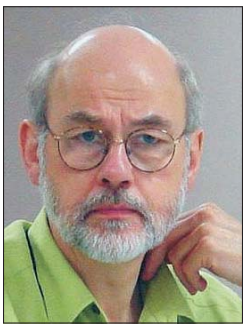

Jitse van der Meer

Background Beliefs, Ideology, and Science

Jitse van der Meer

The notion that not only facts but also personal and communal beliefs contribute to scientific knowledge has become commonplace. It raises two important questions. How can people with very different belief systems work together in science? Can scientific knowledge be trusted if it is shaped and sometimes distorted by beliefs operating in the background of science? I begin by pointing out that scholars who believe in the existence of a mind-independent reality have the moral calling to oppose distortion in their understanding of natural phenomena. I then explain why background beliefs are required for the construction of theories in science. I argue that background beliefs do not necessarily distort scientific knowledge because God created an objectively existing reality that resists distortion. When distortion occurs, science has standard ways of detecting that distortion. These include convergence of mutually independent lines of evidence on the same explanation, the possibility to disconnect background beliefs from scientific explanation, and the self-destruction of background beliefs that assume a dogmatic function. Next I show that in their work scientists, in fact, do sometimes oppose their personal background beliefs. The conclusion is that the background beliefs of scientists do not dictate the content of scientific knowledge, and that people with different belief systems, including Christians, can work together in scientific research. This is not to suggest a return to a Christian form of neopositivism because it fully incorporates what has been learned over the last decades about the extent to which science is embedded in a sociocultural context.

The role of *religious* background beliefs in shaping knowledge became an influential research program in The Netherlands through the work of the theologians Abraham Kuyper (1837–1920) and Herman Bavinck (1854–1921), the philosophers Dirk Vollenhoven (1892–1978) and Herman Dooyeweerd (1894–1977), and the historian of science Reijer Hooykaas (1906–1994).[1] This role was not discovered in historical research. Rather, it was a normative claim grounded by both Kuyper and Bavinck in the comprehensive character of Christ's redeeming work. The need for a redemption of scholarship followed from the long-established notion that human cognitive ability had been affected by the fall into sin.[2] The conviction that Christ uses people as instruments of redemption promoted the development of a program for the redemption of culture including scholarship. One of the implications of this program was that scientific knowledge has a subjective component consisting of background beliefs with a religious function that originate in the knower rather than in the nonhuman world.[3]

While the Dutch research program became internationalized, it never became widely accepted. The notion of the subjectivity of science was popularized, however, as the result of two develop-

Jitse M. van der Meer, *PhD, MA, is Professor of Biology and History & Philosophy of Science, at Redeemer University College, Ancaster, Ontario, Canada.*

ments independent of the Kuyperian school. First, the issue was also explored in Poland, the United Kingdom, and the United States.[4] This pioneering work in the history and philosophy of science and medicine led to a recognition of the role of background beliefs in shaping scientific knowledge. It also triggered the downfall of positivism, the view that not only scientific knowledge, but all knowledge depends only on what can be perceived by the senses and established by reason. These developments were independent of the Kuyperian school of Dutch neo-Calvinism, and they were not motivated by the religious notion of the redemption of scholarship. Their basis in historical scholarship and their justification by philosophical argument made them more widely acceptable. However, the acknowledgment of a subjective dimension of scientific knowledge led some to the extreme of denying that knowledge of nature was possible at all (relativism). Nevertheless, orthodox Christians in Europe and North America welcomed the new philosophy of science because it opened up a role for religion in science, at least potentially. An engagement between the Kuyperian and Kuhnian schools ensued. Few Christians, however, were aware of the relativism implied particularly in Kuhn's views.

The notion that background beliefs shape science is now common currency. It has been variously interpreted. At one end of the spectrum, we have the sociology of knowledge school. Its members hold that truth about nature depends largely or completely on the communal agreement of scientists (subjectivism), not on nature itself. The other extreme is represented by what is left of the logical empiricists also known as the positivist school. For logical empiricists, truth about nature is gained by observation and reason, with the understanding that the outcome depends solely on the object being explored and on the proper use of logic (objectivism). Some Christians have joined the sociology of knowledge school, not because they want to acknowledge the social dimension of knowledge acquisition, but because it allows them arbitrarily to deny the truth of those parts of science that are threatening to them. They reason as follows: if the content of scientific theories is influenced substantially or even completely by background beliefs, then this levels the playing field between, say, naturalism and theism. They do not realize that this move is very costly from a Christian perspective. For one, truth about nature is made to depend completely on the beliefs of the community with the most power. For another—and implied in the previous point—truth no longer depends on what exists objectively as created by God. Is it possible to acknowledge the role of background beliefs in science (subjectivity) and avoid turning background beliefs into the sole source of knowledge of nature (subjectivism)?

The purpose of this article is to review some of the relationships between background beliefs and scientific theories and explanations that have been uncovered. I take for granted that, normally, background beliefs are needed for the construction of theories in the natural sciences.[5] Examples are given in step 3 below. But I argue that this does not justify the popular myth that science consists of a collection of arbitrary opinions exemplified in the expression "it is just a theory," or that relativism reigns supreme in science. My argument is developed in six steps.

Step 1: The Religious Duty of Theists in Science

Two of the less desirable uses of background beliefs have been in the promotion of relativism and in the distortion of scientific knowledge. Postmodern relativists deny that stable knowledge of nature can be attained, because this depends on one's belief of the day. A response to such abuse of background beliefs must begin with the notion that any scholar who believes in the existence of a mind-independent reality has a moral obligation to identify and avoid relativism and distortion. The majority of scientists irrespective of their religious commitments, acknowledge this responsibility and are *critical realists*. That is, they believe that scientific knowledge of nature is shaped by objects of nature and by the beliefs scientists bring to them, and they tend to be critical of the latter. Many are motivated by a desire to be socially responsible and work for the good of the community that supports them. Few want to spend a lifetime attempting to understand something that does not exist.

Theists believe that God created an objectively existing reality. They are *realists* in that respect. This belief gives them an additional reason for the obligation to understand nature with integrity. For

them, it is a religious duty to glorify God in the work of his hands. This cannot be done if one denies that humankind has access to this creation. Such a view is maintained by those who believe that knowledge of nature is a pure mental construction and truth is achieved when all the parts of this construction are mutually consistent (*antirealists*).

Scientific realists do not deny that, in coming to understand nature, humans contribute their beliefs, but they insist that reality decides whether a belief becomes knowledge. Moreover, like everyone else, scientists—both theists and nontheists—are familiar with failure and error. Christians have additional reasons to be sensitive to the imperfection of knowledge, for they recognize it as a consequence of their finitude and of living in a world affected by the Fall. Thus Christian and non-Christian scientists alike tend to be *critical realists*.[6] A Christian's sensitivity to the danger of self-deception is a gift that equips one to be a good scientist. But sensitivity to self-deception is not enough. A range of measures is employed to guard against distortion by background beliefs in science. One of these measures uses the convergence of different lines of evidence on the same explanation or theory, which will now be discussed.

Step 2: Independent Lines of Evidence

A theory or explanation that is supported by evidence contributed by several independent scholars is better protected against distortion than one supported by a single scholar. This is a matter of common sense. News agencies give most credence to consistent reports that have been independently confirmed. When different reports agree among each other about an event, irrespective of the reporters, the reports are taken to be *true*. Likewise, patients decide to undergo medical treatment with more confidence when a second opinion agrees with the first. When a diagnosis is consistently given by different independent physicians who identify the same cause, this is taken to point to the *true* cause of the disease. The principle applied in such cases is that if the same event is reported by different journalists or the same symptoms reported by different physicians, the report is taken to be true—because it does not depend on the reporters. Rather, the report corresponds to reality. The expression "independent lines of evidence" refers to the fact that the content of the reports does not depend on the reporters.

