

SCIENCE,
RELIGION,
AND
SOCIETY

AN ENCYCLOPEDIA
OF HISTORY, CULTURE,
AND CONTROVERSY

VOLUME ONE

FOREWORD BY THE DALAI LAMA

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Preface

Seven years ago we sent out an open invitation to the faculty at our university to participate in a science and religion reading group. We hoped to attract a dozen or so colleagues to share ideas and readings over weekly lunches for a semester. More than sixty professors from disciplines as diverse as medicine, physics, ethics, public health, biology, and religion wrote us back, eager to attend. As we have discovered, more than a casual interest in interdisciplinary ideas inspired such a surprisingly large response. From this beginning came more faculty reading groups, undergraduate courses, grants from within and outside our institution, publications, and several well-attended public symposia—all around topics lying at the crossroads of science and religion. And this is just our work at one university; many others at our school and other universities have established centers of scholarship and initiated rigorous research programs in mind and body, complementary and alternative medicines, and other areas where science and spirituality overlap.

The interest extends far beyond the bounds of the university, too. The public is hungry for material that explores how religion and science overlap, as well as how the tensions between them are negotiated in political, legal, scientific, and theological terms. The volatile debates around evolution, the extraordinary discoveries in physics, the spiritual dilemmas faced at the end of life—these are just a few of the familiar issues that have recently captured the public's attention and demanded increased collective reflection on deeply fundamental questions about human existence.

Why has there been such an explosion of popular interest in science and religion in the last few decades? A major reason we developed this encyclopedia is to find answers to this question. At least four very general answers have emerged to help explain what is driving this significant societal interest:

- People are more aware of the influence of science in realms of human life that have traditionally been considered personal and spiritual—end-of-life decisions and fertility, for example—and many are concerned

about therapies that might affect complex human behaviors and diseases, such as brain analysis techniques, pharmaceuticals, stem cell research, and gene therapy.

- In the United States especially, the science versus religion discussion, usually within the realms of politics and education—evolution versus creationism being the most well known—polarizes communities and creates well-trodden media stories that do not capture the complexities and confusions surrounding what are presented as antagonistic perspectives.
- Recent research has probed the deep mysteries of the mind and the cosmos—resulting, for example, within the study of consciousness in the development of the new fields of neuroethics and neurotheology, and within the study of physics in the emergence of profound questions about the makeup of the universe.
- The science and religion conversation has opened up to include more voices from around the globe and more awareness of other perspectives—for example, the relationship between the two terms that is perceived by someone in India who is contending with postcolonial linguistic and political realities and has a non-monotheistic point of view.

In this encyclopedia we focus on the *collaborative* angle, to discover how to bring the best of *both* science and religion to the table to address these and other issues. As readers will discover, there is much to learn from a collaborative approach that bridges disciplines but also religions and regions of the world.

The science and religion discussion is richly multidisciplinary; scholars from nearly every field have performed research in the areas examined in these volumes. We learned from our initial reading group that engaging a broad spectrum of disciplines and traditions in the discussion is vital; thus, contributors to these volumes include clergy, physicians, art historians, psychologists, geneticists, ethicists, theologians, historians of science, physicists, and philosophers, as well as scholars from the fields of religion, physics, neuroscience, biochemistry, history, ecology, evolution, and cosmology. And contributors are Christian, Muslim, Buddhist, Hindu, Jewish, Taoist, as well as agnostic and atheist, and from African and Native American traditions. With all of this in mind, we thought it best *not* to claim that the encyclopedia is working with one specific definition of each term, “science” and “religion.” One of the most striking impressions from reading all of these essays is the divergence, as well as occasional convergence, in how writers understand the meanings of each term separately and both together.

To make it easier to examine the diverse and varied responses these essayists provide, we divide the encyclopedia into eight topical sections, fully aware that these divisions are in some sense arbitrary and also create artificial differences as well as areas that overlap with other sections. Each section opens with an introduction outlining its major themes and framing that section’s

essays, trying to highlight commonalities between them but also recognizing the particularities of each one.

The first section, *General Overviews*, is a good starting point for readers who want to explore some of the larger, more wide-ranging perspectives on science and religion. With broad personal and scholarly stories from an array of viewpoints, essays in this section provide a road map for exploring the major challenges and questions in science and religion. This section is followed by *Historical Perspectives*, which grounds these major questions in the past and demonstrates how they have developed into the six broad areas of contemporary research and discussion that follow. These sections—*Creation, the Cosmos, and Origins of the Universe*; *Ecology, Evolution, and the Natural World*; *Consciousness, Mind, and the Brain*; *Healers and Healing*; *Dying and Death*; and *Genetics and Religion*—represent one attempt at organizing the questions and research that undergird the enormous, unabating interest in science and religion today, an interest we think is more compelling when it is informed by a multitude of views and a variety of positions.

