Science and the Spiritual Quest

New essays by leading scientists

Edited by W. Mark Richardson, Robert John Russell, Philip Clayton and Kirk Wegter-McNelly

ROUTLEDGE
Taylor & Francis Group

London and New York

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Introduction

W. Mark Richardson

What is this volume about?

Scientists are accustomed to experimentation, but this book is the result of a very unusual experiment indeed. This volume presents leading figures in the sciences, widely published in their respective fields, who now venture to write about the interdisciplinary ground between their science and matters that are *spiritual*. The philosopher and theologian, Paul Tillich, named this the dimension of "ultimate concern": the source of meaning that structures and interprets all aspects of one's experience.

This writing was inspired by a project named Science and the Spiritual Quest (SSQ). In 1997, sixty leading scientists from around the world met in SSQ workshops in Berkeley, California to discuss together the relationship between theory in their science and major themes from some of the world's great spiritual traditions. It is not so rare for scientists to have been shaped and influenced by one religious tradition or another, but it is very unusual, perhaps unprecedented, for scientists to meet with colleagues from different traditions, to reflect on the relationship between these aspects of their lives; and to consider the areas of consonance and dissonance they find at the points of interaction between science and religion.

These essays were born from the discussions and interactions that occurred at the SSQ meetings. There are physicists and astrophysicists, biologists and computer scientists, all representing major themes which emerge at this interface between two of the most powerful forces in human cultures today.

The value of this dialogue

Should we take such conversation between science and spirituality to be a cultural breakthrough, or a step backward from twentieth-century ideals? Throughout much of the twentieth century, intellectual culture preserved a radical independence of science (as publicly accessible objective knowledge) from religion (as subjective ideas based on personal preferences derived from the contingencies of one's background). Under this perspective, religion, spiritual practice and even metaphysics were irrelevant to the pursuit of knowledge. Others in this era were more explicitly hostile to traditional ideas of Western religion, seeing them as simply wrongheaded and in conflict with the present scientific worldview. Ironically, this latter view at least affords matters of religious scale enough cognitive value to merit the status of "in conflict." In neither model, however, is anything informative thought to emerge at the nexus of science and religion.

Why are these scientists writing about these matters? In many cases the essays constitute a tacit rejection of the dogma of "separation," the idea mentioned above, that science and religion have no grounds on which conversation between them can occur. Most of these sixteen scientists see the intersections between intellectual frameworks of interpretation produced by the spiritual quest for meaning and the theories and data that inform but cannot create a meaningful worldview.

We often marvel at the success and power of contemporary science. In countless ways it is transforming Western civilization. But rarely do we note that science of today originates in the cultures of Western monotheism – Christianity, Judaism and Islam. This connection seems distant, under the apparent strain between religion and science in our day. But if we probe beyond appearances and biases, as these scientists have done, there are hints of science's context within a larger framework of the human quest for meaning and purpose. Is religion's pursuit of ultimate concerns insinuated in the scientists' pursuit of truth? Will common features in the practices, experiences and disciplines of science and of religion be discovered and acknowledged?

Most of the scientists represented in this volume recognize the influence upon them of one or another of the monotheistic traditions. They wish to explore how these formative experiences have influenced their professional work. Conversely, they explore how the new perspectives gained through the sciences have affected their understanding of the great religious themes about God: the nature of the human person as moral and spiritual agent, the purpose and meaning of the universe. Some of these scientists are very tentative about the way they express their views on these topics, others are more bold. In all, one senses subtle and complex factors in the relationship between scientific and religious pursuits of truth.

Others represented in this volume do not acknowledge faith in a transcendent reality, but recognize the human quest for meaning and are in pursuit of a coherent moral vision, consonant with the scientific worldview, that will capture the motivational core of human beings.

Notable themes and features of these essays

There are recurring themes running through the essays.

- A noticeable wrestling with the *status* of spiritual insight or "truth," and the wisdom of tradition: it resonates deeply in human experience, yet lacks the "test-ability" and exactness we demand in the sciences.

- The theme of religion's *moral* center surfaces often, with several scientists finding the heart of spirituality in its contribution to moral issues and policy decisions related to scientific research and application.
- A number of the scientists remark on the limits of science: what it does, it does well, because it limits itself to certain kinds of measurable properties of objects and states of affairs. So how can it touch upon questions of such breadth as those posed by spiritual traditions?
- Others wish for the major spiritual traditions to recover an open and inquisitive spirit (and through this recover their vitality). They worry that religion is locked in dogmas that are kept out of contact with living experience and has lost its power to interpret experience.

Ironically, one burning issue in popular culture that drives a wedge between religion and science – the apparent conflict between evolutionary theory and theological ideas about "creation" – seems not to motivate these scientists at all. This, of course, is the most passion-filled nexus of science and values in American culture today at the level of public school education and other areas of popular culture. No one seemed burdened on a spiritual level by Darwinian biology and its implications regarding the human person. Those that consider the question at all recognize that evolution is open to various interpretations and does not have devastating effects on their spiritual self-understanding.

Consonances and dissonances between different domains and modes of knowledge and experience come and go as a result of this dynamic flux in all spheres of knowledge. This works against the expectation that science will, at all times, be complementary with long-held perspectives rooted in religious tradition. While religious traditions may, and indeed must, change themselves, the pace of such change depends on many factors and will not always be determined by changes in the sciences.

Readers will be struck in these essays by how the classic questions of every age remain central in this one, regardless of scientific advancement. Concern for:

- the reality of pain and suffering against the backdrop of faith in God's goodness;
- balancing nature's unremitting regularity with the intuition of freedom, and discerning the place of God in this;
- making sense of belief in the *purpose* of life and the universe in the face of the ambiguity of natural evidence, and science's methodological resistance to the search for meaning;
- finding the meeting place between scientific pursuits and the moral responsibility of the scientific community within the larger culture.

What is noteworthy about the attitude of these scientists on these issues, and impressive in their conversations, is their seriousness and reverence with respect to classic religious issues, without dogmatism. The open, exploratory spirit of science – so fundamental to its success – is carried over to these questions about cosmic and human origins and destiny, and about the source of being and object of our worship. There is no false certitude, and no stubborn refusal to consider the evidence from any source of human experience. We see here a model for something that may be informative to broader world religious dialogue: stepping back from our respective certitudes and adopting a posture of deep listening; receiving the voice of the "other" so that it can inform and expand our own long-held convictions.

The diversity of opinion

The insight that arises most clearly in this collection is that there is no single answer to the questions posed at the juncture of science and religion. Although there are agreed upon elements in the practice, method and theoretical outlook of each scientific discipline, the practitioners themselves are persons with many and varied influences on their lives. As a consequence, each appreciates the mutual influence of science and religion in his or her own unique way: some acknowledging a high degree of integration, others complementary relations but real differences in the modes of knowing and objects of knowledge, still others are uncertain that the two domains of their lives interact extensively at all.

Indeed the variety of possible understandings among people who share so much in common as scientists is part of the story told by this book. One's first impression is of a rich, almost startling diversity; clearly the sixteen scientists who have spoken and written in these pages do not reflect a "party line." Instead, they represent a vast array of positions running from strict atheism through agnosticism to the deepest forms of devotion to God. Some draw very tight lines of connection between their science and their religious belief; others are cautious about even the most limited of connections.

How are we to make sense of diversity such as this? If science depends upon repeatable results, what does it mean that a vast range of interpretations pop up once we interpret science on this level of human quests for meaning and spiritual fulfillment?

When systematic inquiry in any given field of natural knowledge takes us to the edge of that field, it often leads the inquirer to apprehensions beyond the discipline itself. A well-known contemporary example is the breakdown in the equations when one reaches singularity in classical Big Bang theory. Once we have pushed back as far we can toward the singularity, we finally face the question of cosmic origins and the fundamental question "why is there something and not nothing?" which has occupied human imaginings since the dawn of civilization.

These boundaries demonstrate the inherent limitations of the scientific method. Nevertheless, there *is* a relationship: what physics can tell us affects the relative viability of the various metaphysical options. Conversely, the metaphysical commitments dispose us toward the interpretations we make of the available scientific evidence. This is a peculiar situation: no necessary relationship, but real interdependence. For example, "chance" in nature signaled meaninglessness for the philosopher of biology, Jacques Monod, but it indicates insight into the creative activity of God for biochemist and theologian, Arthur Peacocke. They each have access to the same science. The science as such cannot arbitrate their differences in interpretation, but the philosophical commitment only survives if it can make sense of the known data. This is a situation somewhere between necessary entailment and complete independence.

All too frequently the large-scale commitments that guide conversation and writing at the nexus of science and religion go unstated. Consider the diversity of views in the following list:

- Paul Davies writing about the "*mind of God*";
- E.O. Wilson interpreting religion through the lens of socio-biological explanation;
- John Polkinghorne's and Arthur Peacocke's theological revisions based on contemporary science;
- eco-feminists using feminist principles to reconstruct a contemporary cosmology;
- Brian Swimme's and Thomas Berry's mythic-like narratives of the universe.[1]

All of these are attempts to pose worlds of meaning within a contemporary scientific perspective. The range of viewpoints in this list alone is staggering. How do we sort it out?

Understanding the diversity: a typology

A typology might be useful here for understanding the ways that many today are making the links between science and religion. One way to categorize contemporary explorations at the nexus of science and religion is to use three common motifs in nineteenth-century intellectual culture.

- There are those who adopt the Enlightenment quest for universal and ahistorical principles of reason by which to speculate on matters of ultimate concern. We will refer to this as the *rationalist-speculative* type.
- Others represent something analogous to the Romantic movement's reaction to this: a drive to restore a sense of cultural *telos*, to elicit the affective dimension in the understanding of one's place in the universe, and to appreciate a fundamental unity of consciousness and personhood with the whole of the cosmos and nature. We will name this the *affective-holistic* type.

- Still others place stress on the cognitive dimension of religious belief, applying critical historical and philosophical bridges to connect what appear to be very different conceptual systems of science and religion. Here there is recognition of interaction between science and religion, but also distinction between them and their institutional histories. This last group will be referred to as the *critical-historical* type.

I will concentrate on issues of *language, attitude* and *method*, to characterize the types and to draw out the distinctions.