The principle of independent lines of evidence applies also in more complex circumstances in which, instead of simply seeing the same thing, two journalists see different things but infer the same cause. Likewise, two physicians can infer the same cause of a disease from two different sets of observations. For instance, a psychiatrist can attribute insomnia and depression to an abnormally low activity of the thyroid gland. A radiologist can attribute weight gain and an abnormally low level of thyroid hormone to an underperforming thyroid gland. When this happens, it is taken to be a stronger confirmation for the existence of the inferred cause—the malfunctioning thyroid—than in the simple example. In the simple case, two journalists report the same observation. In the complex case, two physicians not only infer the same cause from different observations, but they also make the observations using different methods. One has two different lines of evidence observed by two different people pointing to the same cause. In other words, the existence of the cause, though inferred, is independent not only of the persons doing the inferring, but also of the differences between what is observed and of the method by which the observations were made.

This complex case is analogous to what is meant by independent lines of evidence in science. I see three reasons why the background beliefs of scholars that enter the natural sciences today do not easily distort the interpretation of evidence in theories and explanations (from now on "explanation" for short). First, the number of scholars contributing different pieces of the puzzle is large. Below I will describe examples of scholars who converged on the same explanation despite holding mutually exclusive background beliefs. This shows that their personal background beliefs do not necessarily distort explanation.

Secondly, when convergence fails, science has standard ways of correcting distortions of explanations. In such cases, individual scholars may have to reconsider how their personal background beliefs entered their science. Therefore, taking these two reasons together, a convergence of evidence on the

same explanation is most likely due to the fact that the explanation is correct. It is possible that all participants in a research community distort the evidence in the same direction by contributing the same background beliefs. If these individual background beliefs are mutually independent, the probability of such a random convergence of background beliefs on the same belief is highly unlikely, due to the communal character of research. However, unlikely as that is, the members of a research community may share whatever background beliefs characterize their research community or tradition, if for no other reason than that they share the same education. Their education has socialized them into the background beliefs of a research community. These communal background beliefs may also distort their scholarship.

The third reason why background beliefs do not necessarily distort explanations and theories concerns such communally distorting background beliefs and why they can be excluded from science. Since the development of an explanation may take a long time, the contributing scholars may have lived in different eras, and they therefore tend to belong to different research traditions. When two research traditions separated in time converge on the same explanations, one has increased confidence in the validity of this explanation. This is what happened when quantum physicists realized that classical Newtonian physics remained valid as a special case of quantum physics. This also holds for scholars living in the same era and belonging to different schools of thought. In the history of biology, scholars in the mechanist and vitalist schools of thought eventually converged on the notion that organisms are like machines that can generate their own purposes.[7] Earlier forms of mechanism assumed that purpose was externally imposed, whereas earlier forms of vitalism interpreted purpose as a nonmaterial force. One can have confidence in the validity of an explanation independently arrived at by scholars in two communities that used to be considered mutually exclusive.

I shall explain why personal as well as communal background beliefs are open to questioning (steps 3 and 4). But let us first look at examples of convergence of different lines of evidence on the same explanation in the natural sciences. We will take physics first and focus on the contributions of Galileo, Kepler, Newton, and Laplace to the theory of mechanics.[8] Galileo (1564–1642) developed descriptions of the parabolic path of a projectile and of the relation between speed, time, and distance traveled by a body that falls with uniformly accelerated motion. Kepler (1571–1630) formulated mathematical laws for planetary motion. Isaac Newton (1643–1727) unified the work of Galileo and Kepler and expanded it in the three laws of motion first published in his *Philosophiæ Naturalis Principia Mathematica* on July 5, 1687.[9] The first law states that every body persists in its state of rest or of uniform motion, that is, motion with constant speed in a straight line, unless it is compelled to change that state by forces impressed on it. This means that in the absence of a net force, the center of mass of a body either is at rest or moves at a constant velocity. The second law states that a body of mass m subject to a force $\boldsymbol{F}$ undergoes an acceleration $\boldsymbol{a}$ that has the same direction as the force and a magnitude that is directly proportional to the force and inversely proportional to the mass, i.e., $\boldsymbol{F} = m\boldsymbol{a}$. Alternatively, the total force applied on a body is equal to the time derivative of linear momentum of the body. Finally, the third law asserts that the mutual forces between two bodies are equal, opposite, and collinear. This means that whenever a first body exerts a force $\boldsymbol{F}$ on a second body, the second body exerts a force $-\boldsymbol{F}$ on the first body. $\boldsymbol{F}$ and $-\boldsymbol{F}$ are equal in magnitude and opposite in direction. This law is sometimes referred to as the action-reaction law, with $\boldsymbol{F}$ called the "action" and $-\boldsymbol{F}$ the "reaction."

Newton used his three laws to explain the motion of many physical objects and systems (including those studied by Galileo and Kepler), as well as the fall of an apple from a tree.[10] For example, in the third volume of the *Philosophiæ*, Newton showed that these laws of motion, combined with his law of universal gravitation [$F = Gm_1 m_2 / R^2$ or $\boldsymbol{F} = m\boldsymbol{g}$ for earth], explained Kepler's laws of planetary motion. Further included in Newton's unifying account were Galileo's descriptions of the parabolic path of a projectile and the relation between speed, time and distance traveled by a body that falls with uniformly accelerated motion. Finally, the mathematical description of planetary orbits in Newtonian mechanics was simplified by Lagrange (1736–1813) and given a historical explanation by Pierre-Simon

Laplace (1749–1827). Laplace postulated that the solar system began as a nebulous cloud which gradually separated into rings, each of which in turn eventually coalesced to form the planets. This explained why the planets moved approximately in the same plane and direction. The simplification was taken by many to imply that divine corrections were no longer required to keep the planets in orbit, as Newton had thought. Together, Lagrange and Laplace had shown how the solar system could stabilize itself.

The point is that Galileo was a Roman Catholic, Kepler a Protestant platonist, Newton a Unitarian deist, and Laplace an atheist. Despite these differences in personal religious and metaphysical background beliefs, they contributed to the development of mechanics. Kepler's commitment to Platonism caused him to expect planetary orbits to be perfect circles. Famously, it took him more than thirty years to come to grips with their elliptical shape. Laplace was an atheist and his nebular hypothesis was designed to replace references to purpose and design with those to the operation of physical laws. But note that this motivation plays no role in the question of truth which depends on the facts about our solar system. This illustrates that physical reality resists being distorted by the background beliefs of individual contributing scholars. On the other hand, they shared a view of the cosmos as a machine. But this only moves the question of how they could contribute to the theory of mechanics from the level of theory to that of background belief. What calls for explanation is how they could share a mechanical view of the cosmos given their different background beliefs. This will be explained in step 3.

We will next consider a more technical example of convergence of different lines of evidence on the same explanation in modern physics.[11] According to theory, the sun is powered by nuclear fusion. How do we know this? This claim is what one could call a high-level theory under which several unrelated models and theories are brought together. Each model and theory in turn employs several lower-level models and theories. Finally, each of the latter is supported by converging lines of evidence. So we do not have just one theory on which different lines of evidence converge. We have a network of such convergences. At the most directly experimental level, an abundance of evidence gives strong support to a limited number of theories and models. The latter all point with great clarity toward substantiating the theoretical claim that the energy of the sun is produced by nuclear fusion. The number of contributors of all this evidence runs in the thousands. But it is not only the sheer number that ensures diversity of background beliefs. The scientists also lived in different places and times, and in nearly every case, they were confronted with completely unexpected results with which they had to grapple, and which were significantly resisted by the scientific community at large. Some of the evidence is listed below.