Acknowledgments

We thank our many colleagues and students at Emory who have inspired us to explore religion and science across disciplines. Conversations in classes, seminars, and in various other stimulating settings established the groundwork for this encyclopedia. We also thank student assistants Kelley Friedgen, Paula Shakelton, and especially Ajay Pillarisetti for their strong logistical support in developing and executing this project, and both Todd Hallman and Cathy Prisco from M.E. Sharpe for their editorial guidance and advice. This encyclopedia is dedicated to our families.

General Overviews

Introduction to General Overviews

In recent years, many of us have become very familiar with the public debates surrounding science and religion. These debates often surface in the midst of compelling, controversial moral quandaries faced by communities struggling with the limits of scientific authority. The place of evolution in public education, human interventions at the beginning and end of life, the role of prayer in healing, and environmental crises in the face of diminishing natural resources are only a few of the contemporary topics that bring religious and scientific views into sharp relief and a shared frame of reference.

In Western societies, the terms of these debates draw from a common conceptual heritage, deeply rooted in but not entirely limited to historical and cultural developments in Christianity, particularly after the scientific revolution. Are science and religion in *conflict*? Do they represent two separate, *independent* spheres of knowledge and experience? Can they be in *dialogue* to probe the intricacies and mysteries of the universe? Can they be *integrated* to produce dramatically new visions, grounded in science and theology, of the cosmos? Historian of science and physicist Ian Barbour popularly and convincingly argued that the relationship between science and religion can be reduced to these four possibilities.

Our contention in the production of this encyclopedia is that the range of possible interactions between religion and science is much more complex, confusing, and confounding than any schematic representation could possibly convey. Indeed, it will become clear to the reader that even the very notion that the two central concepts can be defined in any fixed, universal, essentialist way begins to crumble in light of the wide-ranging, interdisciplinary, cross-cultural spread of essays contained in this encyclopedia. These essays seek to explore the interconnections, interactions, and intersections of science and religion in a variety of cultural and historical settings throughout time and around the globe. In doing so, they broaden and enrich but also problematize the relevant terms and concepts in the ongoing public conversations about science and religion in human society.

The essays in the first section provide the reader with a series of general overviews, offering perspectives on science and religion from a variety of cultural and religious vantage points. Some essays provide a larger historical framework within which to think about relations between science and religion in specific cultural contexts (compared with more focused historical discussions of specific eras, figures, cultures, and issues in the next section). Well-known physicist, philosopher, and theologian Sir John Polkinghorne, for example, explores the longstanding efforts to integrate science and religion in Western Christian cultures from Augustinian thought in the fourth century to process theology in the twentieth. Norbert Samuelson, a professor of Jewish studies, covers Jewish perspectives on integrating the two—both of which, in his words, shared the same goal of intellectual wisdom from experience (what he identifies as “science”) and from holy scriptures (“religion”)—in the classical and modern periods. Historian Toby Huff covers the critical history of Islam, another monotheistic faith, and the rise of “Islamic science” as a vital source and influence in the emergence of a number of scientific fields, including astronomy, mathematics, and medicine. (Huff also notes that there is no equivalent word for “science” in Arabic—or, for that matter, in Greek or Chinese.) Physicist P. Venugopala Rao provides both historical and philosophical material to explain how science and religion coexist in the worldview of Hinduism, beginning with Indus civilization but also carefully exploring the impact of colonialism and nationhood on Indian perspectives.

Also included in this section are more wide-ranging, less historically grounded explorations of science and religion in different cultural settings, though often authors return to an undeniable theme throughout many essays in this encyclopedia: the political and social impact of Western science on non-Western, nonindustrialized communities around the globe. Yet these essays do not only retell stories of conflict, conquest, and colonization; they also engage with indigenous views and practices that blur the lines between science and religion, and they raise questions about how adequate these categories are for a range of cultural phenomena. Historian Gloria Emeagwali writes about the intersections of science and religion, looking at the development of medicine, metallurgy, and mathematics in various parts of Africa. She begins with reflections from philosophers of science, including Paul Feyerabend and Karl Popper, who broaden and complicate traditionally narrow understandings of science. This is a common theme the reader will encounter in the general essays in this section but also in the more specific cases described in the other sections, where simplistic definitions of science—and of religion, for that matter—no longer adequately capture the realities on the ground.