Rationalist-speculative approaches

The rationalist-speculative type is not invested in a rigorously developed link between the scientific view of nature and historic religious traditions, especially Western theistic traditions, which stress the personal source of all existence. Consider, for example, Andrei Linde, SSQ scientist and Professor of Physics at Stanford University:

> from the beginning this understanding of God as somebody sitting and creating the universe was from, well, bad movies. There are some primitive ideas in the minds of people until they have found something better. The question is, what is the deepest level of ideas about God that may survive after science investigates things?
>
> (interview)

The rationalist begins within the rigors of the sciences, and from there engages in the speculative task of building inferences about principles of ultimacy from this rational and empirical grounding in the sciences. There is optimism about uncovering universal and timeless principles of scientific rationality that, when followed, will lead to understanding the basic laws of the universe. From these we will be able to speculate about matters of meaning and value we attach to our experience of the universe, informed by human judgment and knowledge as well as by physical cosmology.[2]

This type does not invite much self-involvement or affective attachment in this process. As Paul Davies states, "There is a long and respectable history of attempts to confront such issues by rational and dispassionate analysis."[3] The suggestion here is that it is scientific rigor that leads to knowledge of the world, which can then be generalized in meaningful ways.

The movement is in a single direction: beginning within the standards and methods of one's science and moving toward its boundaries, at which point one looks for connections, or patterns that can be extended as inferred from the science, and applied as ultimate principles lying beyond science *per se.* This becomes the basis for all cognitive claims.

Exemplars of this type may be suspicious of any ideas or assumptions derived from ordinary human experience. The potential for delusion in common-sense experience can make it an unsatisfactory route to knowledge. In contrast, it is thought that the natural sciences, especially physics, lead to results which may be counter-intuitive. Knowing the "cosmic code" through science and following the assumptions of common-sense experience can be at odds. If this is the case, then those who are trained in the intellectual habits and procedures of physics are in a privileged position to provide "true" principles of the universe. Again, Andrei Linde:

> When you look around yourself, there are some solid, well-established facts of your life. This is quite satisfactory for 99% of the population. But then somebody tells you that space is curved, and that parallel lines might intercept somewhere, and that the universe may be closed on itself, and that particles are not particles but in some sense waves. These things are so much against the intuition of your everyday life. Nevertheless, even though these things seem like a miracle and are absolutely anti-intuitive, they are solidly grounded in truth and in experimental evidence.
>
> (full interview)

If principles of ultimacy are going to be shaped directly out of science, and if we forecast science's continued success, then according to some exemplars of this type, we may be optimistic about eventually pushing back the boundaries of mystery, and resolving some classical questions thought to lie beyond science. In discussions in a workshop for physicists, the question arose over the distinction between *puzzles* (i.e., problems to be solved) and *mysteries* (i.e., those things that are not known via science, and thought to be in principle unknowable). "Does physics recognize this difference?" we asked. In reply, Nobel physicist Charles Townes, and SSQ participant, rejected the distinction. His claim was that if science were to pre-determine what cannot be known, progress would end. Resort to mystery closes down the inquiring spirit of science. Many have argued, for example, that the question of human consciousness and freedom lies outside the full reach of science. SSQ scientist, Geoffrey Chew, retired Professor of Theoretical Physics at the University of California, Berkeley, and inventor of bootstrap theory, states, "I deeply believe that absolute truth is unobtainable." Nevertheless, in the spirit of this unrestricted quest within the sciences, he goes further to state that many phenomena thought to be mysteries beyond science must not go unexplored scientifically: "We have to know what human self-consciousness means. Science cannot ignore the phenomena of 'soul' " (full interview).

Given the central role of science in this type, the language it employs at the science–religion interface can be austere and impersonal. The goal is to remove all elements from the interdisciplinary engagement which would individualize or personalize knowledge and judgment. At the juncture linking science to ultimate concerns, exemplars of the intellectual type either turn silent and retreat into stances of personal commitment (that are regarded then as personal preferences); or they speculate about the other side of the boundary by way of inference from science itself, staying close to the conceptuality of science in doing so. Paul Davies, for example, when exploring frontiers of meaning, highlights the combined features of *order* and *contingency* evident in the universe, and finds the insinuation of intelligence underlying the universe. Freeman Dyson, impressed by the scientific observation of *diversity* on so many fronts, develops the metaphysical value of this feature.[4]

Although this cosmological picture may engender awe and wonder, there is little or no resource for capturing the aspect of self-involvement, and little need to remain in tension with the rich symbolic power of religious traditions on such matters. The problem posed by this type is whether the God derived from natural theology (if, indeed, "God" is a term seriously employed) is a God that can be worshiped, or whether the principles of the (C)osmology thus derived can inspire human passion and direction.

Affective-holistic approaches

Those who have the affective and holistic orientation toward the relating of science and spirituality are driven by the quest for unity of one's consciousness and being with the cosmic whole. To achieve this goal, they see the need to recover a cosmology that derives from the most integrative picture we have from contemporary sciences, that we then invest with a worldview which underscores this thesis of cosmic wholeness and synthesis.

SSQ scientist, Pauline Rudd, molecular biologist at the glycobiology labs of the University of Oxford, and member of the Church of England, states:[5]

> As Wordsworth knew, there is a kind of intuitive wonder that we experience when we look at the natural world and see a glorious sunset or a leopard running across the plains … eventually this type of intellectual wonder can give way to the intuitive, for the mechanisms can become so well studied and understood that the distance between the observer and the observed is somehow eclipsed and the scientist understands the sunset from the inside. Perhaps this is like those in some spiritualist traditions who claim to be transformed into animals or trees, or to be able to predict the weather. I, for example, would like to be able to empathize with the molecules I work with.

An SSQ scientist represented in this volume, George Sudarshan, a physicist at the University of Texas, expresses the unity of life and knowledge, from the perspective of his grounding in the spiritual life of Indian culture:

> My tradition affirms that any spiritual search, whether academic or not, is bound to lead to God. Within Hinduism, there is nothing which is not sacred. God is not an isolated event, something separate from the

> universe. God is the universe. … Yes, God is more than the universe, but He is the universe.
>
> (essay)

The expression of this integrative vision is often in narrative form and in highly symbolic language. This linguistic strategy reflects the unity sought after, for the story is a synthesis – a bringing to oneness of cognitive, aesthetic, affective and moral dimensions of knowing into a single language.

SSQ scientist, Joel Primack, theoretical physicist and cosmologist at UC Santa Cruz, and discoverer of cold dark matter, states:[6]

> We may see in the first decades of the Twenty-first Century the emergence of a new [scientifically inspired] universe picture that can be globally acceptable, and with this and the contributions of image-making writers, artists and spiritual visionaries, it is possible that the painful centuries-long hiatus in human connection with the universe will end.

This quest evokes a connection of the self with a larger whole. It is recognized that cognitive, aesthetic and moral dimensions must be drawn upon to make this connection. Consider the following example from Brian Swime and Thomas Berry's *The Universe Story*. They use the mythic name Tiamat, the ancient Near-Eastern god, to identify supernovas, the stellar deathly violence that brings new diversity and eventually rich communion. By personalizing a natural force they evoke intentionality in the rendering of the cosmic story, making the bond between personal existence and the whole of reality. Similarly, the same authors state, "the eye that objectively searches the Milky Way is the very eye shaped by the Milky Way in search of its own inner depths."[7]

The language is personal, and personally engaging, to reinforce this fundamental unity of consciousness with the cosmic whole. Says Pauline Rudd:

> We need to develop a language to express these intuitive ideas … and it is symbols – used by science, religion, music and painting – that bridge between earth and heaven; between intuitive and rational understanding.

As with the rationalist-speculative type, there is no clear motivation to preserve the institutional histories of Western theisms, or for that matter, any tradition at all. Historical traditions are seen as unlikely vessels for holding the spiritual sensibilities of the contemporary, scientific age. The effect is to relax the need to relate, in any rigorous and systematic way, the conceptually distinct systems and traditions of science and religion. The emphasis here falls on synthesis.

According to the affective-holistic approach, history only conveys the movement toward unity that one intuitively finds in the present context, a general movement toward a goal of complexification, or self-creation, or diversity within unity. This cannot be done through the austerity of scientific language alone. Consider, again, the words of Swimme and Berry:

> Any cosmology whose language can be completely understood by using one of the standard dictionaries belongs to a former era … an encounter with the new cosmology is a demanding task, requiring a creative response. … Human language and ultimately human consciousness need to be transformed to understand in any significant way what is intended.[8]

The pressures of reality, according to these authors, drive the creative and questing spirit to push against the boundaries of language, and to be an insurrectionist and bold form of expression.

In conclusion, the strength of this type is that it elicits a passion and self-investment in this dialogue between science and spirituality. This is accomplished through the power of synthesis, drawing upon the affective dimension of humanity's quest that is missing in the rationalist-speculative model. This sometimes comes at the expense of critical examination of the various *cosmic* stories. Whose rendering of the "new story of the cosmos" are we to believe, and on what grounds? Does the sense of unity achieved come at the cost of glossing over the complete scientific picture of nature – one that includes not only its beauty but also brutality? This absence, however, is not something intrinsic to this type and is rather a tendency to be guarded against.

This model, more sparsely represented in this volume, was nevertheless present in the outlook of some of the scientists in the SSQ project.

Critical-historical approach

What concerns those within the critical-historical type is the way the historical tradition functions in the conceiving and conditioning of the present understanding of the God–nature relationship. There is sensitivity to the cumulative and progressive relation between conceptions of God and nature. New knowledge from the sciences reveals new integrations with religious tradition, its mysteries, and its positive conceptions of God. It is a recognition of the way the past is embedded in present communities of inquiry. For this reason, those who are committed to traditional theistic traditions are attracted to this outlook and become its exemplars.

As Arthur Peacocke, a biochemist, Anglican priest and SSQ scientist, states it, the task at this interface of contemporary science and spirituality is "to rethink our religious conceptualizations in light of the perspective on the world afforded by the sciences."[9] This involves not only the mixing of historical frameworks (ancient creeds and historical texts) but philosophical and conceptual ones as well. This is *not* a burden for the other approaches because they are less tied to the formalized and integrated belief structure of Christian theism.

Peacocke's way of addressing the philosophical bridge is through the development of an epistemological hierarchy that allows us to see continuity and differences at various levels of natural organization. We find a hierarchy of complexity from sub-atomic, atomic, molecular, cellular levels and so forth, all the way to the most complex levels of organization in the universe. Theology is the most integrative of disciplines concerned with meaning and value. It is constrained from below (by psychology, social theory and so forth), just as theory in molecular biology is constrained by physics (we won't tolerate explanations in biology that violate laws of physics).

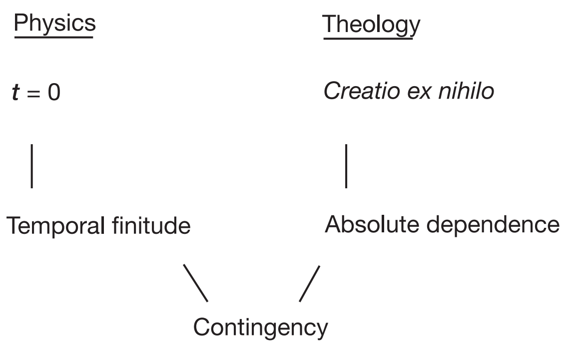
In spite of constraint, each new level of complexity requires explanatory concepts at its own level representing functional properties at work on that level. Through developing disciplinary maps such as this, Peacocke attempts to show how science and religious themes can be related and he sees this kind of integration as a necessary step toward any realization of theology's role in public conversation.

