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PETER ATKINS

Purposeless People

When confronted with the analysis of any concept, however complex, the only intellectually honest approach is to explore the extent to which an absolutely minimal explanation can account for the reliable evidence. There is no justification for departing from this procedure when the complex concept in question is that of the person, however deeply emotive it may be, and however much we may long for a reassuring outcome. Only if a minimal approach is explicitly demonstrated to be inadequate may there be some justification for indulging in the soft furnishings of additional hypotheses. We should begin our exploration, therefore, by asking whether the concept of person, which I take to be the concept of our individual existence, persistence, and role in this universe, can be explained without the sugar-coating of invented attributes of persons, additions that have been proposed by the under-informed or the wiley perhaps, and have been adhered to generally by the religious.

We should ask whether the concept of personal existence can survive stripped-down explanations and their ramifications. Is there any support for the existence of something beyond the absolutely sparse? Is there life beyond bones? Are the fat and tallow of religious, philosophical, and psychological forms of justification necessary and not merely desirable? And if fat and tallow are found to be unnecessary, is there any justification for an ethical view amid the bones of people's purposelessness?

I will argue that it is intellectually dishonest at this stage of human development to resort to the artifice of supposing man's existence to be justified by recourse to something beyond this world. I will argue that the time is ripe for the faithful to relinquish their prejudices and to examine with an open mind the possibility that the world is a happy accident, that we might be creatures of chance, nothing more than fragments of highly organized matter, and that

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Persons and Personality, ed. A. Peacocke and G. Gillette (Oxford: Basil Blackwell, 1987) pp. 12–32. Reprinted by permission of the author.

there may be nothing intrinsically special about us apart from the complexity of our responses. I will also argue that the long-term future of everything is oblivion and annihilation.

I challenge anyone who seeks, hopes, and believes in a seductively richer option and a rosier destiny to accompany me to the bedrock of existence and to build their beliefs on it only in so far as their shelter is shown to be essential. I will argue that *all* softenings of my absolutely barren view of the concept of person and of the foundations of this wonderful, extraordinary, delightful world are sentimental wishful thinking.

THE OMNICOMPETENCE OF SCIENCE

The spring of my apparently barren but, as I hope to show, deeply enriching world-view, is my belief that science is all-competent.

I base this belief on the observation that science has never encountered a barrier that it has not surmounted or that it cannot reasonably be expected to surmount eventually. I admit that this is only a belief, but I will argue that it is supportable, and that it is simpler than the alternatives and should therefore be given priority over more elaborate views. In alluding to domains not yet fully conquered, I have in mind the at least arguable—and certainly not yet explicitly denied—view that, in due course, science will be equipped to deal with aesthetic and religious experience, and will be able to account for our perception of ourselves as distinct, responding entities. It will do so, I believe, by showing that the characteristically human capacities which we lump together for convenience of discourse as 'human spirit' or 'soul' are no more than states of the brain, and likewise that extension of the idea of a soul to expectation of eternal persistence is already quite plainly explicable in terms of a deep-seated desire to avoid, and the inability to come to terms with, the prospect of one's own annihilation.

I do not see any evidence to support the claim that there are aspects of the universe closed to science. Given the success of science in encroaching on the territory traditionally regarded as that of religion, I can accept that many people *hope* that its domain of competence will prove bounded, with things of the spirit on one side of the fence, things of the flesh on the other. But *until it is proved otherwise,* there is no reason to suppose that science is incompetent when it brings its razor to bear on belief. Until the day that science is explicitly shown to be incompetent, we should acknowledge that its not-yet-stopped razor is slicing through the fabric of the heavens and leading us towards an extraordinary deep understanding of the composition, organization, and origin of the world.

As science's razor continues to slice, so it is revealed that much that was once inexplicable stems from the workings of laws that are simplicity itself. What grounds are there for assuming that the razor will become blunt or will run against the uncuttable? Pessimism? Fear? Outrage? Surely such emotional cringing is poor reason for not permitting this supreme device of the human intellect, our science, to run its course.