Native American perspectives included here are particularly attentive to the glaring differences between Western science and indigenous views of the surrounding environment that survived the cultural upheavals of colonization. But they also explore how the systems overlap at some points and, in some cases, how they might work together in common cause, a consideration

found in a few essays that discuss interactions of indigenous systems and Western science. Keith James, a professor of social and organizational psychology, covers some of the potential risks and benefits of combining Western scientific views with native perspectives and practices to mitigate the wide-ranging social dilemmas faced by Indians in contemporary society. Physicist Phil Duran compares the dominant Western epistemology that treats the earth as a commodity with indigenous spirituality and knowledge about reality, looking specifically at recent developments in physics to think across what has been seen as an unbridgeable divide between the two cultural systems. Finally, Indian activist and writer Vine Deloria Jr. discusses the epistemological and practical differences between traditional tribal knowledge and advances in Western science.

In a similar vein, but with an entirely different perspective, Laurence I. Gould writes about epistemology, and specifically the ultimately incompatible methods to gain knowledge operating in religion and science: faith for the first, reason for the second. Physicist Paul Utukuru sees other possibilities, offering commentary on the intersections of religion and spirituality, more generally conceived, and science in light of recent advances in a number of domains, including physics, biology, and the neurosciences. In a more idiosyncratic, personal style, mathematician Jagdish Srivastava recounts his own personal journey, beginning with life in independent India in 1947, into a life of science and the implications this life had on his religious views. In another idiosyncratic contribution, biologist Leslie Real provides an overview, extraordinarily brief though it is, on Zen perspectives, encouraging the reader to close the gap separating science and religion.

Ibrahim Kalin provides readers with more extensive “notes on an ongoing debate” taking place in the Muslim world over the value and purpose of modern science, a compelling, complicated debate in a culture that has made tremendous contributions to intellectual and scientific inquiry—and one that still can, primarily by offering a nonreductionist framework with which to study nature while preserving its sanctity. After reading Jiang Sheng’s examination of science and religion in China, the reader will understand that these two categories cannot be separated in the Taoist context, where the driving force that unites both is the search for immortality. Shigeru Nakayama, a professor emeritus in the history of science, compares the cultural settings tied to monotheism in the West with the religious pluralism of East Asia, contrasting the two settings by focusing on the place, and rigidity or flexibility, of science in each.

With training in the psychology of religion, Ralph Hood Jr. presents a general discussion about the wide-ranging diversity of religious and spiritual experiences, including those that will be addressed in other sections of the encyclopedia, such as near death experiences and the effects of prayer and meditation on health. Sociologist Barbara Strassberg and education specialist Eva Krugly-Smolka turn our attention to the necessity of placing discus-

sions about science and religion in a multicultural frame of reference. Strassberg brings a distinctly social scientific perspective to the real-life dynamics between science and religion, focusing on the significance of cultural inclusiveness in these discussions. Krugly-Smolka considers how science is taught in schools and argues for the need to see science as a cultural form.

Many of these essays will raise questions that will be taken up in more detail in other sections of this encyclopedia, questions often focusing on but not limited to the adequacy of conventional definitions for science and religion. Our goal here is to provide readers with an assortment—admittedly fragmented and incomplete—of more general perspectives on science and religion, putting on display the incredible, nearly inexhaustible array of topics that come to mind for these authors. We also hope that these essays, and the essays in the rest of the encyclopedia, contribute to public awareness of just how complicated the relations between religion and science can be when the conversation includes a range of cultural views on these matters.

1 Integrating Science and Religion

John Polkinghorne

Science plays an influential role in contemporary thinking, both through the content of its actual discoveries and through its style of evidence-based thinking. If religion is to retain credibility, it must find a voice that is audible in this intellectual setting. It is no wonder, therefore, that today vigorous activity is taking place across the science and religion frontier. However, the attempt to integrate these two great aspects of human enquiry is not just a current concern, for it has had a long history.

The Abrahamic faiths, Judaism, Christianity, and Islam, all understand the world to be God's creation. Consequently they see the world as expressing something of the character of its creator. This attitude is at least as old as the wisdom writings of the Hebrew Bible. In contrast to the other biblical authors, the sages did not appeal much to the unique events of salvation history, but they reviewed the generality of human experience. Culture is the medium for expressing and reflecting upon that experience, and so the interaction between culture and religion has had a long history. Science's study of the pattern and history of the natural world has made a significant contribution to this process.

Augustine took the science of his day seriously; in fact, his disillusionment with Manichaeism partly arose because he noticed its adepts were less accurate in the prediction of eclipses than were secular astronomers. Later he was to say that if an interpretation of scripture seemed in conflict with well-established natural knowledge, then that interpretation should be reconsidered.

