beyond the immediate hypothetico-deductive or statistical-relevance methods of science, which deal with objects that are naturally observable.

It is beyond the scope of this essay to introduce the full panorama of arguments for and against the need for theology in a comprehensive world-

view. However, a theological worldview is more extensive than a strictly scientific one, because it asks questions that science alone does not ask. Furthermore, it seems clear that the debate in the science-religion dialogue is between comprehensive philosophical worldviews and comprehensive theological worldviews, which act as umbrella worldviews encompassing noncomprehensive scientific worldviews. It also is clear that any comprehensive worldview must take into account the modern noncomprehensive scientific worldview for the obvious reason that if it did not, it would be by definition noncomprehensive itself, lacking the questions the scientific worldview asks and effectively answers.

## NOTE

1. Numerous other cases abound, including the law of gravity in physics, chemical-bond theory in chemistry, and the Central Dogma in molecular biology. All of these ideas have been formulated robustly enough and supported repeatedly enough in experiments that they are incorporated in the modern scientific worldview and are likely to remain, though perhaps with slight modifications. In addition, these tenets are then used for the exploration of new scientific knowledge. As a case in point, the Central Dogma in molecular biology was used for the further exploration into the nature of transcription factors and transcription biology.

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