If we are to approach our topic with an open mind, we should prepare ourselves to see sliced from the concept of person many of some people's most cherished beliefs. It would be premature to say that science, which at present is undeniably in full flood, cannot deal with the great questions. Give science time: it is in the midst of its achieving; do not yet merely deny its omnicompetence, and do not resort to traditional explanations unnecessarily. In assessing whether a purely scientific world-view is likely to be complete, do not assume that because religious views have been around longer, they are more likely to be right. In wondering whether a sparse scientific view of the person could suffice, I think it only fair to play the game of reversing history, of envisaging a religious upstart battling against a high ground held for millennia by science. Could anyone seriously take religion's mysteries to be more compelling than science's public achievements? I picture a dog suddenly woken into our intellectual level and presented with the offerings of religion and science. What dog, unfettered by our cultural heritage and free from the iron grip of religion's social, economic, private, and artistic propaganda, would opt for religion's 'explanations'? Surely, any honest dog would accept that science

was so well along the road to full explanation, that it should side with science and discard religion, at least until—if ever—science failed to deliver.

THE JOURNEY INTO SIMPLICITY

My attitude is that the omnicompetence of science and, in particular, the simplicity revealed by its insights should be accepted as a working hypothesis until, if ever, it is proved inadequate. This is relevant to our discussion in a multitude of different ways. Among them is the lesson taught by science about the power of the unconstrained and undirected to lead to rich consequences, consequences that are so rich that they can readily be mistaken for purposeful, directed events.

I think it worth exploring this last statement more deeply, for many non-scientists see science as an increasingly complex edifice, with each new discovery, each new theoretical concept, adding one more pimple to an already over-carbuncled and bunioned body. Such a view could not be further from the truth. Each new discovery of fundamental science—and we are not at this stage concerned with its applications—reveals one more facet of an underlying *simplicity*, a simplicity that allows more to be explained by fewer concepts and precepts.

Not all scientists, never mind non-scientists, recognize or acknowledge this simplicity. Some see only the enormous effort and complex equipment needed to make even the seemingly most trivial advance in understanding and confuse the complexity entailed in gathering information with the underlying simplicity revealed by the information so gathered. Some, seeing how new ideas overthrow old familiar ones, as when quantum theory replaced classical mechanics, do not see beyond the loss of the familiar to the sharp insight that comes from discarding approximations and shifting viewpoint. Some, seeing the mathematics required both to express an idea and to relate it to an observation, confuse the complexity with which simple concepts band together to masquerade as complex phenomena with the simplicity of the concepts themselves.

If there is a deep message that a scientist should convey to non-scientists, it is that simplicity can have consequences of extraordinary complexity, a revelation resulting from science's ability to discern the ways in which these simplicities tangle into testable, observable complexities.[1]

THE MOTIVE POWER OF CHANGE

I must take you to one more level of scientific explanation if you are to appreciate the power of science to attack great problems, and if you are to see what I have in mind when I speak of complexity as the child of simplicity.

The second law of thermodynamics,[2] that child of the steam-engine, has, in the course of the nineteenth and twentieth centuries, grown to become the greatest liberator of the human spirit, and the steam-engines from which it sprang can now be seen to have forged wings for humanity's aspirations. Sadi Carnot—and it is fitting that he was named after a poet—pointed the way to the formulation of this law that acts as signpost in the direction of natural change, a law of such universality that it applies to every kind of change, from the most primitive—such as the cooling of hot metals and the expansion of gases—to the marginally more complex—such as the synthesis of ammonia and the rusting of iron—to the most complex—such as the emergence of new species, the formation of opinions, introspection, hallucination, self-deception, and comprehension.

Carnot's reflections leading to this law, as well as those of his successors Kelvin and Clausius, who formulated it rigorously and explored some of its consequences, were views of matter and its behavior as seen from the outside. Theirs were powerful formulations of descriptions which did not, on their own, lead to insight into the spring of the world. It was left to the short-sighted Boltzmann to see further than all his contemporaries and to formulate an explanation of the second law in terms of the behavior of atoms before their existence was generally accepted. Many of his contemporaries doubted the credibility of Boltzmann's assumptions and feared that his work would dethrone the concept of purpose that they presumed to exist within the world of change, just as Darwin had recently dispossessed its outer manifestations. Suffering from their scorn, Boltzmann, himself committed to the omnicompe-

tence of science, was overcome by instability and unhappiness, and killed himself.