In the later Middle Ages, the rediscovery of the ideas of Aristotle proved of great significance for the Abrahamic faiths. In the case of Christianity, the effect was principally conveyed through the influence of Thomas Aquinas. Science in a recognizably modern form may be dated from the publication of Nicholas Copernicus's heliocentric theory in 1543, and its full flourishing began with the work of Galileo and his successors in the seventeenth century. It has been argued that an important ideological foundation for this development was provided by the doctrine of creation. If God was rational, there had to be an order to the universe—hence the scientific expectation that a cosmic

pattern was discoverable. Yet, since God's creative will was freely exercised, the order of the universe could not be deduced from thinking about a supposed logical necessity. Rather, one had to look to see what God had actually done—hence the need for observation and experiment. Moreover, since the world was a divine creation, it was a worthy object for study, and because its own nature was not divine, it could be interrogated without impiety. All these understandings were certainly encouraging to the development of science.

The Galileo affair was unfortunate, but the issues involved were more complex than a simple confrontation between scientific truth and religious error. Galileo was a religious believer, as were most of the founding figures of modern science, even if some, like Isaac Newton, had difficulties with Christian orthodoxy. The pioneers certainly wished to hold religion and science together, typically claiming that God had written two books, the book of nature and the book of scripture, which, when read aright, could not contradict each other because they had the same divine author.

In the Scholium that Newton added to his *Principia*, he expressed his admiration for the divine handiwork revealed in the structure of the cosmos. Other scientists shared this feeling, which was reinforced by biological studies of the marvelous adaptive powers of creatures, leading to an argument from design, or “physico-theology,” classically expressed in John Ray's *The Wisdom of God in the Works of Creation* (1691). Writers such as William Paley, in his celebrated *Natural Theology* (1802), continued these lines of argument, which were aimed at integrating scientific and religious understanding. However, this harmonious phase, based on a rather direct argument from design, came to an end with the publication in 1859 of Charles Darwin's *Origin of Species*. Its author had shown how the patient accumulation and sifting of small differences could, over long periods of time, produce the appearance of design without the need for the direct intervention of a designer.

The publication of the *Origin of Species* is another event in the complex history of the interaction between science and religion that is often presented, like the Galileo affair, in the oversimplified terms of implacable confrontation. In fact, Christian thinkers such as Charles Kingsley and Frederick Temple welcomed Darwinian insights from the first, seeing an evolving world as being a creation “allowed to make itself.”

Even so brief a survey illustrates something of the complex interaction between science and religion in the course of an intellectual history characterized both by dispute and by fruitful exchange. The last forty years have seen particularly vigorous activity on this frontier. Ian Barbour examined the forms of contemporary interplay through a fourfold taxonomy that has become something of a classic grid. It is based on the contrasting relationships of conflict, independence, dialogue, and integration. The last category has been relabeled assimilation in the discussion below. Before making use of these categories, however, let us consider a set of metaphysical issues of particular significance: realism and limit questions.

Realism

A central question in philosophy concerns what relationship should be held to exist between epistemology and ontology, between human knowledge and what is actually the case. Immanuel Kant took the view that the appearances of phenomena are no reliable guide to the nature of noumena, things in themselves. Scientists, on the other hand, have almost all taken a realist position, believing that what we know is a reliable guide to what is the case. It would be difficult to see what justified the great labor of scientific research if it were not telling us what the physical world is actually like.

Scientific realism, however, has to be a critical realism, based not on a simplistic concept of naive objectivity but on an altogether more nuanced line of argument. The intertwining of theory and experiment in the interpretation of scientific evidence introduces a degree of circularity into the discussion, yet because of the explanatory power and long-term fruitfulness of what is discovered, this circle is believed to be benign and not vicious. Science often speaks of entities not directly observable, such as the quarks and gluons that are considered constituents of nuclear matter. Support for belief in such unseen realities is based on an appeal to intelligibility. The assumed existence of the invisible quarks enables physicists to make sense of great swaths of more directly accessible experience. Science cannot claim to attain comprehensive knowledge, but it can persuasively assert its ability to make reliable maps of physical reality, trustworthy on a given scale even if not affording a total description of the intellectual terrain. Its achievement is verisimilitude rather than absolute truth.

Thinkers in the field of science and religion have mostly adopted a critical realist position, not only in relation to science but also in relation to theology. While recognizing that human knowledge does not rest on unshakeable foundations, they have largely been inclined to trust human rational powers and not to give way to an extreme postmodernist feeling of despair of the prospect of gaining universally acceptable knowledge. In theological thinking, the adjective “critical” carries peculiar force. The infinite reality of God will never adequately be caught in finite, human, rational nets. Religion must heed the warnings of an apophatic theology, emphasizing the mystery of God, while at the same time not abstaining from kataphatic utterance, since it believes that God has acted to make the divine nature known through creation and through revelatory acts in history.