Another SSQ scientist, Martinez J. Hewlett, Professor of Molecular and Cellular Biology at the University of Arizona, follows in the historical-critical path, and echoes Peacocke's methodological concerns. Hewlett sees that careful attention to methodological and historical issues, and to the nature of the object of discourse, will help us see that apparent conflicts between science and religion are often no conflicts at all. In his nuanced essay on the nature of reductionism, its correct use in science, and its potentially abusive use in extra-scientific contexts, Hewlett states:

> Investigations of material reality should be informed by, not at odds with, investigations of spiritual reality, and vice versa. There is no need for scientists to overlook what is perfectly obvious in everyday experience, even if it cannot be measured by instruments.
>
> (essay)

With an interest in the same question of reductionism, SSQ scientist, Robert B. Griffiths, a physicist at Carnegie-Mellon University, contemplates the relation between reductionism in physics and discourse about the scale of reality central to personal and religious experience. He suggests that a careful use of reductionism in the sciences is, in the end, an ally of theological thinking. Pressing reductionism to its limits will make our understanding of human agency, for example, better informed, and will expose the limits of physical description in our accounting for human action and moral responsibility. His essay in this volume is a clear statement of the importance of both distinguishing and respecting different levels of discourse important to human enterprises, some springing from our sciences and others from personal and religious scales of experience.

Here I would like to mention the thinking of Bob Russell on this issue. Russell, the Founder of the Center for Theology and the Natural Sciences, in Berkeley, California, considers the relationship between classical Big Bang cosmology and the monotheistic doctrine of creation as one of consonance. He stresses the fact that, in trying to locate the consonance between theology and science, one must acknowledge both similarity and difference in their respective conceptual systems. This reminds us that any effort to show relations between science and the spiritual quest requires considerable care. One will find points of relationship, but one should not expect to find them on the surface of our language in the compared systems. Consider the following diagram:



Notice that theories in physics and theological beliefs represent fundamentally different conceptual domains. There is no immediate connection between "$t = 0$" and "*Creatio ex nihilo*" in the diagram. Nevertheless, they may share common metaphysical roots. The relation is not direct and must be mediated through the steps shown in the diagram under each tradition, but each can be traced back to a shared fundamental notion of *contingency*.

Coupled with the appreciation for the complementary relationship between the institutions of science and religion, the historical type also is sensitive to the distinct functions and tasks of science, on the one hand, and the worlds of meaning we typically associate with our religious traditions, on the other. Each has its own institutional history, its own functions and language, so that the relationship between them can be complex. The challenge is in finding the appropriate way to mediate the difference so that true connections between them can be located.

SSQ scientist, Bruno Guiderdoni, astrophysicist at the Institute of Astrophysics in Paris, believes his Sufi Muslim tradition provides a motivation for the pursuit of all aspects of knowledge, including science, and instills a moral attitude about this pursuit:

> I think they [religion and science] are complementary. Islam strongly emphasizes the importance of knowledge in life in general and in religious life in particular. … There is restriction in Islamic tradition because the knowledge that must be looked for is useful knowledge, that is, useful to mankind in general. That means that the pursuit of knowledge is not separated from ethical values. … As a Muslim, I feel very comfortable in my scientific activity because I can interpret my research work as the pursuit of knowledge of this world, as the exploration of the richness and beauty of God's Creation.
>
> (full interview)

The apparent conservatism of the historical approach is traceable to both religious and philosophical convictions. In the present postmodern context we have learned that there is no privileged context, no jumping out of our histories in the pursuit of truth and first principles. The emphasis on the historical context of concepts and ideas does not entail complete relativism – there is still a possibility for inter-subjective conversation, even inter-subjective judgment about explanatory schemes. But the foundations, as they are understood in the rationalist model, are looked on with some suspicion; there is more recognition of finitude, of limits.

Western theisms are beginning to appreciate the social dimension of their beliefs and practices. Awareness of one's connection to communities of belief through time leads the historically conscious to an appreciation of the traditional sources of wisdom and truth. Again Guiderdoni:

> In spite of these [scientific] discoveries, the important thing is not there; the important thing is man's spiritual realization because we need more knowledge than science is able to give us. … If we want to address the question of origins, we have different kinds of answers. We have the answer given by modern cosmology, that is the way of projecting the question of the origins onto the plane of scientific method with concepts such as space, time, and matter. We also have the spiritual and mystical approach.
>
> (full interview)

The critical-historical type recognizes that there is a gap, at the very least a conceptual gap, between the language of science and the language of our religious traditions. This gap needs a philosophical bridge if there is to be any hope of integration. It is understood that science may originate within Western monotheistic cultures and share common ideas regarding the rationality and contingency of the universe, but religious history and scientific history have their own independent trajectories. The task at the interface of science and religion is both philosophical and historical: to find intelligibility in the various domains of knowledge and commitment in which we take part.

SSQ scientist, George Ellis, a physicist at the University of Cape Town, South Africa, and a Quaker, construes the relationship in this way:

> Science attains near-certainty by limiting itself to very specific quantifiable issues, but consequently cannot look at many issues of vital importance to human beings. Theology uses broader classes of data that deal with much wider issues – of major significance to everyday life – where much less certainty is attainable. Both rely on judgment and discernment in their practice and allow a similar attitude of questioning and process of testing.
>
> (from conference presentation)

According to the critical-historical type, there must be sensitivity to the philosophical questions that arise at the interface of religious tradition and contemporary science, questions about:

- *language*, e.g., how do models and metaphors function in science and theology?
- *epistemology*, e.g., along with its affective and moral dimension, does religious language refer to the world; does it have cognitive value?
- *method*, e.g., can theology develop a public methodology that demonstrates explanatory power and a predictive aspect, analogous to the successful methodology of scientific research programs?
- *practices*, e.g., what are the goals and activities of religion and science that constitute their differences?

The difficulty with this approach is: how does one persistently engage in the self-critical stance, as expressed above, without a loss of immediacy in relation to one's spiritual/religious heritage? What effect on the religious attitudes of, for example, awe, praise or sanctity, can we expect from such constant self-critical examinations of religious intelligibility?

These writers offer unique perspectives based on their genius and depth of understanding in their particular fields. A typology cannot by itself exhaust the subtleties and finer points of their respective contributions; moreover, exemplars may at times express impulses associated with more than one type, even if there is a predominant tendency in their work. This typology is simply intended as a useful guide in recognizing motifs that arise at the nexus of science and spirituality.

The SSQ project: the context for these essays

Something more must be said about the larger context in which these interviews occurred. The workshops mentioned above were part of a three-year project, Science and the Spiritual Quest, which involved sixty scientists in research, group discussions and conferences. The workshops occurred in four groups of fifteen, organized around professional disciplinary specialties of physics, cosmology, biology and computer science. Each group met twice, for three days each time, over a period of one year.

Something special occurs when scholars and scientists are encouraged to give utterance to ideas, and to think through the implications of their work *together*, rather than pursue such work in private. The workshops were a time of deepening personal understandings at this nexus, gaining a power of expression on such issues, and discussion of these topics with professional colleagues. This last point is nearly unprecedented in the scientific culture today. Through trust and through open exploratory process, the discussions with colleagues drew out a level of reflection in each person in ways that private reflection could not. The scientists were encouraged to bring a spirit of open, hypothetical inquiry, typical of the process of their scientific work, into discussions involving moral and spiritual topics.

Naturally, there is a deeply autobiographical aspect to this kind of reflection, and this comes through in the tone of these essays, in some cases more than others. The personal context of each scientist, his or her movement from struggle to tentative resolution, and from creative idea to systematic expression – all of this is detected in this genre of writing. One senses the intellectual drive and passion that has made these figures leaders in their fields. They reflect an honesty and openness to criticism and revision in matters of spiritual significance that also characterizes their work as scientists.

The results of this process of workshop discussions and research were presented in a public conference in June, 1998, at the University of California, Berkeley. There, twenty-seven of the participating scientists presented the findings of their research. Never before had such a distinguished group of scientists convened to speak about science and spirituality. As a consequence, over thirty national correspondents and reporters were in attendance at the four-day SSQ conference.

The conference proceedings inspired a *Newsweek* cover story based solely upon the views of several SSQ participants, and an NBC-produced segment about the conference on its weekly *Religion & Ethics Report*.

The editors acknowledge, with deep appreciation, the distinguished work of the Center for Theology and the Natural Sciences (CTNS), which made this project and this book possible. We wish to thank especially Holly Vande Wall for her careful editorial work on the interviews and essays. It was because of CTNS's fifteen-year track record of engaging in cutting-edge

research on the interaction of theology and the natural sciences that the John Templeton Foundation generously and confidently funded Science and the Spiritual Quest. Finally, we acknowledge with appreciation the generosity and visionary thinking of the John Templeton Foundation, which has supported this and other very important projects in the field.

Notes

1 Paul Davies, *The Mind of God: The Scientific Basis for a Rational World* (New York: Simon & Schuster, 1992); E.O. Wilson, *Consilience: The Unity of Knowledge* (New York: Knopf, 1998); Arthur Peacocke, *Theology for a Scientific Age: Being and Becoming – Natural, Divine and Human* (Oxford: B. Blackwell, 1990); John Polkinghorne, *Belief in God in an Age of Science* (New Haven, CT: Yale University Press, 1998); Karen J. Warren, ed., *Ecofeminism: Women, Culture, Nature* (Bloomington: Indiana University Press, 1997); Brian Swimme and Thomas Berry, *The Universe Story* (San Francisco: Harper San Francisco, 1994).

2 In a helpful book titled *Before the Beginning*, mathematician and astrophysicist, George Ellis, makes the distinction between (c)osmology and (C)osmology. The former refers to physical cosmology as it is carried out professionally in the sciences by theorists and observationalists. It is a narrower use of the term. The latter, in Ellis's use, refers to matters of meaning and value we attach to our experience of what is the case, that, of course, is informed by our scientific perspectives on the universe and life within it. Whereas many features of physical cosmology may be incontestable relatively speaking, this larger sense of (C)osmology is open because we cannot so easily test unique phenomena, or the meaning and value we draw from our view of ultimate things. I adopt Ellis's idea here and refer to the following questions relating to (C)osmology. See George F.R. Ellis, *Before the Beginning: Cosmology Explained* (New York: Boyars/Bowerdean, 1993).