Yet now we know that Boltzmann's interpretation of the second law in terms of atoms was right in broad terms. Today no one seriously doubts the existence of atoms, and no one has reason to suppose that they are driven by a sense of purpose. They are driven by forces, their intrinsic properties—their mass, their charge, and, more deeply, their wave nature—determining their response and their paths through the world, bundled together as an element here and an elephant there. In the last twentieth century, we see that the direction of natural, spontaneous change, the direction taken by events when the universe is left to free-wheel, is that of increasing universal chaos.

Boltzmann's insight into the deep structure of natural change, which accounts for all the events of the world captured by Carnot's, Kelvin's, and Clausius's phenomenological thermodynamics and has now been extended beyond them, is that the universe is sinking, purposelessly, into ever greater chaos. Thus, energy tends to disperse from compact, highly concentrated regions, such as a nucleus, a lump of coal, a sandwich, or the sun. Similarly, the energy of orderly motion tends to become chaotic, as when a bundle of atoms grouped together as a ball hits a wall and the uniform motion of its atoms is rendered chaotic by the collision, and the net motion is randomized into chaotic thermal motion. Likewise, the location of particles becomes chaotic, when they move, collide, and spread, as when a gas expands into a vacuum.

These three kinds of sinking into chaos account for all natural change.[3] That they account for the decay and decomposition of matter may be self-evident. But the richness of these processes, and that of science, is due to the fact that the very same processes also account for the emergence of structures. That is, the second law allows for the abatement of chaos in one region, as long as there is a greater flood elsewhere, so that, overall, the universe becomes more chaotic. This extraordinary, creative, constructive characteristic of the collapse into chaos is a result of the universe being a network of interdependences: pull a string here and a lever moves there. Falling water here drives a lathe there. A chemical reaction here is linked to another reaction there. A new substance produced in one reaction is used in another linked reaction, and together they add to the chaos of the world; but whereas one reaction has resulted in decay, as when a sandwich is eaten, the other has given birth to a protein.

The universe is an astonishingly, but not incredibly, rich, interconnected network of events. It moves forward as a result of its gradual sinking into chaos, but its interconnectedness is so rich that a surge of chaos there may effloresce into a cathedral, a symphony, or a deed here. Structures—in the broadest sense, including raising a stone in a field to build a house—moving a molecule in a brain to form an opinion—are local abatements of chaos, driven by a greater surge of chaotic dispersal elsewhere.

CHAOS, PURPOSE, AND THE EMERGENCE OF PEOPLE

Of course, we cannot yet trace a surge of chaos at some point and identify it with a particular deed. Perhaps we never will be able to, for it is undeniable that the brain is an exceptionally complex test-tube. Yet this criticism is irrelevant. It is enough for our present purposes to expose the bedrock of the scientific explanation of events: that the chaotic dispersal of energy and matter is interconnected in an intricate web, as in a diabolical organ where depressing one key may sound a chord of a billion unpredictable notes.

As yet, little has been said of purpose. At this stage science can perform its elucidation without appealing to the shroud of obscurity of man-made artifice. A block of hot metal will cool, not because its purpose is to cool, but because the spontaneous chaotic dispersal of its energy results in it cooling. A shoot emerges from a seed and grows into a plant, not because the seed's purpose is to grow, but because the intricate network of reactions in its cells are gearboxes that propel its growth as the rest of the world sinks a little further into chaos. The lily is a flag hoisted by collapse into purposeless chaos. All the extraordinary, wonderful richness of the world can be expressed as growth from the dunghill of purposeless, interconnected decay.

People, too, have emerged as the same dunghill has effloresced. One molecule capable of reproducing itself in its own image is all it needs to set the

world on the progress that has culminated in it being peopled with persons. All that was needed initially was a supply of suitable molecules that could be linked together into one larger molecule with the capacity to act as a template for its own replication. There are several conjectures as to how the appropriate organic molecules might have accumulated in the warm, wet, storm-ridden, and ultraviolet-soaked conditions prevailing on this planet three and a half billion years ago, and how they might have been combined into molecules that are the ancestors of today's DNA. Science, although far from sure, is certainly not defeated when it comes to suggesting how chance may have transformed the inanimate into the animate, with the potential for humanity.