Limit Questions

Science purchases its great success by the modesty of its ambition. An honest science does not pretend to ask and answer every question about the nature of reality. Instead, it restricts itself to asking questions of process (the way things happen), while it brackets out questions of meaning and purpose (what is

going on in what is happening). The insufficiency of a solely science-based understanding is made clear when questions arise from doing science that seem clearly meaningful and necessary to ask, but that science cannot answer. Questions of this kind are called metaquestions or limit questions. Seeking their answers offers the opportunity to extend the frontiers of understanding beyond those set by science alone, through the discovery of a complementary source of insight. In fact, the integration of science and religion is encouraged by recognizing the power of theological thinking to respond to science's limit questions.

Three kinds of limit questions have proved particularly significant. The first asks why science is possible at all. Of course, evolutionary insight into survival needs is sufficient to explain the human ability to make sense of the everyday world of direct experience. However, science goes far beyond any such mundane necessities, as it comprehends the quantum world of subatomic entities and the vast realms of cosmic, curved space-time. Both regimes are remote from direct impact on humanity, and both require highly counter-intuitive modes of thinking for their proper understanding. The universe is deeply intelligible to us, and our experience of its rational transparency goes far beyond anything that could plausibly be considered simply a spin-off from evolutionary necessity. Furthermore, science has discovered that the universe is also rationally beautiful. Scientists speak frequently of the experience of wonder, which is the reward for all the weary labor involved in doing research. In fundamental physics, an actual technique of discovery is to seek equations that are endowed with the unmistakable quality of mathematical beauty. This is no mere aestheticism on the part of the theorists, for it has been a continuing scientific experience that only equations possessing this character will exhibit the long-term fruitfulness that persuades scientists of their verisimilitude as descriptions of the physical world.

None of this is explained by science itself, which is content simply to exploit the opportunities thereby afforded. Yet these facts are too remarkable to be treated as if they were just happy accidents. One could summarize the universe's rational character by saying that it appears to be a world shot through with signs of mind, and the religious believer can claim that this is so because it is indeed the mind of the creator that lies behind its wonderful order. In this view, science is possible because the world is a creation.

The second kind of limit question asks where the laws of nature come from and why they have their particular character. Scientists study the history of the universe over the 13.7 billion years from the Big Bang that have seen an expanding ball of energy become a world of rich and fertile diversity. In the course of understanding many of the details of this fruitfully evolving process, cosmologists have come to realize that its possibility depended on the laws of physics taking a very particular—one might say "finely tuned"—form. While life took billions of years to appear and develop, the universe was pregnant with the possibility of life essentially from the Big Bang onward.

The chemistry of life is the chemistry of carbon. The only source of carbon lies in the interior nuclear furnaces of the stars. The delicate processes by which carbon is produced depend critically on the laws of nuclear physics being what they are in their quantitative detail, and no different. Stars have a second important role to play. Development of life on Earth was possible because it was fuelled by our local star, the sun, burning reasonably steadily over billions of years. If the strength of gravity had been different, stars might have burnt too feebly to support life or so furiously that they could not have lasted for more than a few million years before exhausting their energy supplies. Life needs an energy supply continuing for billions of years for the possibility of its evolutionary development.

Many considerations of this kind have been discovered. They have been collected together under the rubric of the anthropic principle (that is, the structure of the universe is directly related to human existence). A cosmos that is capable of generating carbon-based life is not just any old world but has to be a very special universe indeed. Once again science points to circumstances that do not look like mere happy accidents. Yet science is unable to offer an explanation of anthropic fine-tuning, for it treats the laws of nature as brute facts, the given basis for its thinking, and it then has no more to say about their character. To get beyond this requires a metascientific response. There has been much disagreement about what form it should take. Two contrasting strategies have been employed.

One proposes that there are many different universes, all with different laws of nature. Given this multiverse, then, it would not be all that surprising if one of them, by chance, was suitable for carbon-based life. Since all the other universes are inaccessible to us, this proposal is metaphysical in its character. Many think that it exhibits a high degree of ontological prodigality.

An alternative metaphysical possibility is theistic. Perhaps there is just one universe, which is indeed not any old world, for it is a creation. In that case, it is intelligible that the universe has been endowed by its creator with precisely the fine-tuned laws that have enabled it to have a fruitful history. Once again one sees the possibility of a mutually enlightening complementarity between science and religion.

The third kind of limit question relates to the coming-to-be of persons. The emergence of self-conscious beings on planet Earth is one of the most astonishing developments in cosmic history of which we are aware. In our ancestors, the universe became aware of itself. This seems an event of such significance that many believe the category of happy accident is inappropriate. Persons are perceivers of value. They are moral beings whose ethical intuitions, for example of unconditional altruism, seem to go beyond the genetic survival imperatives of evolutionary thinking. Personal experiences of beauty have such a profound quality that many cannot treat them simply as epiphenomenal froth on the surface of a fundamentally materialistic reality. The human encounter with the sacred to which the faith traditions attest has

an authenticity that demands deep respect. All these experiences lie outside the domain of science, but they fall well within the concerns of religion. An adequate metaphysics must find room to take them seriously.