1. Models of gravitational/radiation balance in stars including the sun are based on

- Newton's theory of gravity, which is confirmed to high precision through solar system observations and through lab experiments.
- The mass and size of the sun, which are determined through distance ranging, the theory of gravity, trigonometry, the speed of light, and the length of the year. In turn, the speed of light is routinely measured and relied upon both in the labs and in the wider solar system, and is well understood in terms of classical electromagnetic theory and the electrical and magnetic properties of the vacuum.
- A theoretical understanding of radiation pressure based on electromagnetic theory and Einstein's theory of special relativity (to understand momentum of particles of light), and confirmed through thousands of unrelated experiments.

2. Models of the interior of the sun, confirmed through helioseismology and consistent with the conditions required for nuclear fusion.

3. Models of nuclear fusion consistent with Einstein's theory of special relativity to relate mass and energy; more generally, high-energy particle theory. Both are confirmed through thousands of unrelated experiments and billions of independent unrelated collision events analyzed in particle colliders all around the world.

4. Coherence with astrophysical explanations of observations of relative abundances of the chemical elements throughout the universe, as observed via

spectral analysis of stars, interstellar matter, and galaxies. The spectral analysis uses standard laboratory practices of wave optics, and probes the gas emission and absorption of electromagnetic radiation which are well understood using quantum chemistry.

5. Coherence with the measured rate of detection of solar neutrinos along with the later experimental confirmation of neutrino oscillations, which resolved an anomaly that lasted three decades.

6. Consistency with a wide range of applications of stellar astrophysics, such as the models of end states of stars in which nuclear fusion plays a well understood role even in the extreme conditions of supernovae, including the production of neutrinos.

In addition, there is the clear failure of every alternative scientific model considered (such as earlier suggestions that the sun is powered by chemical processes) to allow for the observed radiative energy output, stability, spectrum, resonances, etc.

The third example of convergence of different lines of evidence on the same explanation is from geology. We will take the theory of plate tectonics. This theory explains how the continents on Earth are formed by the breaking apart of a single continent into fragments that moved away from each other to form the currently known continents. A small selection of independent lines of evidence includes the geometric fit of the displaced continents (such as between West Africa and the eastern coast of South America), the similarity of rock ages and Paleozoic fossils in corresponding rock strata between continents, the deep trenches in the ocean floor where one plate descends under another plate (troughs), the mountain ranges in the sea floor midway between continents (mid-ocean ridges), and seashells on mountaintops, due to uplift of crust in collision zones.

Furthermore, sea floor spreading explains the movement of continents. Along the length of a mid-ocean ridge, new magma from deep within the earth rises up and erupts in hydrothermal vents or smokestacks to create new oceanic crust.[12] This process pushes continents away from each other and from the ridge. Lines of evidence supporting this explanation include radiometric dates, fossil studies, and earth magnetism. Radioactivity-based rock ages are similar in equidistant bands symmetrically centered on the mid-ocean ridge. The age of the rocks increases as their distance from the mid-ocean ridge increases. Also, identical fossils are found in bands equidistant from the ridge. This shows that a particular band of crust shared a similar history as its corresponding band of crust located on the other side of the ridge. Just as similar age bands and fossil bands exist on either side of a ridge, studies of the magnetic orientations of rocks reveal bands of similar magnetic orientation that are equidistant and on both sides of a mid-ocean ridge. This list is very incomplete, yet its abundance is sufficient to make the point of independent lines of evidence.[13]

The final example concerns convergence of different lines of evidence on the same account in biology. The theory of biological species formation enjoys several instances of independent confirmation. For instance, studies of the history of over one hundred fruit fly species on the Hawaiian islands show a remarkable fit between geological, biological, and geographical lines of evidence. Geological studies of plate tectonics show that the Pacific Plate moves northwestward over a stationary hotspot in the core of the earth. The hotspot melts the plate moving above it spawning a series of volcanic islands as it goes.[14] Thus, the oldest island is expected, and found, at the extreme northwest tip of the submarine mountain chain, 2,400 km from Hawaii and near Kamchatka Peninsula (Eastern Russia).[15] This evidence from plate tectonics correlates with evidence from isotope ratios of $^{40}Ar/^{39}Ar$, showing that the oldest islands by argon dating are also the smallest, i.e., the most eroded, and are located in the northwest as expected. The youngest islands are the largest and located, as predicted, in the southeast (e.g., Hawaii).

These two lines of geological evidence are matched by three independent lines in biology. By and large, the same genealogy of fruit fly species has been obtained from comparison of morphological characters, DNA sequences, and chromosome mutations. Finally, looking at the geographic location of the different species, we see that the phylogenetically youngest species of *Drosophila* are found on the geologically youngest islands of the Hawaiian Archipelago, because they were the last to be colonized by the fruit flies.[16] In sum, we have a cor-

relation among the history of mutations in their chromosomes, the geographic distribution of their species, the time sequence in which the islands surfaced above sea level as a result of volcanic action, and the direction of continental drift. This research program, started in 1963 and continuing, involves five independent lines of evidence. The list of contributors runs into the hundreds and includes people from different cultures around the globe. Their background beliefs are not known, but one can be sure that such an international cast of characters holds a diversity of background beliefs. Yet they all agree on a common reconstruction of the natural history of Hawaiian fruit flies. As in the previous examples, this agreement is likely underwritten by broad agreement about scientific methodology both general and discipline-specific. But, as before, this moves the question of how scientists could contribute to the natural history of Hawaiian fruit flies from the level of theory to that of background belief. The question is how they could share this natural history despite their differences in background beliefs. This will be explained in step 3.

Step 3: Background Beliefs *Can* Be Separated from Scientific Explanation

What happens when different lines of evidence do not converge on the same explanation? There are many reasons why this could happen. We will ignore all of them in order to focus on the possibility that a failure of convergence is due to distortion of evidence by background beliefs. Can this be undone? Logically, a background belief functions as a presupposition of a theory or explanation. Any explanation or theory presupposes one or more background beliefs. In this section, I argue that background beliefs can be logically disconnected from the explanation they support. The key point is that a background belief does not dictate a theory.[17] The reason is that there is no simple necessary (logical) link between belief—Christian or otherwise—and scientific explanation. Background beliefs exist at different levels of generality. The following examples use ultimate beliefs—background beliefs that operate at the highest level of generality as metaphysical or religious beliefs. The conclusions apply also to lower-level background beliefs that characterize schools of thought or research traditions.

A background belief alone does not dictate a theory

Evidence for the thesis that background beliefs can be separated from scientific explanation comes from the fact that mutually inconsistent explanations can be subsumed under the same theistic background belief. For instance, the background belief that God created animals with a purpose—the purpose to reproduce, for instance—has had at least two mutually exclusive explanations (fig. 1).

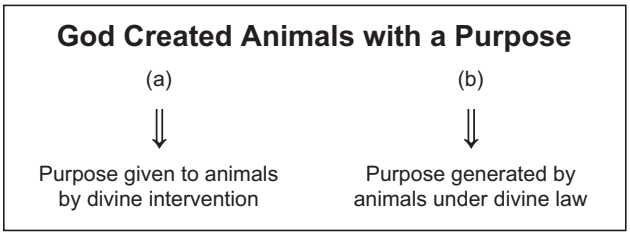

Figure 1. Mutually inconsistent theories (a) and (b) can be subsumed under the same background belief. The background belief that God created animals with a purpose can be specified in at least two different ways. (a) Adding the hypothesis that God acts by intervention makes the purposeful organization of animals directly dependent upon continuous divine intervention. It follows that organisms receive their purposes directly from outside of themselves. (b) By adding the hypothesis that God acts via natural law, it follows that he has created organisms with the capacity to generate their own purposes. That is, organisms receive their purposes indirectly from outside of themselves. Without the specifying hypotheses, the background belief does not dictate (entail) the theories. The theories presuppose the background belief.

