Toward a Theology of Scientific Endeavour

The Descent of Science

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Contents

Four Foundations of Scientific Endeavour

A thick description of natural science inevitably leads to theological questions and cultivates a thick description of nature, humanity, history and God. This is the overall thesis for the four studies that make up the main body of this book. Each of these studies begins with some aspect of natural science and raises questions about what makes such an endeavour possible. Each study uses appropriate scientific disciplines to address those questions and in the process raises further questions and paradoxes that are of theological interest. We then review the resources of the historic Judeo-Christian tradition in search of concepts that will help address those questions. The studies conclude with suggestions for thickening our description of nature, history, and God.

This book is not a study in 'natural theology' in the traditional sense of the term. Natural theology begins with assumed features of the natural world, for example, motion or design, or with the scientific theories that describe them, and develops a rational argument for the existence and attributes of God.[1] Our starting point, in contrast, will be the foundations of natural science as a human endeavour. Instead of using discursive reason, we shall use the tools of various natural and social scientific disciplines to investigate the conditions that make that endeavour possible and then explore the theological dimensions embedded in those conditions. Instead of examining the structure and the origin of the natural world, we shall examine the deep structure and origin of scientific endeavour. Instead of trying to demonstrate the existence of God, we shall demonstrate the need for sustained theological discourse as part of any attempt to carry out the investigation and complete the objectives of scientific endeavour.

We shall map out some of the relationships between scientific and theological discourse in order to show the coherence among various scientific and theological concepts when viewed in relation to the foundations of scientific endeavour.[2] As in the

1 See Alister E. McGrath, *A Scientific Theology, Volume 1: Nature* (Edinburgh: T&T Clark, 2001), 305, for a good review of 'The Purpose and Place of Natural Theology'. In addition to the observable world of nature, McGrath includes human rationality (in general) and human culture among the possible grounds for natural theology. Our starting point does not fit any of these categories.

2 Technically one may distinguish between several levels of argumentation. In Chapter 2 (Anthropological Foundation) I shall offer a level-2 argument for the existence of a spirit world and a level-3 argument for the existence of God. An argument for the existence of something (say the planet Neptune or God) from features of the natural world may be termed a level-1 argument. An argument that posits the existence of something (like Dirac's positively charged electrons) in order to achieve completeness and consistency may be termed a level-2 argument. An argument

study of any map, a reader can follow a particular route without deciding to go there personally. Each step in our argument involves choices that can be assessed rationally if not dispassionately. The style is open ended and invitational, sometimes even playful, rather than foundational or demonstrative. Since my goal is to develop an approach to theology based on the study of science as a human endeavour, I call this a 'theology of science', or, more exactly, a 'theology of scientific endeavour'. It is based on insights and questions that arise from a thorough examination of the conditions that must be fulfilled in order for scientific research to be a viable enterprise.

In the remainder of this introduction, I shall explain the need for a thick description of science – one that takes the life and work of scientists into account – and then proceed to thicken the description by describing four preconditions that illustrate the contingency of scientific endeavour. Each of these preconditions will become the starting point for a chapter to follow.

Toward a thick description of science

Scientists are human beings.[3] They need relaxation and sleep like all other humans. Each day they also need to resume their work and exert themselves, often under considerable pressure, in order to make progress in their work. Scientists struggle with motivation and direction in their lives like the rest of us.

What makes natural scientists different from most other people, and what often makes their work so difficult, is the fact that they work on topics so far removed from everyday life and try to solve problems that have never been solved, or in many cases even articulated before.

A good analogy would be helpful here. The closest example I can think of is that of an Olympic athlete training for years to break a world record. The athlete also struggles with pressure and motivation and is often pressing the limits of what the human frame can accomplish. In this respect, scientists are like athletes. However, the scientist is not simply trying to gain a fraction of a second or centimeter (although the technologies that sustain modern science often work with even smaller margins). Scientists have to face directly the qualitative difference between the known and the unknown.[4] Certainly this is true of what Thomas Kuhn has termed 'revolutionary science' in contrast to the ordinary process of experiment-construction and data-verification. However, the design of experiments and confirmation of known data can themselves lead to confrontations

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that draws tentative implications from the results of a level-2 argument is a level-3 argument. Such arguments are heuristic and must be corroborated by other lines of investigation.

3 These paragraphs are adapted from my article, 'Scientific Work and Its Theological Dimensions: Toward a Theology of Natural Science', in Jitse Van der Meer (ed.), *Facets of Faith and Science*, Vol. 1 (Lanham, Md.: University Press of America, 1996), 229.

4 Thomas Kuhn, *The Structure of Scientific Revolutions*, 2nd edn (Chicago: University of Chicago Press, 1970). A similar distinction has been drawn for observational astronomy between analysis of known phenomena and the search for new cosmic phenomena; Martin Harwit, *Cosmic Discovery: The Search, Scope, and Heritage of Astronomy* (Cambridge, Mass: MIT Press, 1984), 19, 24. The way the latter search depends on new technologies will be discussed in Chapter 4.

with the unexpected or unknown. The work of scientists is always just a step away from the unknown. So perhaps the term 'revolutionary science' is overly dramatic. A more ethnographic category like 'independent, risky work'[5] may be more helpful in conveying the uncertainty involved in all scientific research. In any case, if we are to do justice to the actual practice of science, and not just its documented results, we must include in our description a consideration of the conditions that enable our scientists to do what they do.