Religious responses to limit questions form the basis of a natural theology, the attempt to learn something of God through the use of reason and the inspection of the world. This activity affords a means of integrating science and religion in a complementary relationship. Contemporary natural theology differs from its predecessors, associated with such names as Aquinas, Ray, and Paley, in important ways.

First, in no way does it seek to rival science within the latter's domain. Scientific questions (such as the origin of the eye) are expected to receive scientific answers (such as an evolutionary account). The so-called "God of the gaps," religion's ill-judged attempt to fill in temporary patches of scientific ignorance by appeal to direct divine action, was a bad theological mistake. The raw material for a true natural theology is furnished by the limit questions, which go beyond science's explanatory powers. It is surely significant that someone like Paul Davies, who stands outside any religious tradition, should be inclined to take a kind of theistic view by considerations of this sort.

Second, the new natural theology is modest and does not talk about "proofs of God's existence," as if atheism were simply a logical mistake. Instead, its character is insightful rather than demonstrative. Its claim is that taking a theistic view explains more than atheism can. In the realm of metaphysics, no one can aspire to more than that, for no overarching worldview can legitimately claim absolute logical necessity.

Conflict

In Barbour's grid of the interplay of science and religion, the conflict category regards science and religion as rivals that can give no quarter to the other point of view. People who take this stance frequently point to the Galileo and Darwin affairs, historically misunderstood as occasions of implacable confrontation. That the relation is one of conflict can be asserted either from the standpoint of religion or from the standpoint of science. The religious version is most clearly expressed in the cruder forms of creationism. The Bible is read not only as the deposit of religious truth and experience, but also as a divinely given textbook of science, so the Genesis stories of creation are considered a literal account of how the world came to be. The scientific version is expressed through a triumphalist scientism. In its most extreme form, it claims that the only questions worth answering are scientific, and the only knowledge one can have is that which science can provide. Religion is dismissed as antiquated and fantastic, at best irrelevant and at worst untruthful distortion.

Both versions are implausibly imperialistic. They fail to acknowledge the authenticity of different kinds of enquiry into different kinds of experience.

Not all questions are scientific; not all answers are religious. A just encounter with reality will be concerned both with the uniqueness of personal experience (which lies at the root of religion) and with the repeatability of impersonal experience (which is the subject matter of science). Scientists need to recognize the frontiers of their discipline and the kind of limit questions that take the enquirer beyond that domain. Religious believers need to recognize that the creator acts through nature as well as in other ways, and that what science tells us of nature's character and history is a gift worthy of grateful acceptance and respect.

Independence

The independence stance aims to achieve a degree of harmony between science and religion based on their peaceful and strictly separated coexistence. The possibility of such a truce is commonly held to arise from a series of dichotomies: science is concerned with the impersonal, religion with the personal; science is concerned with facts, religion with values; science is concerned with public knowledge, religion with private opinion. The two subjects are supposed to represent what Stephen J. Gould called "non-overlapping magisteria." Let them go their own separate ways in peace. The stance of independence is popular among scientists who do not want to be wholly dismissive of religion, but who also do not want to take its cognitive claims with any seriousness. Despite its appearance of modest reasonableness, independence is unsatisfactory, for it is based on half-truths about its two subjects.

Their differences do not hold science and religion in complete separation from each other; instead, these differences place them at opposite ends of a single spectrum of human enquiry into the nature of reality. There is a greater degree of mutual influence and cousinly connection than independence is able to acknowledge. Science does not deal in simple facts, for all interesting scientific facts are necessarily interpreted facts and, as theory and experiment inextricably intertwine, the role of interpretation introduces an element of opinion into scientific thinking. Religion is not merely based on internalized opinion, but faith appeals to motivated belief as the ground of its commitment. The question of truth is as fundamental to religion as it is to science, and the appeal to experience, albeit of a kind that cannot be replicated at will, is central to theological thinking.

As a matter of observable fact, science and religion do not exist in insulated isolation from each other. Scientific discoveries about the universe (Big Bang cosmology) and the history of life (evolution) have demonstrably influenced theological thinking about creation. It has already been argued that religion's answers to limit questions complement a scientific understanding of the world. There is no direct entailment between science and religion, but the stance of independence fails to do justice to the substantial amount of mutual interaction.