If, with the Tübingen physiologist Carl Friedrich Kielmeyer (1765–1844), we add the specifying hypothesis that God acts via natural law, it follows that God has created organisms with the capacity to generate their own purposes. On the other hand, if, with the French zoologist Georges Cuvier (1769–1832) organisms are seen as depending directly on God for their purpose, it follows that organisms receive their purposes from outside of themselves when they were created. Thus, in conjunction with the shared background belief that God created animals with a purpose, different specifying assumptions on how God acts in the world—by natural law or by intervention—lead to different explanations for purposeful behavior of animals. Purposeful behavior is generated internally by the organism if God creates by natural law, but externally if organisms are created without this internal capacity. Both explanations logically presuppose the background

belief that God created animals with a purpose. But the background belief alone does not dictate (entail) either explanation.

A background belief is more general than a specifying assumption. A specifying assumption differs from a background belief in that it specifies the latter. The resulting explanation is less general than the background belief from which it is derived. The reason why two mutually exclusive explanations can be derived from the same background belief in the Creator lies in the different specifying assumptions about how God acts in the world. If theories were dictated by background beliefs, then a single theory would be associated with just one background belief without involvement of specifying assumptions.

The second example of mutually exclusive explanations under the same background belief is from astronomy. Isaac Newton (1642–1727) had developed a mathematical description of the planetary orbits. The description implied that a planet would gradually leave its orbit. To prevent this, Newton believed God would intervene from time to time to make a correction in the orbit. Gottfried Wilhelm Leibniz (1646–1716) objected that this was not in keeping with God's perfections. God is all-knowing, and so he would have foreseen this problem by creating a planetary system without the need for intervention. The point is this: both Newton and Leibniz believed that God is the Creator of the cosmos. They agreed that God is all-powerful, all-knowing, good, and free. But they disagreed on the need for divine intervention in the planetary system because they emphasized different attributes of God (fig. 2).

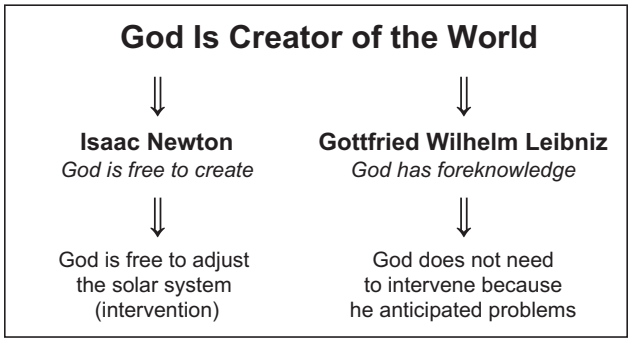

Figure 2. Newton and Leibniz disagreed on the need for divine intervention in the planetary system because they had different ideas on how divine omnipotence is manifested in divine action.

Newton emphasized divine omnipotence. This meant that God was free to create what he willed, leading Newton to add the specifying assumption that God acts in the world by intervention. In contrast, Leibniz stressed that God is omniscient. An all-knowing God can anticipate all the implications of what he wanted to create before he had created it, so that there was no need for corrections afterward. This led Leibniz to add the specifying assumption that God created things so perfectly that they act according to their own laws.[18] Hence Leibniz rejected Newton's specifying assumption.

Again, two mutually exclusive explanations of planetary behavior can be subsumed under the same theistic background belief. Each explanation presupposes the background belief that God created the world. But this background belief alone does not dictate the explanation. The difference between the two explanations of planetary behavior lies in the different emphases Newton and Leibniz placed on the attributes of the Creator—the freedom to create or the foreknowledge of what would happen in the products of his creative action. This led them to add different specifying assumptions to their common background belief.

These two examples show that mutually inconsistent explanations in biology and in physics can be subsumed under the same religious background beliefs by adding different specifying assumptions about divine action. Therefore, the background beliefs alone do not dictate explanations. They do so in conjunction with a specifying hypothesis. By changing the specifying hypothesis, the background belief can be made to dictate a different explanation. Therefore, if a background belief is suspected of disrupting a convergence of different lines of evidence on the same explanation by distorting the evidence, this can be undone by changing the specifying hypothesis. Conversely, the explanations dictate the background belief. But this is irrelevant for the purpose of removing distortion of evidence by background beliefs.

There is more evidence showing that background beliefs can be separated from scientific explanation. In the preceding two examples, mutually inconsistent explanations were subsumed under the same religious background belief. But the converse is also

possible. Different background beliefs can provide presuppositions for the same explanation. That is, the same explanation can be subsumed under mutually exclusive background beliefs by adding different specifying assumptions to the background beliefs. This would not occur if background beliefs dictated explanations. A case in point involves teleomechanism—the theory that organisms are machines that generate their own purposes. Christian teleomechanism is a background belief held by a number of nineteenth-century German biologists. They believed that organisms were designed by God with a built-in ability to generate their own purpose. Both materialism and Christianity have been made more specific in order to support the theory that organisms generate their own purposes (fig. 3).

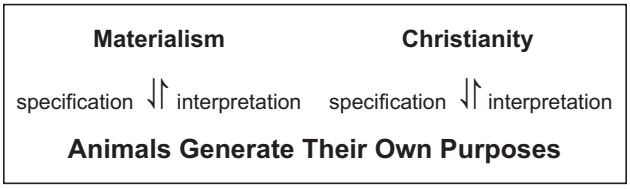

Figure 3. The same theory under mutually exclusive background beliefs. The theory does not dictate the background beliefs (materialism and Christianity do not dictate the theory).

Materialists, who believe that the purposive behavior of organisms is real and not only apparent, made their background belief more specific by adding the specifying hypothesis that matter has the potential to produce purposive organisms. Christians specified their belief in the Creator by adding that God designed organisms with the ability to generate their own purpose. In other words, the purposiveness of organisms can be derived from nonreligious as well as religious background beliefs by adding different specifying hypotheses. Therefore, the theory that organisms generate their own purposes is logically independent of the background belief that God has created things for a purpose. God could have intervened to impose a purpose. Moving in the opposite direction from theory to background belief means that the purposiveness observed in organisms can be interpreted in religious and nonreligious ways. Logically, this example is identical to the previous ones in that the two background beliefs alone—materialism and Christianity—do not dictate the theory that organisms generate their own purposes. It is the background belief in conjunction with a specifying assumption that entails the theory that organisms generate their own purposes. But this example is different from the previous examples in that the theory does not presuppose either background belief.

These examples show that the same theory can be subsumed under mutually inconsistent background beliefs. This also supports my thesis that background beliefs can be separated from scientific explanation by changing the specifying assumptions. As before, this conclusion applies to background beliefs at all levels of generality. Since the examples use religious beliefs this conclusion includes the highest level of generality or ultimate beliefs.