For convenience, I shall refer to such a consideration of practical conditions as a 'thick description' of science. The phrase is borrowed from the work of Clifford Geertz, who argued against strictly cognitive views of cultural anthropology in the early 1970s. Taking exception to the notion that a culture consists in rules of human behavior and interpretation, Geertz argued for a 'thick view' of culture that includes the actual contexts that make both behavior and interpretation possible.[6]

In the case of science-fostering societies, culture is just one of many aspects of such a thick description,[7] and anthropology is just one of many tools of analysis. So there is some semantic stretching involved in extrapolating the idea of 'thick description' from anthropology to our entire project. However, the concept will prove useful as a way of summarising the main points of the following chapters in an easily recognizable form. Those summaries will have the following form: a thicker description of natural science leads to a thicker description of some area of theology, for example: (1) the relation of God to creation; or (2) the cosmos; or (3) the history of theology; or (4) the attributes of God. This formulation helps to make the overall case that theological questions and options flow naturally out of a consideration of scientific endeavour.

In arguing for a thick description of science – one that takes the life and work of scientists into account – I am tilting against the conception of science fostered by most media and by the teaching of science in most of our schools and universities. In most people's minds and in most science-theology discussions, science consists primarily of scientific 'facts', scientific theories, and sometimes scientific applications.[8] More sophisticated discussions may include simplified scientific methods. But only rarely do students get to know anything about the actual history of science or even about the lives and the projects of the scientists whose ideas they study.

The problem with understanding human enterprises is not unique to science. The usual approach is a little like studying visual art simply by going to lectures and

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5 The phrase 'independent, risky work' comes from Sharon Traweek, *Beamtimes and Lifetimes: The World of High Energy Physicists* (Cambridge, Mass: Harvard University Press, 1988), 87.

6 Clifford Geertz, *The Interpretation of Cultures: Selected Essays* (New York: Basic Books, 1973), 9-13, 17.

7 Some other ways of thickening the description of natural science would be to look at the way in which it is taught and studied in our schools and to consider its technological applications or social and environmental impacts.

8 A good critique of the presentation of science in American middle-school textbooks can be found in John Hubisz, 'Middle-School Texts Don't Make the Grade', *Physics Today* 56 (May 2003), 50-54. Such truncations of the thickness of scientific endeavour are comparable to the reduction of human cultures to ideas and rules in the cognitive anthropology against which Geertz argued so passionately.

visiting museums rather than visiting artists' studios. Both science and art are important human endeavours, but most of us have very thin views of either. Our culture almost always enforces a separation of the private aptitudes and motivations of producers from the public marketing of goods for consumers. So the problem I am addressing here should not come as a complete surprise.

Some light can be shed on the problem by considering the few endeavours that are exceptions to this cultural norm. Two areas of Western culture that do not generally separate personal aptitude and motivation from public performance are politics (where other kinds of obfuscation are often at work) and sports. To focus on the latter for a moment: it would be unthinkable to publicize a sports event today without conveying information about the health and morale of the athletes. The rigours of the sport and the conditions imposed by the aging process are commonly discussed in relation to the limits of what is physically possible. The contrast to disciplines like science and the visual arts could not be greater. We are used to very thick descriptions of sports events – everything from detailed statistics to Mother's Day greetings. Our understanding of science is rather thin by comparison.

The reasons for these differences among disciplines have yet to be investigated. Clearly the fact that athletes have to perform in real time in the presence of the public has a lot to do with it. But the same is not true for professional musicians. We do not learn very much about the lives of symphony musicians or ballet dancers. On the other hand, we do get to know a good deal about very special kinds of scientists, like astronauts, who happen to fascinate the public. So media exposure is an important factor. The separation of the products of science from our knowledge about the life and work of scientists is a cultural artifact based on the fact that our relationships transcend the traditional limits of small communities: only the mass media are in a position to reconnect producer and consumer and thereby thicken the description of marketable human endeavours. The issue of public knowledge bears further consideration.

For now it is sufficient to conclude this part of the discussion with the following result: limiting 'science' to its cognitive dimensions (a set of ideas or theories or methods) is a relatively thin abstraction. If science is viewed abstractly, all kinds of problems naturally arise for the dialogue with theology (also viewed abstractly) – different views of creation, different approaches to human nature, different epistemologies. These are certainly important problems, and they deserve all the attention that they get in current discussions.[9] But a thicker view of science will engage theological endeavour more directly. Apparent tensions between the two disciplines can be viewed in a more positive light when they are seen to result from questions and paradoxes in the description of science's foundations. Then theological endeavour is part of a thicker description, leading to a broader rationality that makes more sense out of scientific endeavour itself.[10]

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9 For a wide-ranging review of the various models for dialog, see Ian G. Barbour, *When Science Meets Religion* (San Francisco: Harper, 2000). For an analysis of Barbour's typology, see C. Kaiser, 'Scientific Work and Its Theological Dimensions: Toward a Theology of Natural Science', in Jitse Van der Meer (ed.), *Facets of Faith and Science* (Lanham, Md.: University Press of America, 1996), 1:223-46 (224-8, 240 n.63).