Dialogue

The dialogue stance is based on taking seriously the mutual exchange between science and religion as they seek together to provide as comprehensive an account of reality as possible. The discoveries of science do not determine theological discourse, but they place constraints on what can properly be said. Religion is not in a position to give the answers to scientific questions, but by its responses to limit questions, it can set scientific knowledge within a broader context of understanding. There has to be mutual consonance between the discourses of the two subjects. In consequence, a continuing and fertile conversation is possible between them. Many examples can be given of this fruitful exchange.

Science's discovery of the evolutionary character of the world encouraged theology to explore the concept of continuous creation. The history of the universe is not to be taken as the performance of a fixed score, composed by a creator in eternity, but it has the character of an unfolding improvisation in which creatures and their creator all play a part. This idea has been particularly developed in the writings of Arthur Peacocke.

A world "making itself" in this evolutionary way can be seen as a greater good than one brought into being ready-made at the command of its creator. The God of love will not create a cosmic puppet theater in which creatures must all dance to the divine tune and where all is under tight control, but creatures are given the freedom to be themselves, to explore and bring to birth in their own way the potentiality with which they have been endowed. This insight helps religious thinking with its greatest perplexity: the presence of evil and suffering in the world. A creation making itself is a great good, but it has a necessary cost. There will inevitably be ragged edges and blind alleys in the course of its history. Genetic mutation has been the fertile driving force of the development of life, but genetic mutation is also the source of malignancy. The sad fact of the presence of cancer is not gratuitous, something that a more compassionate or competent creator might have avoided. It is the necessary cost of a creation making itself. Natural disasters, such as earthquakes, occur because entities like tectonic plates are allowed to behave in accordance with their nature. Elsewhere I have called this "the free process defense," paralleling for inanimate objects the free will defense in relation to the evils acts of human beings who have been given the good of moral freedom.

In the 1990s the principal discussion in relation to science and religion was concerned with the issue of divine providential action. Given science's account of the causal structure of the world, was it still possible to believe that God acts in history in particular ways on particular occasions? Twentieth-century physics had seen the death of a merely mechanical view of the world. The widespread presence of intrinsic unpredictabilities, first noted in quantum physics and then in chaos theory, meant that the processes of the world were not as tame and controllable as classical Newtonian thinking had seemed to suggest. Unpredictability is an epistemological property (one cannot know

what future behavior will be) and, once again, one faces the issue of the nature of the relationship between epistemology and ontology. Is the matter just a case of unavoidable ignorance, or are intrinsic unpredictabilities signs of an ontological openness to the future? The latter possibility would correspond to the conventional physical account that the action of causal principles goes beyond the exchange of energy between constituents. The assumption of ontological openness would be a legitimate move for a critical realist to make.

A variety of metaphysical conjectures were proposed to express an openness present within the grain of nature, some looking mainly to quantum effects for their basis and others appealing principally to chaos theory. No universally agreed-on, detailed understanding has emerged. However, it has become clear that the “defeaters” (those who claimed that science had ruled out divine providence) have been defeated. To make the assertion that divine action was excluded by physics was, in fact, to make a metaphysical claim open to rational refutation. Given philosophical perplexities about the nature of causality, general argument could hardly be expected to lead to a more specific result. After all, science is currently unable to give a detailed account of how it is possible for human beings to act as intentional agents. Yet if we can influence the future in this way, it would be highly surprising if God were to be totally bereft of a similar capacity.

Assimilation

The assimilation stance has the ambitious aim of constructing a single account that unites the insights of science and religion in an overarching metaphysical scheme. The most widely pursued example of this kind of endeavor has relied on process thinking, deriving from the philosophical ideas of Alfred North Whitehead. Its most prominent supporter in the field of science and religion has been Ian Barbour.

Process thought sees reality as composed of discrete events (“actual occasions”). Each event comprehends what has happened previously and is open to a variety of future outcomes. In a process called concrescence, God is a party to each actual occasion, seeking to lure it toward a divinely desired result, but the determination of that result lies with the event itself. Process thinking envisages a continuous ontological spectrum linking proton to person, an idea that its critics tend to refer to as panpsychism and its defenders as panexperientialism. Of course, the experiential component of an atom is considered to be at a very low, residual level. Even so, process panexperientialism has seemed unappealing to many.

Process ideas face two further major difficulties. The punctuated, event-dominated picture of reality does not cohere well with the account of modern physics, which exhibits a great deal of continuity as well as some degree of discontinuity. Theologically, the God of process theology seems to be too evacuated of power, acting only through persuasion (“lure”). To many, this appears too weak an account of divine interaction with creation.

In general, unitive strategies seem often to grant too much influence to scientific ideas, risking the subordination of theological insights (which is why I have chosen the less flattering word assimilation in preference to Barbour's integration). In consequence, the most favored form of integration between science and religion has proved to be some version of dialogue.