Interim conclusion

A particular philosophical or religious belief, operating in the background of science, cannot dictate or entail a particular explanation in a simple way because the explanation is connected with many other specifying assumptions. The examples show that, logically, an explanation can be separated from its background belief. This is possible because background beliefs of a high level of generality need to be made specific before they can be tested. This specification is achieved by adding specifying hypotheses to the background belief. Since the specifying hypotheses can be replaced, background beliefs do not simply dictate explanations of natural phenomena. This takes care of the scientific relativism implied if religious and other background beliefs dictated scientific explanations. Different religious background beliefs can be made consistent with the same observations and explanations by adding different specifying hypotheses.

It follows that scriptural presuppositions do not dictate a kind of scholarship with a uniquely Christian content. The difference between two kinds of scholarship remains limited to the background beliefs of scientists. This conclusion is supported by the existence of schools of thought in science which differ in their background beliefs. In physics, there are different interpretations of quantum physics. In biology, gradualism and punctuated equilibrium represent different schools of evolutionary theory. In geology, uniformitarianism and catastrophism were different interpretations of earth history. Scholars in different traditions have different background beliefs, but they share observations and ex-

planations. Likewise, Christians and non-Christians can share observations and explanations because science is rooted in an objective reality.

Conversely, a particular explanation in science may or may not presuppose a particular worldview or philosophy, as the case of teleomechanism shows. Unfortunately, the complexity of the relationships between background beliefs and explanations, and the associated complexity of separating ideology from science, provides a cover for those who abuse theories for the promotion of ideologies. Preachers of a secular religion, such as Carl Sagan, Richard Dawkins, and Daniel Dennett, have not done sober science a favor by promoting an aggressive anti-Christian atheism in the name of science. Christians need to learn to see through this abuse of science if they do not want to throw out the baby of science with the bath water of ideology. Otherwise, they will have failed their God-given calling to glorify the Creator in his creation. Sober atheists can see through the charade, as their critique of Richard Dawkins shows. The Canadian philosopher and religious skeptic Michael Ruse commented recently: "I am indignant at the poor quality of the argumentation in Dawkins, Dennett, Hitchens, and all of the others in that group [of atheists]."[19]

It is unfortunate that many Christians have been unable to distinguish between the science and the background belief. Thomas Nagel—a self-declared atheist—recently whipped up a storm of protest among "the secular theoretical establishment and the contemporary enlightened culture which it dominates" by observing that it is devoted beyond all reason to a "dominant scientific naturalism, heavily dependent on Darwinian explanations of practically everything, and armed to the teeth against attacks from religion."[20]

Step 4: Scientists Have Kept Their Background Beliefs out of Their Theory

The examples just described focus on the logical aspect of connections between background beliefs and explanations in science. They show that, from a logical point of view, the two can be disconnected by changing specifying assumptions. This looseness of connection between background belief and explanation also applies to the work of scientists at a personal level, as will be shown with two sets of examples.

First, one reason not to worry about distortion by background beliefs is the phenomenon of repeated independent discovery. For instance, in ancient Chinese culture, the scarcity of written records caused mathematicians often to rediscover or reinvent earlier achievements.[21] In Western Europe, the laws of Mendel in genetics were rediscovered independently in 1903 by three geneticists. This is analogous to four different reporters confirming the same event. Clearly, the content of such reports or discoveries does not depend on the background beliefs of the discoverer. The phenomenon of repeated independent discovery excludes a possible distortion by background beliefs at the individual level.

The discovery of the same mathematical and scientific knowledge in different and isolated cultures excludes distortion due to shared background beliefs such as found in research programs and schools of thought. For instance, mathematical knowledge discovered independently in Western Europe and ancient China includes the binomial theorem, the solution of n-th roots and polynomial equations via Horner's method, the earliest use of negative numbers, combinatorial analysis, Gaussian elimination for the solution of systems of linear equations, solutions of indeterminate integer equations, algebra with infinite series and finite-difference interpolation methods.[22] Further, in physics, Newton's first law (the law of inertia) apparently occurred to several different natural philosophers and scientists independently. The inertia of motion was described in the third century BC by the Chinese philosopher Mo Tzu, and in the eleventh century by the Muslim physicists Alhazen[23] and Avicenna.[24] The seventeenth-century philosopher René Descartes also formulated the law, although he did not perform any experiments to confirm it.[25] These scholars are separated by many centuries as well as by deeply different cultural values. They could not have shared background beliefs that might explain their convergence on the same discovery.

Let's return to the distorting role of background beliefs held by individuals. The second set of ex-

amples is from the history of racism, which involves the interaction between society and genetics. I will focus on the social and individual background beliefs of the geneticists Karl Pearson (1857–1936), Ronald Fisher (1890–1962), and John Haldane (1892–1964). They resisted the temptation of allowing their personal background beliefs to distort their scientific knowledge.

Pearson is a founder of modern statistics. His statistical approach to human genetics has been shown to be motivated by biological problems, and not by the ideology of eugenics which he held strongly. Fisher is a founder of population genetics. He showed how difficult it would be to eliminate harmful genes from a human population despite the fact that this was the ideal of the eugenics movement which he endorsed. Finally, Haldane developed important parts of the theory of natural selection despite his suspicions of the eugenics movement which wanted to apply artificial selection to purify the human race.[26]

These scholars did not allow their work in genetics to be distorted by their background beliefs, even though the two were contrary to each other. "The ideology of eugenics does not dictate a kind of scholarship with a uniquely eugenics-oriented content."[27] The point is twofold: the theory of biological evolution does not dictate eugenics theories or practices; the theory is not evil just because some ideologues abused it for their evil purposes. Such a conclusion would be as unwarranted as characterizing the internet as evil because some terrorists post recipes for bomb making. This becomes even more obvious by considering that the theory of biological evolution actually worked against racism in at least two ways. First, the genetic theory of natural selection undermined the idea that parallel evolution of different human races would produce or had produced different human species. It did so by pointing out that races had not been separated long enough to have become different human species. Second, the genetic theory of natural selection emphasized the genetic unity of all humans by pointing out that all humans have a common ancestor. In that way, it opposed discrimination based on race.

So far, I have argued that a Christian has the responsibility to remove distortion by background beliefs from scientific explanations, that the communal nature of research in science helps guard against such distortion, that the removal of distortion is possible from a logical point of view, and that scientists have developed explanations and theories that went against their personal background beliefs. Distortion is a derailment of the normal and generally constructive role of background beliefs. What is this constructive role, and how can background beliefs fulfill it without encouraging relativism?

Step 5: The Constructive Role of Background Beliefs

Normally, background beliefs help construct scientific theories and explanations. A scientific theory goes beyond the data—otherwise it could not explain anything.[28] Background beliefs contribute the part of a theory that goes beyond the data. Scientists are free to take any suitable background belief from their social and cultural context. Take, for instance, Galileo's heliocentric cosmology, which suggested that the tides might be the result of the daily and annual movements of the earth. He came upon his theory of the tides one day as he observed the movement of water in a gondola in Venice. As the gondola moved forward, the water in it sloshed backwards, piling up at the stern. Galileo thought the tides might be water piling up on a global scale.

Picture the orbit of Earth moving around the sun once a year.[29] At the same time, Earth is also rotating daily anticlockwise around its axis. Now draw an imaginary line connecting the center of the sun with that of Earth. This line intersects the circumference of Earth at two points: one toward the sun (B) and the other (A) away from the sun opposite (B). At (A), the direction of Earth's orbit around the sun coincides with that of its axial rotation. With the two movements reinforcing each other, Galileo reasoned that water in the oceans would pile up at the trailing end of Earth just as it did in the gondola: high tide. At (B), the two movements would occur in opposite directions, one cancelling out the other, and no water would accumulate. In fact, water would flow to the other side: low tide. The theory was based on a background belief and on the experience of everyday life in Venice.