3 Paul Davies, *The Mind of God: The Scientific Basis for a Rational World* (New York: Simon & Schuster, 1992), p. 20.

4 Freeman J. Dyson, *Infinite in All Directions* (New York: Harper & Row, 1988).

5 Pauline Rudd's essay is not represented in this volume but a more extended view of her understanding at the nexus of science and religion can be found in Routledge's companion volume to this, edited by Richardson and Slack. Although Rudd shows strong leanings toward the affective-holistic position, she shows a stronger appreciation than others in this type for the deep and abiding elements in the historical religious tradition of Anglicanism, from which she comes.

6 Joel Primack's essay also cannot be found in this volume. However, the Routledge companion volume of interviews offers a more complete picture of his treatment of this topic. Primack also shows a tendency to combine features of both the rationalist and affective models, once again indicating the value of viewing typologies only as general guides.

7 Brian Swimme and Thomas Berry, *The Universe Story* (San Francisco: Harper San Francisco, 1994), p. 45.

8 Ibid., p. 24.

9 Arthur Peacocke, *Theology for a Scientific Age: Being and Becoming – Natural, Divine and Human* (Minneapolis: Fortress Press, 1993), p. 4.

6 Martinez J. Hewlett

Martinez J. Hewlett is an Associate Professor at the Department of Molecular and Cellular Biology at the University of Arizona in Tucson. He has been awarded research grants from the National Institutes of Health, the National Science Foundation and the Kroc Foundation. Hewlett is a founding member of the St. Albert the Great Forum on Theology and the Sciences. His interests in science and theology led to his first novel, *Divine Blood* (Ballantine, 1998). Hewlett is currently the Southwest Regional Director for the Science and Religion Course Program administered by CTNS.

Interview by Gordy Slack

GS: Would you say a few words about your own religious background?

MH: I was born into a Roman Catholic family and I was educated in Catholic schools through high school. I went to a secular university, The University of Southern California, and after that started drifting away from the faith. It wasn't until quite late in my life – I was in my mid forties – that I came back, in a very dramatic way, to the church. Since that time I have been very active in my faith. I'm very involved in the community at the Newman Center. I'm a lector and a Eucharist minister, and I'm in the process of becoming a lay Dominican, which hopefully, God willing, will occur soon.

GS: How would you describe the transformation that took place in your mid forties?

MH: Epiphanic. I suffered a heart attack and had triple by-pass surgery. In the recovery process I had to sort out what had happened to me and where my life was going at that point. I saw that I had been brought through the trauma of disease and surgery for a purpose. During that period a dear friend of mine – who is also a scientist and a Christian, although not a Catholic – helped me to see what was going on.

GS: The question of purpose comes up a lot in discussions about Darwin and evolution. Some scientists and philosophers insist that religion and religious thinking provide obstacles to thinking clearly about human history and the history of life. In particular, the idea that things happen for some higher purpose. I wonder how you, as a molecular biologist, keep those two ideas going in your life at the same time?

MH: When I came to these questions, I found that I was very ill trained philosophically and theologically. The question of purpose is an interesting one, because most scientists will deny to the death that there is any teleology involved in what they do. But ask any biologist why the chromosomes segregate the way they do during mitosis and meiosis. They will say, "So that the offspring's cells can be the following way." But if you then look at them and say "Well, that is teleological," they will say, "No, of course it isn't. It is strictly mechanistic." I think we are trapped in this underpinning of teleology and trying desperately to be like physicists, which we biologists are not. Some people call it physics envy. I see the purposefulness of creation as an integral part of what I study and what I teach.

GS: When you are looking at a particular scientific problem in biology, you don't try to subtract teleological thinking from your methodology?

MH: I am a molecular virologist. I think in tiny detail about the little intricate parts of viruses. I don't for a minute confuse purpose with that, but I think that it is wrong to feel that there isn't a purpose surrounding all of that and underpinning it. I think science operates on faith without even realizing it. The very nature of my going into the laboratory and doing an experiment demonstrates a faith that there is an essential order which I can observe. If that weren't true, if that faith weren't there, I would have no reason to go into the laboratory.

GS: Is there any link between the points of discovery in your own scientific career and moments of religious insight or religious discovery?

MH: I think most of my scientific career took place during the time between my childhood religious training and this rebirth of religious feeling on my part. When I was working as a reductionist molecular biologist cranking out the data, there were moments of discovery, but I don't think I ever tied them to a religious experience. Since I found my faith again, several interesting things happened, including the fact that I closed my research lab. I wrote my first novel, and I also do theoretical work. I've had a very different experience with science. All of the theoretical things that I've been working on are freshened by this religious insight that is tied to them. It's almost as though I am going back over all of that slowly and fitting it into this larger picture.

GS: In the popular press we so frequently read about a gene being found that suggests an ultimate reductionism – that humans and their behavior boil down to and are determined by their genes. Will this change the way we see human beings and their relationship to the divine and to divine purpose?

MH: Once I was in northern Arizona giving a lecture, making my plea that we are not just simply a collection of genes, and a woman in the audience said her son died of cystic fibrosis. In the hospital, during his final days, a physician said to her, "It's too bad that our science isn't advanced enough that we could take some DNA from your son and create another one for you." She was appalled that he would say that to her. That is where the danger lies. It's mainly the applied molecular biologists who really believe that if I can monkey with your DNA, I can monkey with you.

GS: How do you explain the current fascination with the idea that genes are the sum of what we are about?

MH: I think it is the religion of the day, this faith that molecular biology will solve all our problems. It touches something primal and essential in us, but it's the high tech flavor that everybody likes, with buzzing and flashing lights and everything. We have this dream of "Can we do that, can we play God?" I think that's the fascination in the popular mind – that scientists are in the laboratory and they are actually going to design a better me.

GS: The idea that we could finally know ourselves in some fundamental way is also very attractive.

MH: I'm not sure if, in the popular mind, it's really a desire to know themselves so much as it is a desire to be able to control what happens. Somebody who is dying of cancer wants very much for you to go in and turn that gene off. Give me an injection of this virus if I've got a tumor and it will just destroy the tumor and I'll be free. That's the kind of thing people are drawn to: the promise that what scares them most – dying – can be staved off.

GS: Do you think that neurobiologists' work on the brain is narrowing in on the self?

MH: Well, so long as the area of study is the physical, by definition, all you will ever see is the physical. How could you see anything that I tell you is spiritual in aspect? It will always be thus, until somebody is willing to admit that the spiritual is a different realm. This is what is called scientism: the belief that science not only is powerful but also defines all knowledge. Anything that doesn't get defined by science is therefore not knowledge or is not real. Scientists are seduced into thinking that our science has the complete view. The only reason we think it has the complete view is because we don't know any others.

GS: Do you think that the seductions of science and of material reductionism have permanently siphoned energy and attention away from religion and spiritual life?

MH: My colleagues, those in my age group and perhaps a little bit younger than I, are seduced. But the students that we are talking to now are much more open to other possibilities. That openness can lead them in a lot of very strange directions, questioning of everything, without any kind of foundation. But I see in them a willingness at least to accept that there may be something more than they are being shown in their textbooks. I was in a lecture one day and one of my colleagues happened to be visiting. A student asked me why a cell did something. It was one of those places in science where we don't really know, so I did a God of the Gaps answer and said "Because God made it happen." Everybody laughed. When we were leaving the lecture hall, my colleague pulled me aside and said "You know, you shouldn't have said that."

I said "Well, what should I have said?"

He said "You should have said Mother Nature made it happen that way."

I have a sense from this generation of students that there is a chance they may view things differently than we did. That means there may be permission for them to be scientists and be spiritual at the same time.

Martinez J. Hewlett

What price reductionism?

Introduction

At the start of the twenty-first century it is probably correct to say that we are at the pinnacle of the scientific program envisioned by the philosophers of the post-Enlightenment. When David Hume proposed that the material world be the strict domain of the scientist and that empiricism should be the approach to understanding that world, an experimental method that had begun with Galileo and had been refined by Newton and Bacon was embraced with fervor. The Cartesian dualism that inspired this separation of the material and non-material aspects of reality into different spheres of human inquiry clearly led, in a pragmatic sense, to the progress of modern experimental science. But how did the exclusion of the non-material or spiritual aspect from consideration by science lead to the denial of its existence that has become a hallmark of the current view? Is this denial a reasonable result of the scientific enterprise? I will argue that the philosophical stance of science in which the spiritual not only is excluded from investigation but is *de facto* deemed to be impossible stems from two features of the research program followed in the natural sciences: reductionism, and the replacement of classical causality with scientific causality. For purposes of this argument, examples will be taken mainly from the biological sciences.

A molecular biologist looks at modern biology

How is it that someone trained in modern molecular biology, who is also a virologist, concerned with the smallest of things that exist at the border between the living and the non-living world, would come to question the central place held by the reductionist approach?

I have been associated with the St. Albert the Great Forum on Theology and the Sciences, currently entering its eighth year at the Catholic Newman Center of the University of Arizona. I was asked to be on the advisory board of the Forum and have served there since its founding. Originally, I had little interest in philosophy, seeing my purpose in planning this series as the "voice of reason and science."

The Forum has invited distinguished scientists, philosophers and theologians to present their ideas in an atmosphere of Christian discussion. One visitor early in the series was Fr. Benedict Ashley, the great Dominican philosopher and moral theologian. During his presentation he spoke of the nature of living things, emphasizing their wholeness. He used a cat as his example.[1]

At one point I rose to object to Fr. Ashley's characterization of living systems.

"I could take an organ from the cat, extract the DNA from the cells, sequence that DNA and, after computer analysis, I could tell you that the DNA is 'cat'."

I, of course, spoke with all the arrogance of my profession.

Fr. Ashley, however, replied immediately.

"It's no longer a cat."

I remained self-righteous.

"When did it stop being a cat?"

"When the cat died," he replied.

His answer left me stunned and propelled me on the journey into the philosophical underpinnings of modern science upon which I find myself today.

Reductionism in modern biology

The evidence suggests that molecular biology has finally "made it" on the popular scene. DNA took center stage in Michael Crichton's novel and movie, *Jurassic Park*. More recently, the double helix, or a fragment thereof, has main title billing in *GATTACA*.

The story presented here describes a future world in which the entire progress of a person is dictated by the knowledge of his or her genetic information. With the sequence of As, Gs, Ts, and Cs known at birth, all of the possibilities for the life of the individual are "predicted."

GATTACA represents the ultimate nightmare for a society that fears modern biology as reductionist. And yet this very approach has been extremely useful and productive for science. Why should this raise the specter of a world such as described in this movie?