10 Lesslie Newbigin posited a 'wider and more inclusive rationality' that makes room for key Christian doctrines in contrast to reductionist views of science in his 1984 Warfield

The contingency of scientific endeavour

Let us start with the purpose of natural science: its general purpose is to explore all accessible features of the space-time world and to explain them by positing principles and laws. In order to carry out this endeavour it is necessary to collect ever-wider fields of information by developing new technologies and to interpret them by constructing mathematical models and histories.[11] Progress results from a cycle that alternates between experimentally derived information and theoretically constructed models: models are built in order to explain the available information, and information is gathered in order to test available models. As a rule there are always 'anomalies' – features that are not accounted for by any available model. So, new models need to be constructed. But new models are usually underdetermined – their validity is generally not decidable on the basis of available information. So, new experiments must be designed to gather further information. And the cycle goes on.

All of this adds up to the crucial observation that science is a highly contingent enterprise. There is nothing either automatic or guaranteed by its progress. This outlook could be termed 'scientific fallibilism'. It can be compared with the traditional philosophical fallibilism, for which all predictions are viewed as being uncertain. Strictly speaking, no one knows for sure that a warmer spring season will follow winter or even that the sun will rise again after it sets. In the case of these regular cycles, however, we can discover natural mechanisms that at least make the recurrence of phenomena like the seasons highly probable. We can be sure that spring will come again unless there is a catastrophe of some sort. At least, that is true for the short to moderately long term.[12] In the case of scientific endeavour, however, there are no natural mechanisms to ensure such a probability. Scientists are continually facing the unknown. They do succeed in solving problems, but there is always the nagging possibility that they may be wasting their time.[13] The wonder is that they succeed as much as they do.

Lectures, published as *Foolishness to the Greeks: The Gospel and Western Culture* (Grand Rapids: Eerdmans, 1986), 90. A similar point was made by John Polkinghorne, 'The Reason Within and the Reason Without', in Ronald E. Mickens (ed.), *Mathematics and Science* (Singapore: World Scientific, 1990), 181.

11 In terms of information theory, such laws and histories can be described as algorithmic compressions of the information we have about the universe; cf. John D. Barrow, *Theories of Everything: The Quest for Ultimate Explanation* (Oxford: Clarendon Press, 1991), 10-11; Paul Davies, *The Mind of God: The Scientific Basis for a Rational World* (New York: Simon & Schuster, 1992), 135-6. However, most laws and histories are originally derived as speculative hypotheses rather than actual compressions of data.

12 On the longer scales of tens of thousands, millions, and billions of years we can look forward to a new glacial era and the eventual destruction of earth; Peter Ward and Don Brownlee, *The Life and Death of Planet Earth: How the New Science of Astrobiology Charts the Ultimate Fate of Our World* (New York: Times Books, 2002).

13 See Traweek, *Beamtimes and Lifetimes*, 75-6, 100-101 for a realistic description of the anxieties that high energy physicists live with. This entire study is a good example of a thick description in Geertz's sense.

Following our previous statement of the purpose of natural science, we can suggest two kinds of contingency: those on the side of information gathering and those on the side of model building.[14] Information gathering is of course limited by the technologies that are available. For example, in the early nineteenth century, Auguste Comte stated that scientists would never know what the stars are made out of.[15] Although his pessimism sounds incredibly short-sighted today, when he made this statement the tools need for optical spectroscopy were only beginning to be developed, and their possible impact on science was unforeseen. One might argue that Comte should have been more circumspect about his strictures. We have come to take progress in technology for granted. A new space probe or more powerful computer is always just around the corner. However, a degree of agnosticism about developing technologies is always in order. The fact that we have to work with material substances places limits on what we can do – we simply cannot build a particle accelerator the size of the solar system or run a computer program for 10^{127} years as would be required to solve some important scientific problems.[16]

There are also economic and even political limits: even relatively feasible technologies cannot be built and deployed unless they can be paid for. One of the most famous examples of a scientist's encounter with the contingency of government funding was Steven Weinberg's advocacy of the Superconducting Super Collider (SSC) in the early 1990s. According to Weinberg, 'The urgency of our desire to see the SSC completed comes from a sense that without it we may not be able to continue with the great intellectual adventure of discovering the final laws of nature.'[17] The SSC was designed to provide enough energy (up to 20 trillion electron volts) to reveal the existence of hypothetical particles needed for the unification of three fundamental forces and to account for the origin of the masses of elementary particles. But funding for the SSC was cut off by the US Congress in October 1993. It was felt that the cost of the project was greater than the American public would willingly support. As a result, physicists in America were forced to contemplate the possibility that the frontier of high energy particle physics might soon be closing – not the actuality, but at least the possibility.[18]

Here is another example of such a contingency – one that is still undecided at the time of my writing. On 30 April 2003 an ultimatum was delivered to the team of physicists and technicians who were developing a space mission designed to test important aspects of Einstein's General Theory of Relativity (Gravity Probe-B).

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14 The following discussion is inspired by the work of John D. Barrow, *Impossibility: The Limits of Science and the Science of Limits* (Oxford: Clarendon Press, 1998), but it is organized differently.

15 Comte, *Cours de philosophie positive* (1830-42), cited in Gillispie, ed., *Dictionary of Scientific Biography*, 16 vols (New York: Scribner's, 1970-80), 3:377; cf Barrow, *Impossibility*, 47.

16 Aviezri S. Fraenkel has shown that computing the structure (folding) of even simple proteins (with 104 amino acids) would take a supercomputer 10^{127} years; John L. Casti, 'Confronting Science's Logical Limits', *Scientific American* 275 (Oct. 1996), 103; cf. Barrow, *Impossibility*, 104-107.