Now let us consider the implications of this theory. For instance, Earth rotates around its axis in 24 hours. So Galileo's high tide moves around the globe in 24 hours and so does his low tide. But anyone living near the sea knows that there are two high tides per day. The background belief received no support from observation and had to be replaced.

I wrote that scientists are free to use any suitable background belief, but that is where the freedom stops. In theory construction, the support from a background belief can become permanent only if this belief corresponds with observation and with other well-established theories. Only then is it rational and justified to accept the background belief as scientific knowledge. Therefore, background beliefs do not necessarily distort scientific knowledge into a collection of arbitrary opinions (subjectivism). Nor do they make scientific knowledge of nature impossible (relativism). This is illustrated by the subsequent history of the theory of the tides which led to the acceptable theory as we have it today.

Scientists are called to construct their theories in the closest possible correspondence with an objectively existing reality. If a background belief does not become scientific knowledge, it will have to be specified by a different specifying assumption or make place for a better alternative. Failure to do so is one of the reasons why the constructive role of a background belief can turn into a destructive one distorting the truth. The transformation of an open-minded heuristic attitude towards an explanation to a close-minded dogmatic one can be a gradual one as the case of Galileo demonstrates. Scientists are human and they do not easily part with their work. There can be many reasons for this reluctance. Let us look at an example.

Galileo and his contemporaries were aware of the shortcomings of his theory of the tides because there are two daily high tides at Venice instead of one, about twelve hours apart. Galileo dismissed this anomaly as the result of several secondary causes, including the shape of the sea, its depth, and other factors.[30] While these were valid reasons for retaining his theory, Galileo had a far weightier reason to do so. His theory explained the tides as the result of the daily and annual movements of the earth. If true, the theory of the tides would become evidence for his theory of a planetary system with the sun in the center. The latter was the crowning achievement of Galileo's career and the reason for his conflict with the church. The stakes were high. But in the end these personal and social interests made no difference. Observations shaped the understanding of the tides as we have it today. Already during Galileo's lifetime, his colleague, the astronomer Kepler, had suggested that the moon was one of the causes of the tides, and it is part of the explanation today.[31] This shows how the communal character of scientific research screens out personal preferences.

When we look at the history of a theory such as the theory of the tides, we see that the recruitment by science of support from culture may go through cycles. When a theory needs to be reconstructed, a new background belief may be required again. Thus background beliefs need to be replaceable. They cannot be held dogmatically because, at one point or another, they will start to distort scientific knowledge.

The kind of background beliefs that are recruited to support a theory depend on local cultural and historical circumstances. In current pluralistic Western societies, a wide variety of other sources provide supporting background beliefs. From the Middle Ages through the Early Modern Era, the Christian religion was an obvious source of background beliefs because the European culture was largely Christian. In our time, this still holds for individual Christians. This raises a question. I wrote that a background belief will have to be specified by a different specifying assumption or make place for a better alternative, if it does not become scientific knowledge. If this background belief is one of the fundamental beliefs of the Christian faith, would this not imply that a Christian should be willing to live and die for an ordinary background belief in the same way as a Christian is committed to live and die for one's Savior and Lord? On the other hand, would this not imply that a Christian ought to be prepared to replace one of the fundamental beliefs of Christianity along with other undesirable background beliefs when necessary?

Both implications are wrong because they fail to distinguish the limited function of background

beliefs in scientific reasoning from a relationship with a person—in this case, the person of Jesus Christ. It is true, of course, that a Christian can lose the faith. But this is almost always due to personal experiences. Any personal relationship has a much broader basis than a rational commitment to a background belief, even though the latter is part of this basis. A Christian background belief, such as the belief that God is the Creator of all that exists, has this broader basis by virtue of being embedded in such a personal relationship.

Any specifically Christian background belief has a broad spectrum of functions by virtue of having this broad basis. When a Christian uses such a belief in a scientific argument, then the broad spectrum of its functions is modulated such that its intellectual function dominates.[32] That intellectual function can be changed without affecting the entire spectrum of functions. Besides, the intellectual function might not have to be changed, because one can replace the specifying hypothesis that connects the background belief with a scientific explanation. Sometimes, however, the need to reconsider a specifically Christian background belief leads to loss of faith. This may be due to a leveling of the playing field between a personal relationship with Jesus Christ and background beliefs that function in science. This has the effect of reducing the personal relationship to a purely rational connection. The problem then lies with the reduced relationship, not with science.

Background beliefs that function dogmatically are not the only ones inadmissible in science. God also cannot be part of a scientific explanation. This is in part because asserting that God created volcanoes, for instance, while true, would not explain where volcanoes are located or why they erupt. Scientific explanation has the narrow goal of finding material causes by learning from experience, and God just is not a material cause because this would turn him into a creature. Rather, God is the Creator of all material causes. In this way, a scientist is like the farmer in Isa. 28:23–29 for whom learning from experience is the same as receiving knowledge from the Lord. Further, if God were to be a part of an explanation, this would mean that God would be treated as if he were a variable to be manipulated by an experimenter. To treat God that way would be blasphemous in my view and, therefore, totally unacceptable from a Christian standpoint. Finally, is it not appropriate to explain material phenomena in terms of material causes, because God made them of matter?

Step 6: Self-destructive Background Beliefs

So far, I have argued that background beliefs are required for the construction of scientific explanations and that the two can be logically separated. But logical relationships between background beliefs and science are not the only relationship at issue.

Mary Hesse observed,

> Those (like philosophers) whose business is logic and argument are too prone to neglect the fact that there can be very important tendencies and plausibilities among ideas which are less than strict entailment, but which are highly influential upon thought, and are not simply exorcized by pointing out that they are not logically conclusive. We should look very carefully at such tendencies to see how far we ought to be pushed for good reasons to accept them, and how far we ought to resist them.[33]

Hesse made her observation in connection with reductionism. Reduction or redescription of reality, Hesse argued, can be a legitimate part of discovery. For instance, religion and morality can be redescribed as social or biological phenomena. This can be constructive if the social or biological redescription is intended heuristically with a mind open to other aspects of religion and morality. But the same redescription can become destructive when it is offered dogmatically as a complete characterization of religion and morality. In other words, while background beliefs function logically in arguments, they can assume a dogmatic function.

I have argued that background beliefs function at different levels of generality. I now add that at each level they can function heuristically or dogmatically. In our example, any background belief would function dogmatically if it denied the reality of aspects of religion and morality other than social or biological aspects. In that way, the constructive function of a background belief can turn into a destructive one when it becomes a rigidly dogmatic ideology. This is what I think Abraham Kuyper had in mind

when he spoke about the antithesis between the "two cities" of Augustine, Christianity and the world. He was pointing to the ideological functioning of background beliefs primarily at a higher level of generality, far removed from observation and theory.

I have also argued that background beliefs at any level of generality can be disconnected from associated theories by changing the specifying assumptions. One might ask whether the dogmatic attitude with which background beliefs can be held does not trivialize this freedom. I do not think so because ideologies can be disconnected from theories in other ways than changing specifying assumptions. Let me support this claim with two well-known examples of such ideologies: naturalism and empiricism.

Naturalism is the view that nature is all that exists and that knowledge consists of accounts in terms of natural causes. The example focuses on the reduction of mind to matter. Charles Darwin seems to have been the first to recognize the problem now referred to as "Darwin's Doubt."