Time

The nature of time is a matter of significance for both science and religion. If the world is open to its future, then it is a world of true becoming. The future is not up there, waiting for the present to arrive, but it is brought into being as processes unfold. Theology believes that God knows things truly, according to their actual nature. This has seemed to many to imply that if reality is temporally unfolding in an open way, God will know creation in its becomingness. This means that God will not simply know that events are successive, but God will know them in their succession. There must be an experience of time in God.

Such a view stands in stark contrast to the tradition of classical theology, from Augustine to Aquinas and beyond, which had pictured the eternal God as knowing creation atemporally. The whole of created history, past and future, was supposed to be laid out before its creator, to be taken in by the divine gaze all at once, "totum simul," in the classic phrase of Boethius. Today many adopt a more complex view of God's relation to time. While there must be an atemporal aspect of the divine nature, corresponding to God's unchangeable attributes and eternal existence, there is also believed to be a temporal aspect of the divine nature, through which the creator engages with the temporally unfolding reality of creation. This dipolar way of thinking about God was pioneered by process theologians, but it has received wide acceptance beyond the process community. The divine polarity of eternity/time appears highly consistent with the biblical picture of God, both eternally steadfast in the divine love and also intimately engaging with the twists and turns of history.

If the future is not yet there to be known, even God cannot yet know it. Theists will certainly wish to assert divine omniscience—but in a world of becoming, this has to take the form of a current omniscience (knowing now all that can be known now), rather than an absolute omniscience (knowing all that will ever be knowable).

This insight forms part of an important concept of twentieth-century theology, recognizing that the divine act of creation is also a divine act of self-limitation, or kenosis. This was first acknowledged in relation to divine power. If creatures are allowed to make themselves and to be themselves, then not all that happens (a murder, an earthquake) will be in accordance with God's good and perfect will, though it is permitted because of the creator's gift of freedom to creatures. In this way, God has freely limited the operation of divine power. Mainstream Christian theology sees this limitation as internally accepted within

deity, as an expression of the divine love, though process theology regards it as a necessary metaphysical limitation enforced on the divine nature.

God's acceptance of a current omniscience can similarly be understood as a further free act of divine self-limitation. It is the kenosis of absolute omniscience.

Future Developments

The recent history of the integrative discourse between science and religion has had the spiral character of circling inward toward matters of increasing theological specificity. Certain frontier topics, such as natural theology and creation, will always engage attention but are rather general in their character. Most of what is said about them is as consistent with the distant God of deism, who simply set the worlds spinning and then left them to it, as it is with the providentially active God of theism. Twenty-five years ago these general issues tended to dominate the dialogue. The concentration in the 1990s on the question of divine action turned the discussion in a distinctly more specific theological direction. Recently there has been some interesting dialogue on eschatological matters, taking seriously science's prognostications of the eventual collapse or decay of the universe. One may hope that this tendency will continue, with the result that theology will play a greater role in setting the agenda for the dialogue.

A great deal of the activity in the discourse between science and religion has originated from within the Christian community. Another hope for the future is that there will be increasing participation by the other world faith traditions. Not only will this provide complementary sources of religious insight, but the activity will also offer opportunities for the faiths to meet each other in a context of serious significance, yet one that does not pose an immediate threat or challenge to any tradition's core beliefs. The integration of science and religion may play a modest but useful role in the ecumenical dialogue among the world religions.

Bibliography

- Barbour, Ian. *Religion and Science*. San Francisco: HarperCollins, 1998.
- Brooke, John Hedley. *Science and Religion*. Cambridge: Cambridge University Press, 1991.
- Clayton, Philip. *God and Contemporary Science*. Edinburgh: Edinburgh University Press, 1997.
- Davies, Paul. *The Mind of God*. New York: Simon and Schuster, 1992.
- Gould, Stephen J. *Rock of Ages*. New York: Ballantine, 1999.
- Jaki, Stanley. *The Road of Science and the Ways to God*. Chicago: University of Chicago Press, 1978.
- Peacocke, Arthur. *Theology for a Scientific Age*. London: SCM Press, 1993.
- Peters, Ted, ed. *Science and Theology*. Boulder, CO: Westview, 1998.
- Polkinghorne, John. *The Faith of a Physicist*. Minneapolis: Fortress, 1996.
- . *Scientists as Theologians*. London: SPCK, 1996.
- . *Belief in God in an Age of Science*. New Haven, CT: Yale University Press, 1998.
- Rolston, Holmes. *Genes, Genesis, and God*. Cambridge: Cambridge University Press, 1999.
- Watts, Fraser. *Theology and Psychology*. Aldershot, UK: Ashgate, 2002.