17 Steven Weinberg, *Dreams of a Final Theory* (New York: Pantheon Books, 1992), 274.

18 Charles Seife, 'Physics Tries to Leave the Tunnel', *Science* 302 (3 Oct. 2003), 36-8.

The outstanding technical issues were relatively simple ones involving a heater and some fuses. But the completion of the mission had already been delayed for years and the projected cost had escalated by hundreds of millions of dollars. The ultimatum delivered by the National Aeronautics and Space Agency (NASA) stated that funding would be terminated unless several tests and other conditions were fulfilled.[19] As it happens, much of the information to be derived from this mission could probably be obtained in other ways, but an awareness of the economics of the project thickens the description of science and illustrates one kind of contingency that underlies all modern scientific endeavour. We shall look at some of the conditions that underlie modern technology and the theological issues they raise in more detail in Chapter 4.

Information gathering may also have limits in principle. In astrophysics, most information is teased out of faint light signals (electromagnetic waves) from outer space. Other information is collected from high-energy particles and the measurement of magnetic fields in space. Eventually gravity waves may also be tapped. However, there may be regions of the universe, entirely different from our own, that are so distant that no electromagnetic signals from those regions would ever reach us. The theory of cosmic inflation, which is supported by a preponderance of recent observational data, pretty much guarantees this result.[20] Information may also be irretrievably lost in black holes and in the wormholes of space-time.[21] Information about our universe may also be affected by the very process of gathering and storing information.[22] We ought not be dogmatic about positing limits, but neither ought we to assume that we can get around them all. So much for information gathering.

Even when information is available, it must be interpreted, and this step results in further contingencies in scientific endeavour. Scientists usually account for observed patterns and anomalies in the experimental data by constructing mathematical models. The ingredients of these models may already be available, but they may have to be developed or even invented from scratch. Like technologies, new forms of mathematics must repeatedly be developed. There is no guarantee that the needed tools will be available at any given time. In fact, mathematics has its own limits:

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19 'News of the Week – Space Physics – NASA Orders Make-or-Break Tests for Gravity Probe', *Science* 300 (9 May 2003), 880.

20 Barrow, *Theories of Everything*, 52-3; and idem, *Impossibility*, 166-9, 189. The 'ekpyrotic model' of cosmology, first proposed in 2001, can account for the origin of our universe without cosmological inflation. This fascinating theory has yet to be developed in detail but it would imply that even the most distant regions of the universe would probably look very much like our own and avoid the problem raised by Barrow. The observation of very long wavelength gravity waves (or their effect on the microwave background) could decide which of the two theories is to be preferred. The inflationary model predicts the existence of such waves whereas the ekpyrotic model does not; Alison Boyle, 'The Edge of Infinity', *New Scientist* 171 (29 Sept. 2001), 26-9.

21 Barrow, *Theories of Everything*, 109. Information can also be lost in bound entanglement states, which are the equivalent of black holes in quantum information theory; Barbara M. Terhal, Michael M. Wolf, and Andrew C. Doherty, 'Quantum Entanglement: A Modern Perspective', *Physics* Today 56 (April 2003), 49a.

22 Stephen Hawking has made this point in a conversation with Michael Brooks, 'The Impossible Puzzle', *New Scientist* (5 April 2003), 34-5.

some may be due to the limits of the human brain – even with the assistance of computers (back to the contingency of technology) – but others are due to the existence of noncomputable numbers and the impossibility of constructing self-contained deductive logical formalisms (Gödel's theorem).[23]

As a result, there are often patterns in data files that go unrecognized for lack of the needed mathematical models. Scientists hope they will be able go back to look for those patterns once the models become available – a process that involves a complex sequence of steps in insight, perseverance, and successful retrieval. When, for example, a team of high-energy physicists is fortunate enough to discover a new subatomic particle, other physicists can go back over previously collected data to confirm the new result. In such cases, the data were there long before their significance was recognized. There are even cases where looking at old data for confirmation of one new particle leads to the discovery of still further particles.[24] So scientists may sometimes have access to important information without even realizing its significance.

Often we assume that any pattern or anomaly can easily be seen once you look at it in the right way – computer programs can be developed to assist the human eye and textbooks try to make the patterns look obvious to the reader. But there is nothing automatic about the ability of the human brain to recognize subtle patterns, particularly when they have never been recognized before. Anyone who has tried to become proficient at chess or a complex card-game knows the difficulty from experience. Obviously all of the patterns we already know about are humanly recognizable. But in most cases they would not be recognizable to a frog or even to a chimpanzee. Even among humans, the ability to recognize complex patterns varies widely. Consequently, there may well be important features of the space-time world that are far too subtle for any human brain, even a human brain aided by a humanly designed computer.[25] We shall consider the conditions underlying the needed human intelligence in more detail in Chapter 2.

In view of the technological, economic, physiological and mathematical limits just described, we cannot be sure how far scientific endeavour will continue into the future. We should not take its progress for granted. But it is not my purpose to make readers pessimistic about the prospects. The amazing thing is that scientific endeavour works at all in arenas that are so far removed from everyday experience. Our next step is to turn the problem around and consider what general conditions have to be fulfilled in order for science to work as well as it has.

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23 Barrow, *Impossibility*, 210, 215-16; cf. Davies, *The Mind of* God, 104-9, 126-34.