One such global grandfather molecule could have entered the world through the blind, purposeless action of the second law, and at its inception become king. The blind activity of the second law, leads to replications of the king, and with more than one king, the world is at war and natural selection rules. I do not intend to trace the steps of evolution,[4] except to say that we can see in broad outline, and here and there in detail, how, given the conditions prevailing on this planet, the grand sinking into chaos led to us.

We have inherited the earth, at least temporarily, because our ancestors were equipped by chaos with mobility and brains that could respond ever more adroitly to the pressures of circumstance. We are, in a word, the children of chaos. At root there is only corruption and the unstemmable tide of chaos. That is the bleakness we should accept, as the starting-point for our analysis of the concept of person, for science can account for our emergence without the imposition of any extraneous view; it does not need to smear on to its clear, sinewy explanations any invented concept, particularly that of purpose. Purpose is unnecessary; all that is required to account for the emergence of people is interconnectedness and time.

Yet, when we look around and see beauty, when we look within and experience consciousness, when we participate in the delights of life, we feel in our hearts that the heart of the universe is richer by far. But do not be seduced: that is sentiment, and not what we should know in our minds. Unless it can be explicitly demonstrated otherwise, we should adopt the view that all attributes of persons have grown in response to the pressures for survival, and that any rationalization of them in terms of *additional* hypotheses, such as that of a creating, rewarding, or admonishing god or a teleological sense of purpose, are unjustified, superfluous superimpositions.

The bare bones of the scientific explanation of the emergence, existence, and temporary persistence of persons are that the universe is sinking into chaos. Faith in things beyond is a psychologically motivated fat and tallowing of these bones: God, an afterlife, the concept of purpose, are merely attempts to ameliorate the prospect of death, to unload the burden of guilt, and to soften the hardships of life. There is not one iota of justification for them beyond assertion, wishful thinking, and hallucination.

Although I can see that there is in some sense a justifiable temporally local sense of purpose—as for example, when I attempt to persuade others to my views (for reasons I could state), and more generally to contribute to the cultural heritage of the world; but I know that in the long term such activity is futile. For, after billions of years, even though we may have mastered the galaxies, founded new, young worlds, built our own private utopias next to stars we have learned to ignite and perhaps refresh, and have individually acquired physical and mental immortality, there will come a time when activity in the universe will cease. Then, at the dead end of the world, when all matter has decayed, when the expansion of the universe has distended space so much that it is a perfect void, we and all our achievements will come to naught. In the end there will be only dead flat space-time, our castles will have gone, as well as our libraries, our achievements, our selves. We, who will no longer be, will then listen in vain in the void for the Last Trumpet.

The sound of the Last Trumpet could, I suppose, be that of the Big Crunch, when the expanding universe, gripped by its own gravitation, ceases its current expansion, falls back on itself like a returning high-thrown ball, and crashes together in a final fury. Such a crunch could be the precursor of another Big Bang, a new First Trumpet, another cycle of expansion and contraction, another episode of groping for understanding in the liberty of newly refreshed space-time. But, aside from the fact that I consider it more likely that this is a one-shot uni-

verse, with a window briefly and only once opened for comprehension and aspiration, the Big Crunch would erase the tracks of our progress through this episode, and so, just as surely as in a one-shot universe, our achievements would be as though they had never been.

There is no reason to believe, except wishful thinking, that the long-term future of the human race, if it has one, even if it should evolve into superhumans, will be anything other than annihilation and oblivion. The long-term future, and in that sense purpose, of humanity should be regarded as empty. We came from nothing and will return to nothing, leaving behind neither material nor intellectual castles. All traces of our wars, poems, theories, and aspirations, all traces of our existence, and all traces of the existence of all matter will be erased.