> With me the horrid doubt always arises whether the convictions of man's mind, which has been developed from the mind of the lower animals, are of any value or at all trustworthy. Would any one trust in the convictions of a monkey's mind, if there are any convictions in such a mind?[34]

In his elaboration of Darwin's reduction of thought to physics, Alvin Plantinga argues that it is irrational to believe in evolutionary naturalism because it denies that humans can develop reliable, true beliefs about reality.[35]

The same arguments have been made when naturalism is specified as materialism. J. B. S. Haldane offers one of the most succinct renditions:

> If my mental processes are determined wholly by the motions of atoms in my brain, I have no reason to suppose that my beliefs are true … and hence I have no reason for supposing my brain to be composed of atoms.[36]

In the words of Erwin Strauss: "Physics refutes physicalism."[37] As Marjorie Grene explains:

> If there is any knowledge, including, if that were possible, the "knowledge" that there is nothing but material particles in motion, then there must be something other than material particles in motion, namely something—I don't mean some "stuff," but some process, some real existent who can make a competent, if not a veridical claim that this is so. But molecules make no claim to truth, anymore than they can err. So if there is any knowledge, even "molecular science," there is *something* more than the subject matter of molecular science. There are at least molecular scientists. In other words, either there is no knowledge (including the knowledge of philosophical atomism), or there is at least the knowledge that philosophical atomism is false.[38]

Grene explicitly acknowledges that "a one-level ontology contradicts itself."[39] She uses self-contradiction as a criterion for identifying two levels.

Finally, Polanyi makes the argument in a critique of the machine view of organisms. He argues that biologists are mistaken when they claim that a mechanistic explanation of organisms is an explanation in terms of the laws of physics and chemistry. The mistake, Polanyi points out, is that the principles of operation of a machine cannot be explained in terms of the laws of physics and chemistry, but require a reference to design principles provided by engineers who impose a purpose on the machine.[40] In conclusion, denial of the existence of realities other than matter leads to self-contradiction. Self-contradiction can be avoided by acknowledging the existence of these other realities with their own irreducible lawful orders. This is a good reason for rejecting the ideological function a background belief may assume due to the dogmatic interests of the one holding that belief. It keeps open the possibility of disconnecting background beliefs and theories. Dooyeweerd has developed the notion of avoiding self-contradiction as a general strategy for distinguishing different kinds of lawful order in the universe.[41]

Empiricism is the view that sense experience is the ultimate source of all knowledge. Knowledge of nature cannot be had from visions, hallucinations, or mere reflection. The well-known problem of induction serves to illustrate the self-destructive character of empiricism. As Hume argued, the absolute truth and universal validity of empirical knowledge cannot be proven by experience because it presupposes what it aims to prove. According to Hume, insofar as the principle of uniformity is a generalization based

on experience, it suffers from the problem of induction. "It is impossible, therefore, that any arguments from experience can prove this resemblance of the past to the future; since all these arguments are founded on the supposition of that resemblance."[42] That is, the experience of uniformity can be generalized only on the understanding that the truth of the generalization is not absolute, but probabilistic.[43] Hume's escape was to declare the experience-based expectation that the same causes are associated with the same effect a habit. Kant's answer was to declare the principle of uniformity to be a metaphysical principle. That is, Kant redefined knowledge as a product of both sensation and mentition, whereas Hume had defined it as a product of sensation only. Both responses disconnect the dogmatic form of empiricism from theories without the need to change specifying assumptions.

The problem of induction exemplifies that the scientific enterprise also requires the ability to argue about what is true and false. This ability cannot be established by science itself because truth and error are abstract realities. They cannot be perceived by the senses. Also, from this angle, it can be seen that science has needs that it cannot provide itself. Claims to the effect that sense perception can supply those needs are self-destructive, as in the case of naturalism. The implication of this limitation of science is that it cannot produce knowledge about things that are not perceivable, such as values and God. Yet there are many who ignore this limitation. One such value is the notion that sense perception is the only valid method of acquiring knowledge. Others hold that if God can be known, it must be by sense experience. Surprising as this may seem, this is how the controversial Protestant theologian H. M. Kuitert (1924–present) put it: all that can be known about God is known from below by experience, not from above by revelation. This is an example of how one kind of knowledge—empirical knowledge—has become the standard for all knowledge (empiricism). Empiricism fails because it ignores other ways of knowing, such as knowing by acquaintance, knowing by witness, knowing by authority, knowing by faith, tacit knowledge, self-knowledge, and knowledge from memory, all of which can be equally true. In sum, the problem with naturalism and empiricism is that they are self-referentially incoherent.

In general, one finds two basic attitudes toward such high-level kinds of background beliefs as naturalism and empiricism. There are those who take scientific knowledge as the standard for all knowledge—a distortion known as scientism. For instance, the co-discoverer of the structure of DNA, Francis Crick, wrote that "the knowledge we have already makes it highly unlikely that there is anything that cannot be explained by physics and chemistry."[44] The other group, which includes this author, believes that there are other kinds of knowledge, and respects the limitations of science. The Australian philosopher of science Alan Chalmers writes:

> In addition to what is typically regarded as scientific knowledge, we have everyday, commonsense knowledge, we have the knowledge possessed by skilled craftsmen or wise politicians, the knowledge contained in encyclopaedias or stored in the mind of a quiz show expert, and so on.[45]

Further, the British philosopher Mary Midgley asserts,

> Science cannot stand alone. We cannot believe its propositions without first believing in a great many other startling things, such as the existence of the external world, the reliability of our senses, memory and informants, and the validity of logic. If we do believe in these things, we already have a world far wider than that of science.[46]

Recently, Thomas Nagel expressed the same view.[47]

Earlier, I pointed out that scholars in different *scientific* research traditions are unlikely to share background beliefs. This can now also be applied to the scholars in different schools of thought in the philosophy of science. Their agreement that there are realities other than matter shows that distortions due to background beliefs can be recognized independent of background beliefs. Such convergence of ideas can be taken as due to the fact that the idea is correct.

Conclusions

I began by pointing out that scholars who believe in the existence of a mind-independent reality have the moral calling to oppose distortion in their understanding of natural phenomena. This is possible because science has standard ways of detecting distortion of scientific knowledge by background beliefs

and because such background beliefs can be detached from scientific explanation. Next I showed that scientists, in fact, do oppose their personal background beliefs in their work. By and large, practicing scientists are thoughtful people who can distinguish between appropriate and inappropriate use of background beliefs. They understand that while background beliefs are required for the construction of fruitful scientific theories, background beliefs can be employed dogmatically beyond appropriate boundaries. I then asked whether the dogmatic attitude with which background beliefs can be held does not trivialize the freedom to disconnect background beliefs at any level of generality from associated theories by changing the specifying assumptions. Using naturalism and empiricism as examples, I argued to the contrary, that ideologies are self-destructive and can, therefore, be disconnected from explanations without changing specifying assumptions.

The difference between an appropriate and an inappropriate use of background beliefs is a matter of judgment. Such judgments are shaped by cultural influences. Authors have abused this situation to promote various nonscientific agendas cloaked with the authority of science. It is hard for the general public to separate the chaff from the wheat. This includes Christians who have mistaken the need for such judgment calls as an opportunity to dismiss uncomfortable scientific knowledge on account of background beliefs, as if there was no objectively existing creation that can resist distortion. Instead, they should engage in evaluating scientific knowledge in light of the facts of the matter and the roles, if any, of background beliefs. Inappropriate roles of background beliefs can be recognized when they become self-destructive.

A recent example of many such assessments is *Absence of Mind* by Marilynne Robinson.[48] This stance of critical realism is what underwrites the reliability of the planes we fly in, the medical procedures that heal us, and the computers we use. The practical success of the natural sciences gives confidence that scientists are in touch with reality and that their explanations and theories are not easily distorted by the background beliefs they bring to their work. Christians can interpret this state of affairs as the result of an objectively existing created reality that resists distortion. No one can escape the force of this reality. This means that Christians can work with non-Christians in the enterprise of science. When there is a conflict of background beliefs, they can appeal to the limitations placed by objective reality upon scientific knowledge and/or to the limitations of scientific knowledge itself. ⌘

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Notes

[1]An earlier version of this essay was published online at *Reformed Academic* August 16, 2010.