24 On 28 April 2003, researchers at the Stanford Linear Accelerator Collider (SLAC) announced the discovery of a new meson, D_S (2317), which weighed in at 10 per cent lower than the mass that had been theoretically predicted and so challenged the 'Standard Model' known as quantum chromodynamics. Thereupon a team of physicists at Cornell University particle collider (CESR) looked back through their past experimental data and found evidence not only for the D_S (2317), but also another underweight meson, the D_S (2463); 'New Particles Pose Puzzle', *Science News* 163 (24 May 2003), 333. On the current status of the Standard Model itself, see Gordon Kane, 'The Dawn of Physics Beyond the Standard Model', *Scientific American* 288 (June 2003), 68-75.

25 Barrow, *Impossibility*, 89-90.

Four foundations supporting scientific endeavour

Examining the preconditions that make scientific endeavour possible is one way of thickening the description of scientific endeavour.[26] Scientific work has a set of necessary, cumulative preconditions or foundations that open avenues for thickening our way of doing theology (theological endeavour).

Some of these foundations were suggested already in our discussion of the contingency of the scientific endeavour. Among those contingencies were the development of information-gathering technologies and the capacity of the human brain for building effective theoretical models. Underlying the development of the needed technologies is the existence of industries, transportation systems, and means of communication that can exist only in a highly industrialized society. I shall refer to this as the *societal condition* of scientific endeavour. It will lead us to consider the possible role of industrialization and secularization in a biblical view of history and its implications for the attributes of God (a thicker doctrine of God).[27]

The development of industrial technologies is based on earlier (pre-industrial) developments in the sciences like Newtonian mechanics and thermodynamics. Therefore, advanced technology also requires the pre-existence of a cultural tradition that fosters the investigation of hidden recesses of the space-time world. I shall refer to this as the *cultural condition* of scientific endeavour.[28] The scientific revolution of the 16th and 17th centuries would not have been possible without such a science-fostering culture to sustain them. The cultural values and beliefs needed for an investigation are not unique to Western civilization, but neither are they universal. This condition will lead us to a review of the role of the 'creationist tradition' in Western civilization and to reevaluate the way the history of Western theology is presented in most courses and texts (a thicker historical theology).[29]

Unlike cultural traditions, the underlying ability of humans to create scientific models and theories is a cultural universal. I shall refer to this as the *anthropological condition* of scientific endeavour because it relates to intrinsic capabilities of the human

26 Some other ways of thickening the description of scientific endeavour would be to study the aesthetics of scientific endeavour or the psychological stresses and ethical issues that scientists face; cf. Traweek, *Beamtimes and Lifetime*, on the latter pair.

27 My analysis of the secularization issue was developed in 'From Biblical Secularity to Modern Secularism: Historical Aspects and Stages', in S. Marianne Postiglione and Robert Brungs (eds), *Secularism versus Biblical Secularity* (St Louis: ITEST Faith/Science Press, 1994), 1-43.

28 In 1924, Edwin Arthur Burtt's idea of 'metaphysical foundations of modern science' corresponds roughly to what I am calling the Cultural Foundation of scientific endeavour; Burtt, *The Metaphysical Foundations of Modern Physical Science*, 2nd edn (London: Kegan Paul; New York: Humanities Press, 1932).

29 The historic 'creationist tradition' is a composite of beliefs that supports scientific endeavour and is not to be confused with 'creation science'. I reviewed the history of the 'creationist tradition' in *Creation and the History of Science* (London: Marshall Pickering, 1991), and more extensively in *Creational Theology and the History of Physical Science: The Creationist Tradition from Basil to Bohr* (Leiden: Brill, 1997). Subsequent references will be made to the latter work.

species.[30] An evolutionary approach to the emergence of science-fostering intelligence will lead us to examine the evidence for the practice of soul journey in Paleolithic societies and to consideration of the spirit-matter complex (a thicker cosmology).[31]

Underlying all of these conditions, the most basic condition of all is the particular kind of universe we live in. Science would not be possible without the existence of a lawful cosmos. Of all the possible universes that might exist, only those that are governed by laws or symmetries of some sort can produce species capable of doing science.[32] I shall refer to this as the *cosmic condition* of scientific endeavour. Analysis of this condition will not lead to a cogent argument for the existence of God (the natural theology option), but it will raise the question of a Lawgiver and, given the biblical tradition, it will require a rethinking of God's role in creation and of the nature of the laws of nature (a thicker view of God in relation to creation).[33]

If we rearrange these preconditions and start with the most basic, we have the following necessary, cumulative conditions or foundations of scientific endeavour:

1. a cosmos with laws or symmetries (cosmic condition)
2. a species with brains capable of investigating those laws (anthropological condition)
3. a culture that fosters scientific investigation (cultural condition) and
4. an industrial society capable of producing the technologies needed to collect the needed information (societal condition).

Each of these conditions will be taken up and analysed in one of the following chapters. Detailed consideration of each one will lead to interdisciplinary questions that call for serious theological endeavour.[34]

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30 There are various branches of anthropology. The capacity of the human brain to create scientific models is a subject for physical anthropology as distinct from cultural anthropology.