NOTES

1. P. W. Atkins, *The Creation* (W. H. Freeman, Oxford, 1981).
2. P. W. Atkins, *The Second Law* (W. H. Freeman, New York, 1984).
3. Ibid.
4. R. Dawkins, *The Selfish Gene* (Oxford University Press, Oxford, 1976).

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MARTIN GARDNER

Science and the Unknowable

Existence, the preposterous miracle of existence! To whom has the world of opening day never come as an unbelievable sight? And to whom have the stars overhead and the hand and voice nearby never appeared as unutterably wonderful, totally beyond understanding? I know of no great thinker of any land or era who does not regard existence as the mystery of all mysteries.

—JOHN ARCHIBALD WHEELER

One of the fundamental conflicts in philosophy, perhaps the most fundamental, is between those who believe that the universe open to our perception and exploration is all there is, and those who regard the universe we know as an extremely small part of an unthinkably vaster reality. These two views were taken by those two giants of ancient Greek philosophy, Plato and Aristotle. Plato, in his famous cave allegory, likened the world we experience to the shadows on the wall of a cave. To turn this into a mathematical metaphor, our universe is like a projection onto three-dimensional space of a much larger realm in a higher space-time.

For Aristotle the universe we see, although parts of it are beyond human comprehension, is everything. It is a steady-state cosmos, self-caused, having no beginning or end. There is no Platonic realm of transcendent realities and deities. Plato succumbed to what Paul Kurtz likes to call the "transcendental temptation." Aristotle managed to avoid it.

In recent years cosmologists have blurred the distinction between the universe we know and tran-

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scendent regions by positing a "multiverse" in which an infinity of universes are continually exploding into existence, each with a unique set of laws and constants. This is one way to defend the anthropic principle against the argument that the universe's fine tuning is evidence of a Designer. It is known that if any of some dozen constants is altered by a minuscule fraction it would not be possible for suns and planets to form, let alone life to evolve. The counter argument: If there is an infinity of universes, each with an unplanned, random set of constants, then obviously we must exist only in a universe with constants that permit life to evolve.

The multiverse concept, however, is far from a step toward Platonic transcendence. The other universes do not differ from ours in any truly fundamental way. They all spring into being in response to random fluctuations in the same laws of quantum mechanics, varying only in the accidental way their Big Bang creates laws. There is still no need to leap from a godless nature to transcendental regions that somehow lie beyond the multiverse.

A few cosmologists and far-out philosophers have gone much further. They conjecture that all possible universes exist—that is, every universe based on a noncontradictory set of laws. In the many-worlds interpretation of quantum mechanics, the universe is constantly splitting into parallel worlds, but these countless worlds all obey the same laws. The multimultiverse of all-possible-worlds is a much larger ensemble, obviously infinite because the number of logically consistent possibilities is infinite. Most physicists do not buy this view because it is the utmost imaginable violation of Occam's razor. Leibniz's notion of a Creator who surveyed all logically possible worlds, then selected what She considered the most desirable, is surely a simpler conjecture by many orders of magnitude.

A question now arises. As science steadily advances in its knowledge of nature, never reaching absolute certainty but always getting closer and closer to understanding nature, will it eventually discover everything?

We have to be careful to define what is meant by "everything." There is a trivial sense in which humanity cannot possibly know all there is to know. We will never know how many hairs were on Plato's head when he died, or whether Jesus sneezed while delivering the Sermon on the Mount. We will never know all the decimal digits of pi, or all possible theorems of geometry. We will never know all possible theorems just about triangles. We will never know all possible melodies, or poems, or novels, or paintings, or jokes, or magic tricks because the possible combinations are limitless. Moreover, as Kurt Gödel taught us, every mathematical system complex enough to include arithmetic contains theorems that cannot be proved true or false within the system. Whether Gödelian undecidability may apply to mathematical physics is not yet known.

When physicists talk about TOEs (Theories of Everything) they mean something far less trivial. They mean that all the fundamental laws of physics eventually will become known, perhaps unified by a single equation or a small set of equations. If this happens, and physicists find what John Wheeler calls the Holy Grail, it will of course leave unknown billions and billions of questions about the complexities that emerge from the fundamental laws.