Let us first define our terms. The process of reduction consists in explaining a phenomenon studied at one level of reality by the principles and processes understood at the level of the component parts of the phenomenon (Agazzi 1991). For example, the explanation of all of chemistry in terms of atomic physics, or the explanation of all biological phenomena in terms of chemistry and physics.

In a very practical sense, the empirical approach that has characterized science since Galileo and, more importantly, since the Cartesians would not have been possible without the use of reduction. In a formal sense, methodological reductionism attempts to frame all sciences in the guise of mathematical physics, with quantitation, deduction from general laws, and what may be called verifiable – or at least falsifiable, in the view of Karl Popper – predictions (Agazzi 1991). In practice, it is simpler experimentally to observe one or two of the components of a thing in a reproducible fashion than to observe the entire thing in action. Further, the level with which the discipline is concerned, especially in the mixed sciences, may dictate a methodological consideration of the components. For instance, the proper province of biochemistry is the study of enzymes within a cell.

The tremendous power and success of modern science owes much to this reductive approach for science's understanding of the physical world. And yet it is the very seductive nature of this power that results in serious problems when misapplied. It is quite easy for the scientist to conclude that the only valid way of gaining knowledge of the physical world is by reducing a complex phenomenon to the structures and principles that describe the components of that phenomenon. This conviction is called epistemological reductionism (Agazzi 1991). When knowledge of the physical world gained in this way leads a scientist to conclude that everything about reality can be completely described in terms of the most basic components of that reality, a metaphysical statement is being made by that scientist. This is called ontological reductionism (Agazzi 1991).

Within biology these three forms of reductionism (methodological, epistemological, and ontological) have varying utility. Clearly, methodological reductionism has been essential for the progress of fields such as biochemistry and molecular biology. The very nature of these "mixed" disciplines requires that aspects of living systems be examined at the level of their chemical and molecular components. Add to this the quantitative and deductive mind-set captured from physics and the picture is complete. From reductionism has come the great scope of modern biology, with its descriptive and explanatory approach that begins with the chemical nature of the gene and includes the view of the cell under the governance of the information residing in the sequence of nitrogenous bases that form the DNA.

As the progress of modern biology continues, it may be easy for the scientist involved in the enterprise to look for more detailed information using the same approach. In fact, it can become the sole approach upon which experimental designs are based. Thus, the great enterprise of the Human Genome Project has, as its premise, the epistemic conviction that the determination of the genomic location and base sequence of the set of all human genes is prerequisite to understanding their functions. Certainly, for the goal of gaining knowledge about the specific molecular subunits that constitute a living system, this research program will be successful. But can this project completely describe what it means to be human?

For some biologists, the very nature of living things must be reduced to the properties of the fundamental particles of which they are made. Francis Crick, the Nobel laureate who, along with James Watson, proposed the currently accepted structure for DNA, wrote: "The ultimate aim of the modern movement in biology is in fact to explain all biology in terms of physics and chemistry" (Crick 1966: 10).

While this may, at first glance, seem to be a logical extension of the methodologic and epistemic programs set out above, this statement in reality constitutes a philosophical position.

If the plan put forth by Crick were to examine the structure of DNA and to attempt to explain the physical properties of this molecule in terms of quantum-mechanical principles, then there would be no difficulty. This effort would merely be a methodologic decision to attempt a quantitative description of the collection of atoms that constitute the DNA molecule, based upon, for instance, approximations to the wave equation for the individual components. Such quantum-biochemical descriptions are not philosophical statements but refinements of the chemical description of this material.

If, on the other hand, the statement purports that all aspects of living systems are explainable by these quantum-mechanical descriptions, the intent is quite different. At the heart of this approach is the belief that nothing exists other than the physical aspects of reality and the correlate belief that all properties of that physical reality result completely from the properties of the simplest elements of that reality. This is clearly Crick's intent, as he goes on to say: "Eventually one may hope to have the whole of biology 'explained' in terms of the level below it, and so on right down to the atomic level" (Crick 1966: 14).

This position is a metaphysical one, in that it proposes a statement about the nature of reality. This may easily be described as ontological reductionism.

Causality and modern science

The classical and modern scientific ideas of causality are quite distinct. In the classical sense, causality indicates dependency. A particular effect is dependent upon a particular cause. Modern science uses the term causality to imply predictability. A particular effect is predicted from a given cause.

In the classic view there are four kinds of causes: the material cause or matter (here "matter" is not used in the same sense as it is in physics or chemistry), the formal cause or form, the efficient cause or agent, and the final cause or end. These causes and descriptive biological examples are outlined in Table 6.1 (with definitions adapted from Wallace 1996 and Dodds 1995). This classic notion of cause and effect was uprooted through the skepticism of Hume, who held that we can have no knowledge of this kind of relationship. His view, which has influenced the philosophy of our scientific enterprise, was that events ("effects") can only be sensed or experienced sequentially and that no relationship between them can be known. Thus, we may often experience one event (an effect) following another event (a cause) but we cannot know that the cause will always lead to the effect. In this case, the idea of an efficient cause (agent) and final cause (end) must be discarded. Hume used the term "causation" to describe this sense-derived expectation of a sequence of events.

If this is the case, how did modern science stray away from this Humean ideal and come to the concept of predictability? In a strict sense, "predictability" implies "determination." Determinism flows from the Newtonian view of the physical world that has only been upset this century by the rise of quantum theory and relativity. In spite of the changes that have occurred in physics, biology has in many ways clung to this deterministic view. Thus it is that "causality" is seen as the ability to predict an effect from a cause.

Another inheritance from the philosophy of Hume is the restriction that the only valid knowledge of reality comes through sense experience during an examination of the material aspects of the world. Hume's rejection of metaphysics included a rejection of possible consideration of any spiritual dimension of reality.

In the modern sense, then, the aspects of the proteins α and β tubulin can be investigated with respect to the material out of which they are made (ultimately, the material cause) as well as the structure which these proteins take (in effect, the formal cause). In no case, however, does modern biology speak of the efficient cause in the classical sense or of the final cause (teleology) of the microtubule subunits. The nature of the structure of the tubulin subunits that promotes their assembly into microtubules is viewed as the "cause" of the formation of the spindle fibers, but not in the classical meaning of the term. In addition, if asked why the spindle fibers form, a biologist might answer "so that the chromosomes will be correctly distributed into the daughter cells." And yet, if told he or she is making a teleological statement, this will be vehemently denied.

Table 6.1

Cause	*Definition*	*Example*
material	that which causes a thing to be; a potential or possibility; proto-matter	the material essence of things, for instance, of proteins
formal	that which causes a thing to be a certain kind of thing	a particular protein, for instance, α or β tubulin
efficient	that which causes the relative state of motion of a thing; the agent of change	the nature of α and β tubulin that allows assembly into microtubules
final	that which is the purpose or sake for which something is done	microtubules organize into spindle fibers that result in correct chromosome movement during cell division

Steps to the scientific rejection of the spiritual

Much of modern biology and perhaps of modern science in general rejects the notion of the spiritual as a possible aspect of reality. For the case of biology, the scientific philosophy that allows this includes the following features: a limitation to exclusive consideration of the physical or material; a rejection of efficient and final causality in the classical sense, in spite of obvious teleological implications of observations; a deterministic causality coupled with a Humean notion of causation; an appeal to physics as the ultimate basis, by reduction, of biological phenomena.

As a case in point, let us examine the developments that have led to what has come to be called neo-Darwinism and the conclusions concerning God which some have erroneously drawn from this molecular view of the evolutionary process. Table 6.2 describes the sequence of events that have occurred since Darwin first published his book *On the Origin of Species* in 1859.

Notice that each of the events described in the table, up to the last two, are well within the province of scientific investigation. The conclusions drawn in these cases derive from experimental observations, hypothesis-formation and testing, as well as theory-construction. In addition, the progress of the enterprise towards the identification of the gene as the physical thing upon which the force of natural selection acts is one characterized by a

Table 6.2

Event	*Method*
Darwin's observations lead to the hypothesis of natural selection as the operative force in evolution (1859)	observation → hypothesis/theory
Mendel quantifies inheritance and proposes the gene as the unit of inheritance (1868)	observation → hypothesis/theory
DNA is shown to be the genetic material (1944–1954)	observation → hypothesis/theory
Genetic changes are the result of mutations	observation
Mutations are random events that result in changes in DNA sequence	observation
Mutations are proposed as the way in which variation occurs, upon which variations natural selection acts	induction
It is not necessary to postulate an intelligent creator to explain the results of random events	metascience
Science (through Darwinian evolution) proves that there is no God	metascience/philosophy

reductive view of biological systems. These events are then coupled with the prevailing philosophical position underlying modern science that the spiritual not only is excluded from scientific investigation but also does not exist. The result is a mistaken view that since mutations are "chance" occurrences and therefore unpredictable (notice the notion of causality in force here) no intelligence is required for their occurrence. Given the *a priori* stand that God does not exist, the evidence of biology is taken to prove the circular argument that God, in fact, does not exist.

The nature of this metaphysical conclusion is exemplified by Daniel Dennett:

> A familiar diagnosis of the danger of Darwin's idea is that it pulls the rug out from under the best argument for the existence of God that any theologian or philosopher has ever devised: the Argument from Design. What else could account for the fantastic and ingenious design to be found in nature? It must be the work of a supremely intelligent God. Like most arguments that depend on a rhetorical question, this isn't rock-solid, by any stretch of the imagination, but it was remarkably persuasive until Darwin proposed a modest answer to the rhetorical question: natural selection. Religion has never been the same since. At least in the eyes of academics, science has won and religion lost. Darwin's idea has banished the Book of Genesis to the limbo of quaint mythology.
>
> (quoted in Brockman 1995: 187)

It must be emphasized that the error is not in the science which, given the current level of understanding and available tools, is based upon relatively sound logical foundations. Rather, the problem here is a philosophical one, wherein the scientist has overstepped the agreed upon limitations of the endeavor and entered into a discussion for which he or she has no logical basis. The fact of the existence of a spiritual dimension to reality or of an intelligent Creator is certainly outside the sphere of examination by science *per se*. And yet the full weight of the scientific method is often brought to bear against these ideas, as in the quote above from Dennett.

Conclusion

The methodology of modern biology is generally reductionistic and deterministic, in spite of the changes which have taken place within physics, the science to which some strive to reduce biology. This "bottom up" causality can lead to a number of conceptual difficulties in light of the observed properties of living systems when compared to their isolated components. Examples abound in the sciences of the inability of the tool of reductionism to answer a particular question. For instance, the chemical properties of the sodium atom cannot be predicted from the properties of an isolated electron. Similarly, the development of multicellular creatures such as human beings is not simply the result of the molecular program found within the sequence of bases in DNA. The physical development itself, to say nothing of the spiritual dimension, is much more complex and requires an interacting system of cells to achieve the ultimate form.