31 I first developed these ideas in reviewing the writings of my mentor, Thomas F. Torrance; Kaiser, 'Humanity in an Intelligible Cosmos: Non-Duality in Albert Einstein and Thomas Torrance', in Elmer M. Colyer (ed.), *The Promise of Trinitarian Theology: Theologians in Dialogue with T. F. Torrance* (Lanham, Md.: Rowman & Littlefield, 2001), 239-67.

32 The deepest laws of physics we know have the form of mathematical symmetries. Symmetries may be ultimate in one sense, but there is also the need for principles of symmetry-breaking and emergent phenomena; George Ellis, 'Physics and the Real World', *Physics Today* 58 (July 2005), 49-54.

33 The basis of these ideas were presented in two of my earlier articles: Kaiser, 'The Laws of Nature and the Nature of God', in Jitse Van der Meer (ed.), *Facets of Faith and Science* (Lanham, Md.: University Press of America, 1996), 4:185-97; and idem, 'The Integrity of Creation and the Social Nature of God', *Scottish Journal of Theology* 49 (1996), 261-90.

34 Theological endeavour is just one way of addressing the issues embedded in the foundations of scientific endeavour. Trajectories could also be traced into philosophy (esp. epistemology), economics, ethics, and politics. Theology and philosophy are perhaps the only disciplines of sufficient generality to address all of the foundations we have listed. Here we view the sciences as human endeavours rather than as bodies of knowledge, and we approach theological endeavour through the foundations of scientific endeavour, in contrast to Nancey Murphy and George F. R. Ellis, who locate theology (and ethics) at the summit of a hierarchy

These four conditions are all necessary for the origin and development of natural science, but they are not sufficient by themselves. A variety of other conditions could be added. For example, special properties of our universe like the force of cosmic expansion and the value of the fine structure constant are required to allow the formation of stars and planets and the evolution of life. This is the basis of the so-called 'Anthropic Principle' – the properties of our universe must be almost exactly the ones that we observe or else it would not have been possible for life to evolve.[35] Much has been written on the theological significance of this topic and its significance for purpose in the universe.[36] However, the Anthropic Principle is not relevant to the viability of scientific endeavour as such. As a condition for the evolution of life, it requires that the laws of nature have a particular form, but it is too specific to affect the most basic condition of the existence of laws of nature, and it is too general to guarantee the existence of species with the intelligent needed to do science. I shall only touch on the Anthropic Principle in Chapter 1.

Another necessary condition for the viability of scientific endeavour is the existence of a stable, habitable planetary environment. Such an environment may be very rare in our universe.[37] In fact, the very special (and fleeting) environmental conditions of planet Earth raise issues of for the study of eschatology – how humans will confront the inevitable deterioration of conditions in our 'habitable zone' around the sun and how that relates to biblical eschatology. Like the Anthropic Principle, however, the condition of habitable environments is not related to the viability of science as such. So, while other conditions could be considered, the four that we discuss here will suffice to demonstrate the method and to stimulate further discussion.

Besides being necessary, these four conditions of scientific endeavour are also cumulative and forward-contingent. The existence of a lawful cosmos does not necessarily lead to the emergence of science-fostering intelligence. The existence of science-fostering intelligence does not necessarily lead to the emergence of a science-fostering culture. The existence of a science-fostering culture would not necessarily produce an industrial base sophisticated enough to produce the technologies needed for modern science. The overall picture is one of necessary conditions and contingent developments.

I shall use the term 'foundations' in this study because it captures the complex idea of conditions that underlie scientific endeavour and that build on one another

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of sciences; Murphy and Ellis, *On the Moral Nature of the Universe: Theology, Cosmology, and Ethics* (Minneapolis: Fortress Press, 1996), 16, passim.

35 Technically this is the 'Strong Anthropic Principle'; John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (Oxford: Oxford University Press, 1986, 1988), 21-2.

36 For good review of the debate concerning the Anthropic Principle and an able defense of its validity as evidence of purpose in the universe, see Karl Giberson, 'The Anthropic Principle: A Postmodern Creation Myth?' *Journal of Interdisciplinary Studies* 9 (1997), 63-90. For a discussion in the renewed interest in the principle since 2003, see Dan Falk, 'The Anthropic Principle's Surprising Resurgence', *Sky and Telescope* 107 (March 2004), 43-7.

37 On the special conditions required for habitable environments, see Kaiser, 'Extraterrestrial Life and Extraterrestrial Intelligence', *Reformed Review* 51 (1998), 77-91; Peter Ward and Don Brownlee, *Rare Earth: Why Complex Life is Uncommon in the Universe* (New York: Copernicus Books, 2003).

in a cumulative, forward-contingent manner. It is easy to visualize foundations of scientific endeavour by imagining a pyramid of blocks laid one on top of the other, with the most basic one, representing a lawful cosmos, on the bottom and the most dependent, scientific endeavour, on the top (see Figure I).