[2]Peter Harrison, *The Fall of Man and the Foundations of Science* (Cambridge: Cambridge University Press, 2007), 26–7.

[3]A word on terminology. I will be using the term "background beliefs" loosely as a synonym for presupposition, worldview, control belief, ideology, and presumption. Whatever differences there are between these terms, I will ignore them because they are irrelevant for this article in which a background belief is a belief one needs before one can even start to think about the full range of realities from God and the world of fermions, frogs, and feelings.

[4]For Poland: Ludwik Fleck, *The Genesis and Development of a Scientific Fact*, ed. T. J. Trenn and R. K. Merton, foreword by Thomas Kuhn (Chicago: University of Chicago Press, 1979). (First English translation of *Entstehung und Entwicklung einer wissenschaftlichen Tatsache. Einführung in die Lehre vom Denkstil und Denkkollektiv* (Schwabe und Co., Basel: Verlagsbuchhandlung, 1935). For the UK: Michael B. Foster, "The Christian Doctrine of Creation and the Rise of Modern Natural Science," *Mind* 43 (1934): 446–8; 44 (1935): 439–66; 45 (1936): 1–27; Michael Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy* (Chicago: University of Chicago Press, 1958). For the USA: Thomas Kuhn, *The Structure of Scientific Revolutions*, 2nd ed. (Chicago: University of Chicago Press, 1970).

[5]John H. Brooke, *Science and Religion: Some Historical Perspectives* (Cambridge: Cambridge University Press, 1991); and John H. Brooke, Margaret J. Osler, and Jitse M. van der Meer, eds., *Science in Theistic Contexts: Cognitive Dimensions* (Chicago: University of Chicago Press, 2001).

[6]For example, Ian G. Barbour, "Commentary on Theological Resources from the Physical Sciences," *Zygon* 1 (1966): 29; Ian G. Barbour, "Theology and Physics Forty Years Later," *Zygon* 40 (2005): 508; John Polkinghorne, "The Metaphysics of Divine Action," in *Chaos and Complexity: Scientific Perspectives on Divine Action*, ed. Robert John Russell, Nancey Murphy, Arthur Peacocke (Vatican City State / Berkeley, CA: Vatican Observatory Publications / The Center for Theology and Natural Sciences, 1997), 148; for a review of the history of the concept of critical realism, see Andreas Losch, "On the Origins of Critical Realism," *Theology and Science* 7 (2009): 85–106.

[7]Charles T. Wolfe, "Teleomechanism Redux? Functional Physiology and Hybrid Models of Life in Early Modern Natural Philosophy," *Gesnerus*, special issue "Entre mécanisme et téléologie: Anatomie, physiologie et philosophie des fonctions," ed. Roberto Lo Presti and Nunzio Allocca (forthcoming), http://philpapers.org/archive/WOLTRT-2.1.pdf.

[8]I am grateful to Arnold Sikkema for help in developing this example.

[9]http://csep10.phys.utk.edu/astr161/lect/history/newtongrav.html.

[10]http://news.cnet.com/8301-1023_3-10438960-93.html.

[11]With thanks to Arnold Sikkema for providing these examples.

[12]For a video of a smokestack: www.ceoe.udel.edu/deepsea/level-2/geology/vents.html.

[13]For more evidence, see http://en.wikipedia.org/wiki/Plate_tectonics#cite_ref-17; http://www.physicalgeography.net/fundamentals/10i.html; http://www.visionlearning.com/library/module_viewer.php?mid=65; http://earthsci.org/education/teacher/basicgeol/platec/platec.html.

[14]See http://en.wikipedia.org/wiki/Hawaiian_Islands.

[15]http://maps.nationalgeographic.com/maps/atlas/pacific-ocean-geophysical.html.

[16]Hampton L. Carson, "Inversions in Hawaiian Drosophila," in *Drosophila Inversion Polymorphism*, ed. C. B. Krimbas and J. R. Powell (Boca Raton, FL: CRC Press, 1992), 407–39, summarized at http://bio.illinoisstate.edu/kaedwar/HawaiianDrosophila/CarsonTree.htm; and Patrick M. O'Grady et al., "Polytene Chromosomes," at http://www.biomedcentral.com/1471 -2148/1/6.

[17]A theory or explanation may or may not dictate a background belief.

[18]Gottfried Wilhelm Leibniz, "A New System of the Nature and Communication of Substances, and of the Union of the Soul and Body (1695)," in *G. W. Leibniz: Philosophical Essays*, trans. and ed. Roger Ariew and Dan Garber (Indianapolis, IN: Hackett, 1989), 143–4.

[19]http://blog.beliefnet.com/scienceandthesacred/2009/08/why-i-think-the-new-atheists-are-a-bloody-disaster.html.

[20]Thomas Nagel, *Mind and Cosmos: Why the Materialist Neo-Darwinian Conception of Nature Is Almost Certainly False* (Oxford: Oxford University Press, 2012).

[21]Harro Van Brummelen, "Mathematical Truth: A Cultural Study," in *Mathematics in a Postmodern Age: A Christian Perspective*, ed. R. W. Howell and W. J. Bradley (Grand Rapids, MI: Eerdmans, 2001), 45–64.

[22]Ibid.

[23]Abdus Salam, "Islam and Science," in *Ideals and Realities: Selected Essays of Abdus Salam*, 2nd ed., ed. C. H. Lai (Singapore: World Scientific, 1987), 179–213, http://www.globalwebpost.com/farooqm/study_res/abdus_salam/i_science.html.

[24]Fernando Espinoza, "An Analysis of the Historical Development of Ideas about Motion and Its Implications for Teaching," *Physics Education* 40 (2005): 141, http://iopscience.iop.org/0031-9120/40/2/002/pdf/0031-9120_40_2_002.pdf.

[25]René Descartes, *Principia Philosophiæ*, trans. *Principles of Philosophy* (1644), §§ 36–9.

[26]Peter J. Bowler and Ivan R. Morus, *Making Modern Science* (Chicago: University of Chicago Press, 2005), 433–4.

[27]I thank one of the reviewers for suggesting this line.

[28]For details, see Jitse M. van der Meer, "Progress in Nature and Culture: How Biology Can Have the Best of Both Worlds," essay review of *Monad to Man* by M. Ruse, *Biology and Philosophy* 15 (2000): 759–72.

[29]http://www.pbs.org/wgbh/nova/galileo/mistake.html.

[30]Maurice A. Finocchiaro, *The Galileo Affair: A Documentary History* (Berkeley, CA: University of California Press, 1989), 127–131 and Galileo Galilei, *Dialogue Concerning the Two Chief World Systems*, trans. Stillman Drake (Berkeley, CA: University of California Press, 1953), 432–6.

[31]For an explanation of the tides, see http://www.sjsu.edu/faculty/watkins/tides.htm.

[32]Jitse M. van der Meer, "The Actor in the Interaction of Science and Religion: An Application of Dooyeweerd's Anthropology to the Study of Religion and Science Relations," in *The Collected Works of Herman Dooyeweerd Series C-Dooyeweerd's Living Legacy, vol. 1: Contemporary Reflections on the Philosophy of Herman Dooyeweerd*, ed. D. F. M. Strauss (Lewiston, NY: The Edwin Mellen Press, 2000), 183–94.

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