The anti-metaphysical stance of the scientific enterprise, inherited from the eighteenth-century philosophers, permits no consideration of the spiritual as a part of reality. For these reasons some biologists mistakenly conclude, by circular reasoning, that the accumulated evidence disproves the existence of the spiritual and of God. It is especially important when biologists take this stand since, unlike cosmologists or physicists, they are looking at human beings as organisms within creation. I contend that there is no necessity for this extreme position and, moreover, that it harms the scientific enterprise by greatly limiting the possibilities. Investigations of material reality should be informed by, not at odds with, investigations of spiritual reality, and vice versa. There is no need for scientists to overlook what is perfectly obvious in everyday experience, even if it cannot be measured by instruments.

Note

1 It is interesting to see the role played by cats in philosophical discussions, as witnessed by Schrödinger's famous and ill-fated (one-half of the time) cat.

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7 Robert B. Griffiths

Robert B. Griffiths is Otto Stern University Professor of Physics at Carnegie-Mellon University, where he has been a faculty member since 1964. He has a Ph.D. in Physics from Stanford University (1962). He is a Fellow of the American Physical Society and a Member of the National Academy of Sciences of the USA. His current research interests include the foundations of quantum mechanics, quantum information theory, and quantum computation. Earlier he worked on the mathematical foundations of statistical mechanics, the theory of critical phenomena, models of magnetic materials, and the theory of incommensurate crystals. His other interests include: the problem of determinism and free will, and the relationship of physical science to Christian theology.

Interview by Philip Clayton

PC: Let me ask you first about your religious background and your own religious commitment.

RG: My parents were Presbyterian missionaries in India, and I'm currently a member of a Presbyterian church, although I have probably moved somewhat toward Baptist theology.

PC: Was there any influence of the pluralistic religious context of India in your own formation as a Christian?

RG: I would find it hard to say that there was. I didn't start seriously thinking about my faith from an intellectual point of view until I got to college in the USA, and at that stage Hindu ideas were far removed.

PC: Do you see your faith and your scientific practices as relevant to each other?

RG: I think people bring to their religious concerns many different styles or modes of operation. What I tend to bring is my training as a scientist, and thus the first thing that's important is: is something true, and what sort of system does one have for thinking about it? I sometimes consciously, but more often not so consciously, bring a lot of my prejudices as a scientist into my religious practice. A certain frankness and openness is, I think, a scientific trait. You tell people why you disagree with them, and that you think they're wrong, and often do this with a lack of sensitivity. I think that's both good and bad in religious practice. But generally, I think bringing to the religious community some of the positive aspects of the scientific community is a good thing.

PC: What areas in Christian practice do you think are radically different from scientific practice?

RG: Faith is one difference, but not totally different, because modern scientists believe in quarks, which are in principle invisible. But religion, or at least Christian theism, says that a Christian's obligation is to serve and worship God. God is the moral authority, and the physical universe around us has no moral authority.

PC: Is faith something that means accepting on the basis of authority a body of truth, and therefore is highly disanalogous to science, which accepts very little on unquestioned authority?

RG: Scientists accept a great number of things on authority. The freshmen that I'm currently teaching believe certain things because the book says so, and I say so, etc. One wants to balance off their acceptance of authority, without which they'll never learn the subject, with an appropriate amount of intelligent fooling around and asking questions, including dumb questions. So both authority and doubt play a role in physics.

Now what do we do as Christians? Certainly a great deal is received on authority from parents and pastors, who pass along the teaching of the Bible, and what the community has produced through the years. But one is free to challenge the tradition handed down, go and think about it, and argue about it. Certainly, one can go off the deep end in the same way that freshmen sometimes come up with stupidities, but I myself feel that the questioning approach is quite appropriate. When I read the Psalms I find honest questioning. The psalmist says, "My God, my God, why have you forsaken me?" It seems to me there is some parallel between that and scientific questioning.

Now, I believe that God's authority in the moral realm is a very different thing from what one encounters in science; there's nothing comparable to that in physics. I don't see a problem with this, because to me the very nature of God means that you have to relate to him in a very different way than you relate to the physical world. I accept the Bible because I believe that God spoke in particular ways to the people whose writing one finds there. And there's a great deal about personal relationships, about how you should behave toward people, to be found in the Bible, and you can go and test it out, see whether it works.

I think that there is a reality "out there." God and moral law and so on are real things which exist. For me, religion should be based on a reality which is "out there," whose truth does not depend upon whether or not we like it or believe it.

PC: For you, are there any developments in the physical or biological sciences which might falsify Christian belief or even count against it?

RG: My way of thinking about Christian belief is to regard it as something which can be discussed, argued about and (potentially) falsified. I don't think that Christianity stands off in some domain by itself, and that it could not be falsified. But it's in the historical sciences, not the physical, that I can at least imagine developments which could falsify Christian belief.

PC: In classical Christianity, like in Judaism and Islam, there was a stress on God's presence in the universe and activity in the world. God was understood to bring about changes in the physical world. Do you see this notion of God's activity in the world as being unaffected by the growth in the physical sciences, or being challenged by it in any way?

RG: I think that God is at work in the world in terms of normal events, because if you believe that he creates the world in space and time, then in some sense he is the origin of all that happens. I say "in some sense," because this belief leads, as is well known, to all sorts of intellectual problems and troubles: fights over determinism and free will, the problem of evil, and so on. Then there are the far-from-normal events which are ascribed to special divine activity. Let's take the case of Jesus walking on the water as reported in the Gospels. Walking unsupported on the sea of Galilee violates the laws of hydrodynamics and therefore it's an impossibility. But the Christian can reply that, after all, Jesus was the incarnate Son of God, the Creator come to live among us.

Given that extraordinary state of affairs, should we not anticipate a few things which don't follow the regular pattern of God's activity as we see it in natural laws? I think that all that contemporary science is able to do is to point out that certain wondrous acts are contrary to the normal behavior of the world. Certainly walking on water violates the laws of hydrodynamics, but hydrodynamics isn't a fundamental law of nature. So far as the laws of quantum mechanics are concerned, the probability of walking unsupported on the surface of water is extremely small, but not impossible. Is God really working in the world? If he is, then, almost by definition, he can do that which is improbable. He controls the probabilities. We roll the dice, and God decides how they fall.

PC: You specify a way of thinking about divine action that would be physically consistent, namely quantum intervention by God. Yet you speak of a habit of mind which is disinclined to accept claims about miracles. Is that sort of tension widespread, not only among scientists, but among Christian believers in the United States?

RG: It seems likely that there has always been a certain amount of tension when people have reported the occurrence of miracles – when Paul was preaching in Athens, were his listeners any more ready than we, who live in the twentieth century, to believe that Jesus rose from the dead? I doubt whether they were.

PC: I want to end by asking a slightly more personal question, namely whether you've derived any religious inspiration from your scientific work?

RG: I would certainly affirm that science provides grounds for worshiping the Creator. I think that it's just glorious what modern science has shown us about the world. If the Hebrew poets could praise God for the wonders of his creation, I think I ought to be able to do it even better – though my poetry is far beneath their standards.

PC: So you say that knowledge of the physical world and the beauty that we discover in the mathematics and in the actual phenomena themselves is, for the Christian, inspiring?

RG: For myself as a Christian, yes. There are Christians who say the world is only 10,000 years old, or that evolution cannot possibly have occurred. Aren't they going to be ashamed, come the day of judgment, to have to say to God, "We saw your wonderful works, but we decided we couldn't believe in them!"

PC: Are there any ways in which your faith as a Christian theist has informed or motivated your work during your career?

RG: Physical science deals with physical objects in the world, and constructs theories about them, but it is carried on by a community of people, and thus all the issues of relationships, of integrity and honesty and personal goals come up and have to be dealt with. I personally have found it very beneficial to be able to bring to my own participation in the scientific community a knowledge of the Bible, and beliefs and convictions about what is right and wrong, and how to treat people, which have a Christian foundation. I don't think I've carried those convictions as far as I should have in terms of compassion and concern about other people. I have sometimes been more ready to argue for theological doctrine than to actually give someone a helping hand. I am, nonetheless, thankful for my Christian upbringing, for support by the Christian community, for instruction in the Bible, and for the people who pray for me and with me, because being a scientist does not mean one ceases to be a human being!

Robert B. Griffiths

Scientific reduction

Adversary or ally?

Introduction

It is widely believed in debates on science and religion that scientific reduction, meaning the explanation of complex phenomena in terms of simpler components, is a threat to religious belief and a support for the materialist view of the world which claims that matter is all there is, and that nothing else is needed in order to understand the universe. The purpose of this essay is to call that belief into question.

Reduction, in the sense of explaining complicated phenomena in terms of simpler components, is very much a part of modern science. It characterizes a great deal of what has gone on in twentieth-century physics and chemistry and is playing a more and more important role in biology. In particular, we do not nowadays ascribe the properties of living organisms to some sort of special "vital force" which is absent from the realm of non-living phenomena. Instead, we think of biological organisms as made up of cells, and cells as complicated structures in which chemical reactions and physical processes obey the same laws which chemical engineers use to design objects having nothing (directly) to do with living systems. Chemical reactions are, in turn, regarded as manifestations of the fundamental principles of quantum mechanics when these are applied to systems of electrons and nuclei interacting through electric and magnetic forces. Granted, the program of reduction is not complete, since the way in which the properties of electrons, quarks, and the like arise out of some more fundamental structures, assuming these exist, is not yet understood, and gravity cannot yet be comfortably accommodated in the quantum world. Nonetheless, one has to concede that there has been an enormous amount of progress in the last hundred years; recall that at the close of the nineteenth century there was still serious doubt about the very existence of atoms, and essentially complete ignorance of their internal structure.

But are there any limits to this program of scientific reduction? If human bodies and human brains are composed of cells, and their operation can be described in terms of physical and chemical processes, is there any room for the human soul? What about the doctrines of immortality and the resurrection of the body? Even those who would gladly dispense with these in the name of clearing away superstitions left over from a pre-scientific age may be troubled by the question of how chemical machines can make those free choices which seem to underlie our notions of human agency and moral responsibility.

For traditional religious belief there is the additional issue of how, if the entire universe is simply a set of atomic particles governed by deterministic laws, there is room for God to act in response to prayer, or in order to perform miracles. To be sure, modern quantum theory has gone a long way in undermining classical ideas of determinism, but replacing determinism with random processes raises questions about whether, and if so how, God governs the world, and whether there is any basis for the hope for the future found in traditional theism.