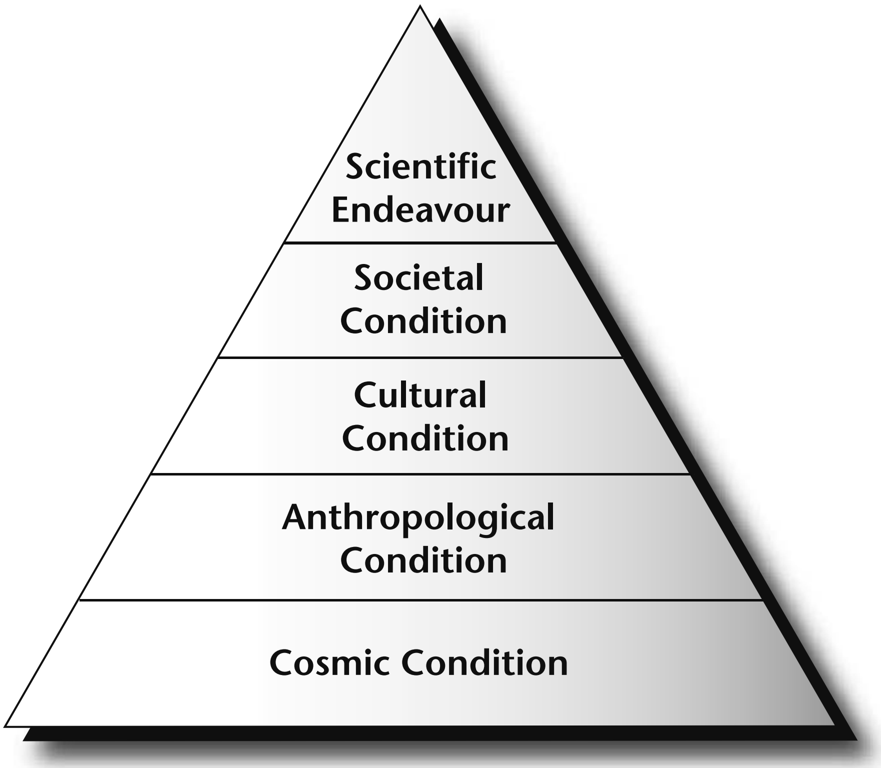

Figure I.1 The four foundations of scientific endeavour

The blocks in Figure I.1 represent the preconditions or foundations of scientific endeavour and illustrate the idea of thick description. The decreasing size of the blocks illustrates increasing contingency as one goes up. One could develop a drawing that includes endeavours besides science simply by adding summits supported by different blocks, all resting on the same Cosmic Foundation. A complete picture would look something like a tree with many branches and even more twigs and leaves to represent the variety of endeavours. The life of each leaf would draw from all the structures that support it.

The idea of foundations here has nothing to do with the idea of philosophic 'foundationalism' – the belief that certain basic presuppositions must be posited in order to sustain any rational discourse.[38] Our preconditions or foundations are actual

38 On the subject of classical foundationalism, see, for example, Alister E. McGrath, *A Scientific Theology, Volume 2: Reality* (Edinburgh: T&T Clark, 2002), 20-39.

features of the world in which scientists work rather than presuppositions.[39] Nor are all of these foundations appropriate for other forms of human endeavour. A different set of foundations would have to be explored in the investigation of social justice or music.

An alternative way to visualize the idea of conditions that underlie scientific endeavour would be to use a set of concentric spherical shells with the cosmic condition at the centre and the other conditions as concentric shells surrounding it (see Figure I.2).

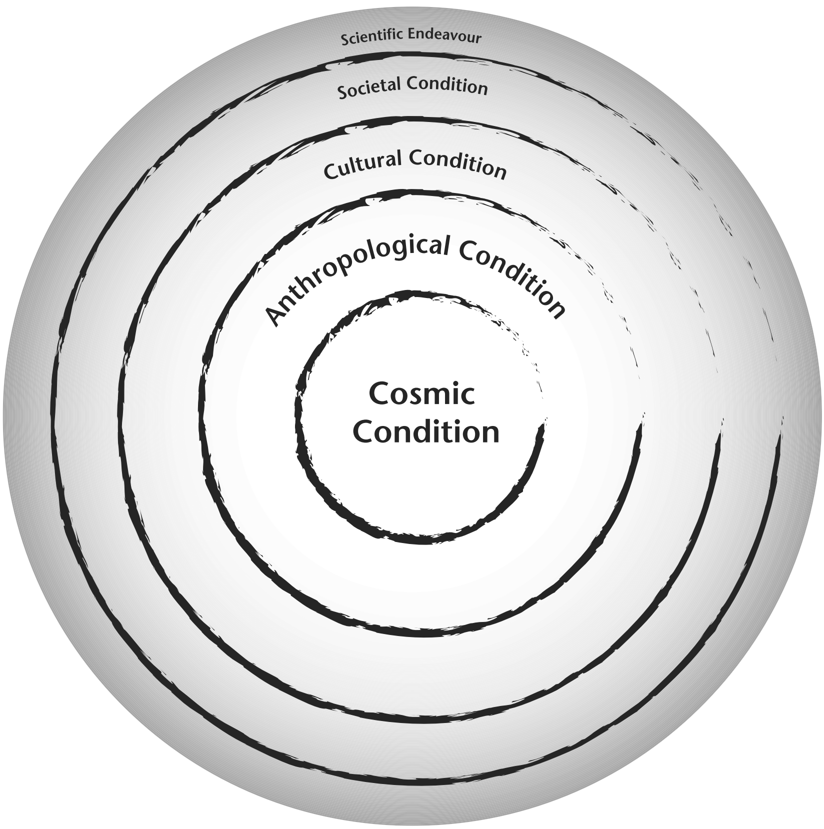

Figure I.2 The interior shells supporting scientific endeavour

The decreasing thickness of the spherical shells in Figure I.2 illustrates the increasing contingency or the preconditions of scientific endeavour. Once again, allowance must be made for a variety of other shells expanding out of the same center and supporting other endeavours besides science.