At the moment, cosmologists do not know the nature of "dark matter" that holds together galaxies, or how fast the universe is expanding, and hundreds of other unanswered questions. Biologists do not know how life arose on Earth or whether there is life on planets in other solar systems. Evolution is a fact, but deep mysteries remain about how it operates. No one has any idea how complex organic molecules are able to fold so rapidly into the shapes that allow them to perform their functions in living organisms. No one knows how consciousness emerges from the brain's complicated molecular structure. We do not even know how the brain remembers.

Such a list of unknowns could fill a book, but all of them are potentially knowable if humanity survives long enough. Too often in the past scientists have decided that something is permanently unknowable only to be contradicted a few generations later. On the other hand, many scientists have predicted that physics was near the end of its road only to have enormous new revolutions of knowledge take place a few decades later.

In recent years, just when it was thought that all the basic particles had been found or conjectured, along came superstrings, the most likely candidate at the moment for a TOE. If superstring theory is correct, it means that all fundamental particles are

made of incredibly tiny loops of enormous tensile strength. The way they vibrate generates the entire zoo of particles.

What are superstrings made of? As far as anyone knows they are not made of anything. They are pure mathematical constructs. If superstrings are the end of the line, then everything that exists in our universe, including you and me, is a mathematical construction. As a friend once said, the universe seems to be made of nothing, yet somehow it manages to exist.

On the other hand, superstrings may, at some future time, turn out to be composed of still smaller entities. Many famous scientists, notably Arthur Stanley Eddington, David Bohm, Eugene Wigner, Freeman Dyson, and Stanislaw Ulam, believed that the universe has bottomless levels. As soon as one level is penetrated, a trap door opens to a hitherto unsuspected sub-basement. These sub-basements are infinite. As the old joke goes, it's turtles all the way down. Here is how Isaac Asimov expressed this opinion in his autobiography *I, Asimov*: "I believe that scientific knowledge has fractal properties; that no matter how much we learn, whatever is left, however small it may seem, is just as infinitely complex as the whole was to start with. That, I think, is the secret of the Universe."

A similar infinity may go the other way. Our universe may be part of a multiverse, in turn part of a multi-multiverse, and so on without end. As one of H. G. Wells' fantasies has it, our cosmos may be a molecule in a ring on a gigantic hand.

Even if the universe is finite in both directions, and there are no other worlds, are there fundamental questions that can never be answered? The slightest reflection demands a yes.

Suppose that at some future date a TOE will provide all the basic laws and constants. Explanation consists of finding a general law that explains a fact or a less general law. Why does Earth go around the sun? Because it obeys the laws of gravity. Why are there laws of gravity? Because, Einstein revealed, large masses distort space-time, causing objects to move along geodesic paths. Why do objects take geodesic paths? Because they are the shortest paths through space-time. Why do objects take the shortest paths? Now we hit a stone wall. Time, space, and change are given aspects of reality. You can't define any of these concepts without introducing the concept into the definition. They are not mere aspects of human consciousness, as Kant imagined. They are "out there," independent of you and me. They may be unknowable in the sense that there is no way to explain them by embedding them in more general laws.

Imagine that physicists finally discover all the basic waves and their particles, and all the basic laws, and unite everything in one equation. We can then ask "Why that equation?" It is fashionable now to conjecture that the Big Bang was caused by a random quantum fluctuation in a vacuum devoid of space and time. But of course such a vacuum is a far cry from nothing. There had to be quantum laws to fluctuate. And why are there quantum laws?

Even if quantum mechanics becomes "explained" as part of a deeper theory—call it X—as Einstein believed it eventually would be, then we can ask "Why X?" There is no escape from the superultimate questions: Why is there something rather than nothing, and why is the something structured the way it is? As Stephen Hawking recently put it, "Why does the universe go to all the bother of existing?" The question obviously can never be answered, yet it is not emotionally meaningless. Meditating on it can induce what William James called an "ontological wonder-sickness." Jean Paul Sartre called it "nausea." Fortunately such reactions are short-lived or one could go mad by inhaling what James called "the blighting breath of the ultimate why?"