One way to counter the threat of scientific reduction is to argue that it does not and will not work: there are limits on what can be achieved, and eventually the program of reducing the human body to physics and chemistry, or human thinking to interactions among neurons, or the human race to a product of evolutionary development, will fail because that is not the way the world really is, or was. It is true that scientific studies have not demonstrated beyond any reasonable doubt that humans evolved from lower animals, or that the human brain operates according to the usual laws of biochemistry, and claims to the contrary are premature. It is entirely proper for critics to raise the issue of how far a given program of scientific reduction has actually succeeded. A disinterested examination of the evidence will generally reveal that progress toward a hoped for "final theory" is a lot less than the enthusiasts claim, though it is often more substantial than the critics will allow. Discussion, argumentation, criticism, and response are all part of the scientific enterprise. Scientists and their critics can both benefit from greater humility.

However, in this essay I want to address a somewhat different question. Suppose some program of scientific reduction were to be extremely successful, what would be the result? For example, if at some future date it should prove possible to relate human consciousness and thinking in a very precise way to the operation of neurons in the brain, in the same way in which we at present understand the operation of computers in terms of transistors and electrical circuits, what would this imply? Would human freedom and moral choice simply disappear, suffering the same fate as phlogiston and the geocentric universe?

From the way I have raised this question, it will be apparent that my own answer is "No."[1] My approach in this essay will be first to discuss what I regard as a very successful case of scientific reduction, that of thermodynamics to atomic physics. Then I will explore whether lessons learned from studying this example can provide some perspective on a different program: scientific reduction of human thought to biochemical processes in the brain. One advantage of starting with thermodynamics is that, so far as I know, there are no important religious or philosophical issues tied to the outcome, so one can discuss it without becoming emotionally involved. Also, since the main developments lie in the past (or so it seems), one does not have to guess what they are going to be.

The reduction of thermodynamics to atomic physics

The science of thermodynamics was developed during the nineteenth century at a time when the existence of atoms was very much in doubt, since all the evidence for atoms and molecules was quite indirect. Nonetheless, efforts were made to explain the first and second laws of thermodynamics in terms of the mechanical properties of atoms and their interactions. These made use of classical mechanics, since quantum mechanics had not yet been developed. The development of quantum theory in the 1920s meant that earlier discussions had to be reopened. There is a continuing debate and discussion about these matters, both in classical and quantum terms, although it is hardly a topic in the forefront of physics research nowadays.[2]

The first law of thermodynamics states that energy is conserved, and for this law the reduction to atomic physics has been quite successful. The basic idea is quite simple: given a mechanical system of interacting atoms (or molecules, or whatever; for simplicity I will speak of atoms), it is possible in classical mechanics to ascribe a kinetic energy to each atom. The total mechanical energy is the sum of the kinetic energies of all the atoms, plus the potential energy associated with their interactions. This total energy can be identified with the thermodynamic energy of the system composed of these atoms, and the first law of thermodynamics is then an immediate consequence of the conservation of potential plus kinetic energy in mechanics. One can, to be sure, still ask why mechanical energy is conserved in the case of atoms. At present, energy conservation is simply a fundamental postulate, one which has been amply and abundantly verified by all sorts of experiments, but which cannot be derived from more fundamental principles. One can certainly imagine universes in which energy is not conserved, but we do not seem to live in one. Anyway, admitting that there are still unanswered questions in the science of mechanics does not indicate any defect in the program of reduction as such. We can still say that we understand the thermodynamic law, and indeed can derive it, from a basic law of mechanics.

This discussion must be modified in certain details, but remains fundamentally correct, if the mechanics governing atomic motion is quantum mechanics. Once again, it is possible to identify a total energy of the system, which in quantum theory is associated with the Hamiltonian operator. Splitting it into kinetic and potential energy contributions turns out to involve some subtleties, but in any case that division is not needed for thermodynamics, since the thermodynamic energy can again be identified with the total quantum energy. Conservation principles and even the ability to state that a system has a definite energy are subtle points in quantum theory. But because thermodynamics provides a rather coarse description (by the standards of atomic physics) of large systems, such subtleties do not pose serious problems for the program of reduction. Or, to put it another way, the problems which still remain in explaining the first law of thermodynamics in terms of atomic physics are part of the general, and somewhat controversial, problem of providing a satisfactory physical interpretation of quantum theory, and thus do not reveal any obvious defect in the program of reduction as such.

The second law of thermodynamics states that the entropy of an isolated system increases with time or, once the system has reached equilibrium, remains constant. Thus it singles out a particular direction of time, and processes governed by the second law are said to be (thermodynamically) irreversible: they proceed in one direction, but not the reverse. Attempts to understand the second law in terms of atomic processes began with the work of Maxwell and Boltzmann during the last century. While much progress has been made since then, a number of problems remain which have not been satisfactorily solved, at least by the standards of the (relatively small) community of scholars interested in such things. Examining both the more successful and the more problematical parts of this program of reduction will help to provide some useful insights into what might be expected in other cases of scientific reduction.

Entropy, unlike energy, has no direct mechanical counterpart, and in a sense this is at the heart of the difficulties which have been encountered in providing a mechanical explanation, based in atomic physics, of the second law. During the nineteenth century, the science of statistical mechanics was developed by (among others) James Clerk Maxwell, Ludwig Boltzmann and Josiah Gibbs, and it is by the use of statistical mechanics that we think we currently understand the second law in atomic terms. Statistical mechanics means applying laws of probability theory to mechanical systems, and that this appears in the reduction process is itself of some interest. For it was not at all evident at the outset that introducing probabilistic ideas would be a useful route to follow in trying to understand the second law. Remember that, unlike the situation in quantum theory, there is nothing inherently probabilistic in classical mechanics. Thus it is not surprising that Boltzmann's attempts to explain the second law in probabilistic terms were initially rather unclear, and met with heavy criticism. Nowadays, the use of probabilistic ideas in classical mechanics is more familiar, since they play an important role in the study of chaos. But even so, there are still many loose ends which remain in the effort to understand the second law in probabilistic terms, whether one uses quantum or classical statistical mechanics (see Sklar 1993).

One of those loose ends is irreversibility: why does entropy always increase in time? There are informal arguments which, at least in my opinion, contain the essential ideas, but these need to be cleaned up. As Sklar (1993) makes clear, mathematical physics has not yet provided results for non-equilibrium statistical mechanics of the same character and generality available in the equilibrium case. We are quite confident we know how to calculate the entropy for a system in equilibrium, but the precise procedure for a system out of equilibrium is not clear, and we don't have a satisfactory demonstration that this entropy will, with high probability, increase with time.

Let us assume for the present discussion that tying various loose ends will not produce any radical changes in our present understanding of how thermodynamics is related to atomic physics. Then one can say that the two laws of thermodynamics are understood in quite different ways from an atomic perspective. The first law follows from a relatively straightforward application of a conservation principle which plays a fundamental role in both classical and quantum mechanics. One can speak about the energy of a single particle, of two particles, of ten particles, or of ten to the twentieth particles, and there is no conceptual gap on the way from the atomic physics of single atoms to the thermodynamic law.

The second law is very different. It doesn't make much sense to talk about the entropy of a single particle; while one can write down a formula for it under some circumstances, it isn't clear that it has much significance. Instead, entropy has something to do with the behavior of large numbers of particles, under circumstances which we do not as yet fully understand, but which seem to be fulfilled in many different objects we encounter in our everyday experience, as well as in the laboratory. Entropy is, one could say, an "emergent" property which does not apply to a small number of particles, but is extremely useful for describing large systems of particles. Perhaps the concept of a "government" provides a useful analogy: the term does not make much sense for a single, isolated, human being, but is very useful when one thinks about societies containing substantial numbers of people.

Furthermore, in the process of reducing the second law to atomic physics, it has been necessary to invent a new discipline, statistical mechanics, or to put it another way, it has been necessary to introduce new, probabilistic concepts into the discipline of mechanics, concepts which are not, at least in classical mechanics, an intrinsic part of the subject. These new concepts appear to be essential to the process of reduction. For example, both classical and quantum mechanics do not single out a direction of time,[3] whereas the second law of thermodynamics does single out a direction of time, the direction in which entropy is increasing. The only way I know of for reconciling these seemingly contradictory perspectives involves, among other things, invoking probabilistic descriptions: thermodynamic irreversibility is not guaranteed by the laws of mechanics, but it is rather likely.

But should we think of entropy as part of the real world? Could it not be just a useful fiction employed by scientists and engineers as part of their calculations? Is entropy as real as some material object, say a brick, or the atoms of which the brick is composed? Even if there are problems reducing entropy to atomic physics, is this anything a good materialist should worry about? Rather than attempting to directly address a question which is full of philosophical difficulties, I shall adopt the coward's tactic of raising an alternative question of the same sort.

The typical man on the street, at least if the street is in Pittsburgh, has never heard of entropy, but he knows we have an "energy crisis," and that our weather is uncomfortably cold in the winter. For the thermodynamicist, entropy, energy and temperature are all closely related.[4] As a consequence, whatever difficulties arise in reducing entropy to atomic physics are also present in the case of temperature. This last point is easy to overlook, because in classical statistical mechanics temperature is related to kinetic energy in a simple way, so that relating thermodynamic temperature to atomic physics seems no more difficult than the corresponding problem for the total energy. However, this is one instance in which quantum theory really does make a difference: the relationship of the kinetic energy of a quantum system to the temperature is not at all simple, and thus one is back to using entropy, or something equivalent. Consequently, to the person who has doubts as to whether entropy is part of reality, I confess to worries of the same sort, but I add that my worries also apply to temperature. And whatever subtleties may be involved in understanding the latter in terms of atomic physics, as a practical matter I find it prudent to have a warm coat, hat and gloves available when wintering in Pennsylvania!

Has thermodynamics been "reduced to" atomic physics? That depends upon what one means by "reduced." Even taking an optimistic view of what has been accomplished to date, with the expectation that the various loose ends will eventually be tied up, or could be if someone were sufficiently interested, there is no reason to suppose that the discipline of thermodynamics could or should be replaced by atomic physics. Thermodynamic laws are extremely good descriptions of what is going on in the world. They are "phenomenological" in the sense that they refer to everyday things accessible to macroscopic human observation, and make no reference to what is going on at the atomic or molecular level. Just because we have atomic explanations for thermodynamic laws (remember, I am taking the optimistic perspective) does not mean that those laws are wrong, or that the entities they refer to are unreal, either in practice or "in principle."