39 The Cultural Foundation involves the presupposition or belief that the world is comprehensible to humans (Chapter 3). However, we treat it here as a contingent cultural tradition rather than a logically necessary presupposition.

Toward theological endeavour

Scientific endeavour occurs within specific cultures and traditions. The same is true of theological endeavour. The discussion of theology in this book will relate primarily to the biblical (Judeo-Christian) tradition – the tradition to which the author adheres. But our discussion will be rigorously science-based, contingent, open-ended, and ecumenically inclusive within that tradition.

Our approach to theology will be science-based in that theological doctrines will be brought in only as they address issues raised in our discussion of the foundations of scientific endeavour and as allowed by rigorously scientific analysis of those foundations. The theological resources drawn on will be derived from the biblical tradition, but the arrangement of the material will be governed by the outline of the foundations of scientific endeavour. Consequently, our theological discussion will take a different form from that found in most textbook theology. There are as many ways to develop an outline of theology as there are to analyse human endeavours like the sciences.

The discussion of theology will also be progressively contingent. Each observation about the foundations of scientific endeavour will lead to unresolved questions and suggest theological possibilities, but no attempt will be made to convert those possibilities into necessary inferences. This will show that scientific endeavour (thickly described) has a variety of seams or trajectories of investigation that lead naturally to theological questions. The theological payoff is in the necessity of addressing the questions, and in the discovery of resources in the theological traditions.

The mandate of modern science is to explore all accessible features of the space-time world in such a way that everything can be comprehended and all relevant questions can be resolved. It will be argued that some wider frame of rationality is needed in order to complete this project and make sense of scientific endeavour itself, i.e., for scientific endeavour to be self-referential. We will show that the invocation of theistic ideas provides at least one way to give such a coherent account of scientific endeavour and thereby contribute to the unity of scientific knowledge. Once you look beneath the surface of either science or religion as social phenomenon you find that they are deeply entangled.

Our discussion will be openended. In some cases, it will be possible to make predictions and test some steps in our argument. In other cases, suggestions will be made for the reordering of theological disciplines as suggested by the study of the preconditions of natural science. The basic point is that thickening the description of scientific endeavour will thicken our view of both Creator and cosmos. But, as already mentioned, a different analysis of the foundations of scientific endeavour could be developed, and a different theological tradition might provide resources for a very different interpretation of those foundations.

Let us return for a moment to our visual model of a series of blocks with the most basic one on the bottom and the smallest on the top. The small block on the top represents scientific endeavour, and the underlying blocks represent its foundations. There may be a large number of these foundations, but we are working with just four of them. The theological issues we will discuss can be visualized as lying in the same plane as the foundational blocks, but extending to one side. The theological resources from the biblical tradition can be visualized as a complementary set of blocks selected in such a way that they dovetail with first set. Each set of blocks can stand on its own, but a stronger arrangement (representing a broader rationality) can be achieved by viewing them together.[40]

Our discussion will also be ecumenical. No one theological tradition has the resources to address all of the issues that will be raised. Therefore, patristic and early Jewish sources will be employed in addition to commonly known Christian teachings. There is no attempt to be strictly confessional.

Each of the following four studies stands on its own and can be read independently of the others. Readers may wish to check the brief abstracts at the beginning of each chapter and pick out the chapters that most interest them. However, there are several interesting overlaps among the studies that contribute to a cumulative effect and there will be some cross-referencing along the way. The concluding chapter will address these overlaps more directly and synthesise the four studies into a unified vision of science as indicated in the title.

On an autobiographical note, I should explain that beginning this investigation with a description of scientific endeavour reflects my own growing experience. My university training in physics and astrophysics and my discovery of spirituality through anthropology and depth psychology are reflected in the observations I will make and the illustrations I will use. For me, this will not be interconnecting abstract ideas so much as reviewing real learnings and personal choices. A theology that is imposed on science from the outside is not likely to carry conviction for those who are not already believers. I hope to show that theological questions and confessional options emerge from analysing the foundations of scientific endeavour in much the same way that scientific questions come from analysing the features of the a space-time world. In short, a thick description of natural science leads to a thick description of nature, humanity, history and God.

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40 In terms of Ian Barbour's typology of ways to interrelate science and theology, the method we are developing might be classed as either a 'Dialogue Model' with an emphasis on presuppositions and limit-questions or an 'Integration Model' along the lines of natural theology and continuing creation; see Barbour, *Religion in an Age of Science* (San Francisco: Harper & Row, 1990), 17-20, 24-6; *When Science Meets Religion*, 23-4, 28-30, 52-4, 59-61, 114-15. However, all of these models presuppose that theology is defined as a body of discourse separate from science, whereas I intend to discern theological issues and theological discourse within the foundations of scientific endeavour and follow those through in search of a thicker view of relevant theological doctrines. It is true that as formal bodies of knowledge theology and science are distinct and need to be interrelated, but as human endeavours they are inseparable. The integration in question is more like that of Maxwell's integration of electric and magnetic force fields than it is like the integration of two separate cultures. Paul Tillich's 'method of correlation' did something very similar for existential philosophy and Christian theology; Tillich, *Systematic Theology*, Vol. 1 (Chicago: University of Chicago Press, 1951), 61. However, Tillich did not work specifically with the natural sciences in this context or with the traditional theology of the fathers and rabbis. His main concerns were more soteriological than creational.