Consider the extremely short time humanity has been evolving on our little planet. It seems unlikely that evolution has stopped with us. Can anyone believe that a million years from now, if humanity lasts, that our brains will not have evolved far beyond their present capacities? Our nearest relatives, the chimpanzees, are incapable of understanding why three times three is nine, or anything else taught in grade school. It is difficult to imagine that a million years from now our brains will not be grasping truths about the universe that are as far beyond what we now can know as our understanding is beyond the mind of a monkey. To suppose that our brains, at this stage of an endless process of evolution, are capable of knowing everything that can be known strikes me as the ultimate in hubris.

If one is a theist, obviously there is a vast unknowable reality, transcending our universe, a "wholly other" realm impossible to contemplate without an emotion of what Rudolph Otto called the *mysterium*

tremendum. But even if one is an atheist or agnostic, the Unknowable will not go away. No philosopher has written more persuasively about this than agnostic Herbert Spencer in the opening chapters of his *First Principles* (1894).

On the beginning hundred pages of this book, in a part titled "The Unknowable," Spencer argues that a recognition of the Unknowable is the only way to reconcile science with religion. The emotion behind all religions, aside from their obvious superstitions and gross beliefs, is one of awe toward the impenetrable mysteries of the universe. Here is how Spencer reasoned:

> One other consideration should not be overlooked —a consideration which students of Science more especially need to have pointed out. Occupied as such are with established truths, and accustomed to regard things not already known as things to be hereafter discovered, they are liable to forget that information, however extensive it may become, can never satisfy inquiry. Positive knowledge does not, and never can, fill the whole region of possible thought. At the uttermost reach of discovery there arises, and must ever arise, the question—What lies beyond? As it is impossible to think of a limit to space so as to exclude the idea of space lying outside that limit; so we cannot conceive of any explanation profound enough to exclude the question—What is the explanation of that explanation? Regarding Science as a gradually increasing sphere, we may say that every addition to its surface does but bring it into wider contact with surrounding nescience. There must ever remain therefore two antithetical modes of mental action. Throughout all future time, as now, the human mind may occupy itself, not only with ascertained phenomena and their relations, but also with that unascertained something which phenomena and their relations imply. Hence if knowledge cannot monopolize consciousness— if it must always continue possible for the mind to dwell upon that which transcends knowledge, then there can never cease to be a place for something of the nature of Religion; since Religion under all its forms is distinguished from everything else in this, that its subject matter passes the sphere of the intellect.

By "Religion" Spencer did not mean religion in the usual sense of worshipping God or gods, but only a sense of awe and wonder toward ultimate mysteries. For him Science and Religion were two essential aspects of thought; Science expressing the knowable, Religion the unknowable. The two merge without contradiction; "If Religion and Science are to be reconciled," he writes, "the basis of reconciliation must be this deepest, widest, most certain of all facts—that the Power which the Universe manifests to us is inscrutable."

No matter how many levels of generalization are made in explaining facts and laws, the levels must necessarily reach a limit beyond which science is powerless to penetrate.

> In all directions his investigations eventually bring him face to face with an insoluble enigma; and he ever more clearly perceives it to be an insoluble enigma. He learns at once the greatness and the littleness of the human intellect—its power in dealing with all that comes within the range of experience, its impotence in dealing with all that transcends experience. He, more than any other, truly *knows* that in its ultimate nature nothing can be known.

The rest of Spencer's *First Principles,* titled "The Knowable," is an effort to summarize the science of his day, especially what was then known about evolution.

> But an account of the Transformation of Things, given in the pages which follow, is simply an orderly presentation of facts; and the interpretation of the facts is nothing more than a statement of the ultimate uniformities they present— the laws to which they conform. Is the reader an atheist? The exposition of these facts and these laws will neither yield support to his belief nor destroy it. Is he a pantheist? The phenomena and the inferences as now to be set forth will not force on him any incongruous implication. Does he think that God is immanent throughout all things, from concentrating nebulae to the thoughts of poets? Then the theory to be put before him contains no disproof of that view. Does he believe in a Deity who has "given unchanging laws to the Universe"? Then he will

find nothing at variance with his belief in an exposition of those laws and an account of the results.