Furthermore, while one cannot claim that thermodynamics or other phenomenological theories, such as hydrodynamics, are essential if we are to understand the natural world – they might someday be replaced by something better – there are excellent reasons to think that they *cannot* be replaced by some sort of detailed atomic description. Naively, one might suppose that all we *really* need to know are the positions and velocities of the atoms, along with the laws governing their interactions, in order to have a "complete" description of nature which would not need the concept of energy or entropy. But such a precise mechanical description, for even a modest number of atoms or molecules, say those in a cubic centimeter of air, requires such an enormous amount of information that there is no way in which it could be stored on any present, or any conceivable future computer. To be sure, nothing prevents us from imagining, as did Laplace, a super-intelligence who in a manner inconceivable to us somehow accumulates the requisite information and thereby manages to understand the situation. But since that understanding evidently cannot be communicated to us, it seems somewhat misleading to claim that a thermodynamic or hydrodynamic description can "in principle" be replaced by a detailed atomic description. Things do not improve if we suppose the super-intelligence uses quantum mechanics rather than Laplace's classical mechanics.

In addition, we are not able to derive the second law from atomic physics without invoking additional, probabilistic ideas. To the non-scientist, this might look like a serious flaw in the program of reduction. The research scientist is likely to have a different attitude, because he or she takes delight in introducing some new idea in order to explain what was not previously understood, or at least not understood as well as is possible using the new idea. The program of reduction, viewed in this way, is not a sledgehammer to demolish prior knowledge, an adversary of whatever was known in the past, but a valuable ally in achieving a better understanding of the world, because it leads us to think of new things and new points of view which we would not otherwise have considered.

Reduction applied to human thinking

Is it possible to take a similar, positive attitude toward reduction, regarding it as an ally rather than as an adversary, in other areas of scientific research which seem to be much more relevant to religious belief than are the laws of thermodynamics? I believe the answer is "yes," but to avoid misunderstanding, let me add that I am *not* suggesting that every phenomenological belief will survive scientific advance. Energy and entropy have been subjected to careful scrutiny and have survived intact. But phlogiston and "heat," regarded as a sort of fluid, have suffered the same fate as the geocentric universe. Thus I am not proposing that all religious belief will emerge unscathed from the critical scrutiny to which it will be exposed in a program of scientific reduction, whether in psychology, sociology or evolutionary biology. But I also see no reason to think that those beliefs which I, as a Christian, consider most central to my faith are in any particular danger of disintegrating through this process. To be sure, I may be wrong about this; one does not know what future science will be like until it arrives, and when it arrives, it will – if it is at all interesting – be very unlike what was expected. But that uncertainty faces the materialist as much as the theist. All we can do at present is to use the best scientific thinking currently available, and make some sort of guess.

Take, for example, the program of reducing human thinking to chemical reactions, or modeling it by means of computers, both of which are popular areas of research at the present time. Suppose they succeed in something like the way statistical mechanics has succeeded in explaining, or reducing, thermodynamic laws to atomic physics. In particular, suppose that at some future date science has progressed to the point where the processes involving neurons which occur inside the brain have been successfully modeled as a type of (massively parallel) computation, and suppose that the connection between these processes and human thought (consciousness, decision making, etc.) is well understood. Would it follow that man is "nothing but" a machine?

Those who have read Donald MacKay will be aware of his strenuous objection to this sort of "nothing-buttery," as he called it. I share his objections, although I prefer a different terminology. The problem with such "nothing but" statements, in my opinion, is that they take what is, or at least what could be, a valuable insight obtained from a program of scientific reduction – that the human body or brain can in some respects be usefully thought of as a machine (or like a machine) – and then claim that this is the whole story, with nothing more to be said. To illustrate what is wrong with this approach, it helps to back off from a direct discussion of human beings, and instead consider an analogous situation with fewer philosophical and emotional overtones.

Let us assume that the work-station on my desk is solving a differential equation using a fourth-order Runge–Kutta procedure. At least, that is how I think of it; let us call this a "functional description." I of course agree that inside the machine there is a rapid succession of electrical impulses which follow certain deterministic laws known to the engineers who designed it. Let us call this the "electrical" description. Is what is going on in the computer "nothing but" what is contained in the electrical description? Can the functional description be reduced to or replaced by the electrical description? More generally, how are the functional and electrical descriptions related to each other?

Unless there is some counterpart in the electrical description for what in my functional description is the multiplication or addition of two numbers in the Runge–Kutta scheme, the result which emerges at the end of the calculation is not likely to be of much use to me. In this sense there must at least be a certain *compatibility* between the two descriptions. But their actual relationship is rather complicated. One could not derive the electrical description from the functional description without a great deal of information about how the machine is put together, what programing language and which compiler was used, what initial conditions were supposed, etc.

What about the reverse relationship? Can it be said that process of solving a differential equation is "nothing but" a series of electrical impulses in the work-station? That might be the right thing to say to someone who asserts that there is, in addition to (or instead of) the electrical circuits, a little immaterial wizard inside the machine who is actually doing the work. But I think it misleading if "nothing but" is taken to mean that the functional description can simply be discarded, perhaps should be discarded, and replaced with the electrical description. As in: "While you may have thought there was a burglar in the house, what you heard was nothing but the cat looking for a midnight snack." It would, in fact, be extremely difficult, simply given the sequence of electrical states, to deduce that the machine was solving a differential equation, much less which numerical method was being employed. To be sure, some super-intelligence might succeed in doing this, but it would require considerable knowledge about the methods human beings typically use to solve mathematical problems, and a certain amount of detective work would be involved. Indeed, the most efficient method (should super-intelligences have to worry about efficiency) might be getting a hold of, or perhaps reconstructing, the symbolic form (in FORTRAN, C, or whatever) of the original program, and figuring out what I was trying to do. But we are now perilously close to the functional description which was supposed to be inessential, given the electrical description!

There may be flaws in this example, but I am convinced the basic idea is a sound one. Human understanding of phenomena in the natural world is in practice based upon a variety of descriptions, which tend to complement one another, and it is a mistake to suppose that because the same object or sequence of events can be described in several different ways, there must be one description which is "more fundamental" in the sense that all the other descriptions can be derived from it. In practice we find that this is generally not the case, and claims that a particular way of approaching the subject provides "in principle" everything we need to know should be treated with skepticism, as in the case involving entropy and atomic physics discussed earlier.

This is not to claim that the program of studying human thinking by relating it to chemical processes taking place in neurons (or something of that sort) could not lead, potentially at least, to important philosophical and religious consequences. I myself certainly hope it will do so, for that would make the research, which is obviously going to take an enormous amount of costly effort, much more interesting and worthwhile. What these consequences will be is of course very hard to say at present, when the research has not yet been done. But I see no reason to suppose that the application of methods of scientific reduction to the human body and brain will lead to the conclusion that humans are "nothing but" machines. Perhaps another example, this one very much at the center of what we think is essential to humanness, will be helpful.

Consider human freedom: the ability to choose to do something, rather than another. Should brain research eventually demonstrate that human thinking is deterministic in a manner analogous to that in which computers are deterministic, is there some way in which this freedom, which seems fundamental to our notions of moral responsibility, can be maintained as a true piece of phenomenology? Or must we resign ourselves to the idea that even though we may still think (in our less reflective moments) that we are free, this freedom is in fact an illusion? I find it helpful to address these questions by drawing an analogy with the reduction of thermodynamics to atomic physics discussed earlier. If we suppose for the sake of argument that the opposite of human freedom is determinism, and that determinism is analogous to thermodynamic energy, a concept which applies to the smallest subsystems in equal degree as it does to the whole, then there is some plausibility to the idea that human beings are deterministic, and therefore (by the definition we have just assumed) not free. Modern computers are very deterministic objects; indeed, this is what makes them so useful. And from this point of view, why should neurons be different from silicon transistors?

On the other hand, if human freedom is (vaguely) analogous to entropy, some sort of "emergent" property which can be ascribed to certain systems of appropriate complexity under certain circumstances, then its absence from computers and other sorts of un-free mechanical systems is no indication that it is an illusion. Instead, if we are going to properly understand its relationship to neurons – which, for the sake of argument, let us assume to be deterministic structures – we will need new concepts, a new approach, some new ideas which are not part of the standard theory of deterministic dynamical systems. Finding these new ideas would then be one of the things which would make this particular program of scientific reduction extremely interesting.[5]

I hardly need add that, in my opinion, the entropy analogy is better than the energy analogy, not because human freedom has any necessary connection with probabilistic models, but rather because many years of philosophical and theological controversy suggest that human freedom is not at all a simple concept, not something which, like energy, has an obvious counterpart in much simpler systems. Of course, both the energy analogy and the entropy analogy could be totally misleading, and that would be even more interesting. But in any case, the notion that human freedom will turn out to be an illusion seems to me as likely a possibility as that Pittsburgh's temperature remains above 50° F (10° C) throughout the month of February. Possible, but not something we need seriously worry about at present.

Conclusion

Is the program of scientific reduction an adversary or an ally? I, as a Christian and a physicist, consider it an ally. A great deal of scientific progress has already resulted from a program of reduction, trying to understand complicated things in terms of simpler components, and I am convinced that there is much more to be learned. We physicists may be close to the practical limits in the subatomic realm, as the cost of accelerators continues to rise. But the possibilities for better understanding how to use methods of scientific reduction remain enormous in fields outside of particle physics: in particular, in biology and psychology. It would be regrettable to have these possibilities lose public support through an irrational fear that the results will surely prove injurious to religious belief. To be sure, before the research is done one cannot say what the outcome will be. But from my perspective, the most likely casualty to further progress is not traditional theism, but instead the naive materialism which supposes that tying human thought to chemical and physical processes in the brain would somehow invalidate descriptions of human beings as free moral agents, under obligation to love God and neighbor.

Notes

1 My thinking on the matter has been heavily influenced by my interaction with the late Donald MacKay, both in person (we first met around 1971) and through his writings. MacKay started off as a physicist, but later his research interest shifted to a study of how the brain processes information, so his own professional work was in a scientific area in which reduction is one of the major research strategies. Additionally, he thought very carefully about the philosophical issues and theological implications of scientific work of this sort.
2 For a helpful overview of progress to date and problems which are still open, see Sklar (1993).
3 A note for the experts: the issue of singling out a direction of time is *not* the same as time reversal symmetry in quantum theory, which most of us believe is not an exact symmetry of nature, due to experiments on kaon decay. Instead what is relevant is that time development in classical Hamiltonian mechanics preserves the volume of phase space, and time development in quantum theory is represented by a unitary operator.
4 Mathematically speaking, (absolute) temperature is the derivative (with appropriate things held fixed) of energy with respect to entropy.
5 To be sure, these ideas may already exist. Donald MacKay, for example, was convinced that he had found the key to understanding how human freedom was perfectly compatible with a brain "as mechanical as clockwork." He did not manage to convince many other people that he was correct, but I think that his proposal deserves, at the very least, further scrutiny.

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