Boundaries and Barriers: On the Limits of Scientific Knowledge (Addison-Wesley, 1996), edited by John Casti and Anders Karlqvist, is one of a spate of recent books on the topic. For almost all its authors, the term "limits" is confined to unsolved but potentially solvable questions. Most of the authors agree with what the editors say in their introduction: "Unlike mathematics, there is no knock-down airtight argument to believe that there are questions about the rest of the world that we cannot answer in principle."

Only British astronomer John Barrow has the humility to disagree. He concludes his contribution as follows:

> In this brief survey we have explored some of the ways in which the quest for a Theory of Everything in the third millennium might find itself confronting impassable barriers. We have seen there are limitations imposed by human intellectual capabilities, as well as by the scope of technology. There is no reason why the most fundamental aspects of the laws of nature should be within the grasp of human minds, which evolved for quite different purposes, nor why those laws should have testable consequences at the moderate energies and temperatures that necessarily characterize life-supporting planetary environments. There are further barriers to the questions we may ask of the universe, and the answers that it can provide us with. These are barriers imposed by the nature of knowledge itself, not by human fallibility or technical limitations. As we probe deeper into the intertwined logical structures that underwrite the nature of reality, we can expect to find more of these deep results which limit what can be known. Ultimately, we may even find that their totality characterizes the universe more precisely than the catalogue of those things that we can know.

Barrow later expanded these sentiments in his 1998 book *Impossibility: The Limits of Science and the Science of Limits* (Oxford University Press). Here are some passages from his final courageous chapter:

> The idea that some things may be unachievable or unimaginable tends to produce an explosion of knee-jerk reactions amongst scientific (and not so scientific) commentators. Some see it as an affront to the spirit of human inquiry: raising the white flag to the forces of ignorance. Others fear that talk of the impossible plays into the hands of the anti-scientists, airing doubts that should be left unsaid lest they undermine the public perception of science as a never-ending success story. . . .
>
> We live in strange times. We also live in strange places. As we probe deeper into the intertwined logical structures that underwrite the nature of reality, I believe that we can expect to find more of these deep results which limit what can be known. Our knowledge about the Universe has an edge. Ultimately, we may even find that the fractal edge of our knowledge of the Universe defines its character more precisely than its contents; that what cannot be known is more revealing than what can.

George Gamow once described science as an expanding circle, not on a plane but on a sphere. It reaches a maximum size, after which it starts to contract until finally the sphere is covered and no more fundamental knowledge about the universe remains. In recent years numerous physicists, Hawking for instance, have expressed similar hopes. Richard Feynman suggested that although the circle may start to contract, it will become ever more difficult to obtain new knowledge and close the circle completely.

That science will soon discover everything is far from a recent hope. William James, lecturing at Harvard more than a century ago, attacked the hope with these words:

> In this very University . . . I have heard more than one teacher say that all the fundamental conceptions of truth have already been found by science, and that the future has only the details of the picture to fill in. But the slightest reflection . . . will suffice to show how barbaric such notions are. They show such a lack of scientific imagination, that it is hard to see how one who is actively advancing any part of science can make a mistake so crude. . . .

> Our science is a drop, our ignorance a sea. Whatever else be certain, this at least is certain—that the world of our present natural knowledge *is* enveloped in a larger world of *some* sort of whose residual properties we at present can frame no positive idea.

Infinite In All Directions, the title of Freeman Dyson's 1988 book, says it all. Near the close of his third chapter he has this to say about a different hope:

> It is my hope that we may be able to prove the world of physics as inexhaustible as the world of mathematics. Some of our colleagues in particle physics think that they are coming close to a complete understanding of the basic laws of nature. They have indeed made wonderful progress in the last ten years. But I hope that the notion of a final statement of the laws of physics will prove as illusory as the notion of a formal decision process for all of mathematics. If it should turn out that the whole of physical reality can be described by a finite set of equations, I would be disappointed. I would feel that the Creator had been uncharacteristically lacking in imagination. I would have to say, as Einstein once said in a similar context, "Da könnt' mir halt der liebe Gott leid tun" ("Then I would have been sorry for the dear Lord").

PART 8 SUGGESTIONS FOR FURTHER READING

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