CHAPTER FIVE

Underdeterminism (II)

In the previous chapter I have discussed how Nature does not offer up its secrets willingly, how it requires creativity and imagination to find hypotheses which are useful for explaining and predicting the way the world is, and how it is possible for rational persons to disagree about the merits of a hypothesis. In this chapter I want to explore an extension of those issues, but here my reflections are considerably more speculative than those preceding. What follows below is not so much an argument whose soundness seems clear to me, but a series of worries and concerns, in a way, an expression of disquiet I have about some of the metaphysical assumptions underlying certain contemporary scientific research. These sanguine, common assumptions may be *methodologically* justified. However, it is far from clear that empirical evidence supports them in any strong way, and at the very least they deserve closer scrutiny than they usually have elicited.

5.1 Human history

When I was a high-school student studying algebra and geometry, I found those subjects so straightforward, so intuitive (if you will permit me to describe them that way), in short, so easy, that I fantasized that had they not already been created, I myself could have invented them with some hard work. The self-delusion continued. In university, I believed that I, too, could have found for myself many of the tricks mathematicians had discovered at the turn of the twentieth century for solving differential equations. But with additional learning, particularly in studying the history of mathematics and science, I came, in due course, to realize what an extraordinary hubris I had been suffering.

I am sure that the cause of my exaggerated belief in my own abilities had a good deal to do with the kind of education I had been given in high school, a kind of education which, so far as I can tell, in looking at contemporary textbooks and in talking with my students and with my children, is still the norm. The trouble, as I said earlier, is that modern textbooks typically avoid controversy. They ignore the route by which thinkers struggle to reach their hypotheses. Worst of all, textbooks usually are silent about, or simply dismiss as having been 'proven wrong', the successions of abandoned theories strewn on the wayside along the road to current theories. If history teaches us anything, it is that many current theories will themselves in due course be superseded. Too little is made of this point in ordinary classroom teaching.

So much of mathematics and science is presented to students as 'fact', as *fait accompli*, as natural and as certain, that it takes on an almost irresistible appearance of inevitableness. "Yes, of course; clearly it can be seen that that is the way the world is", students may all too easily be beguiled into thinking as they are presented with a seemingly finished science. Students are led to believe that virtually all the work has been done, only the mopping-up details remain.

I remember myself what a shock it was, and what at the same time an illuminating lesson it was, to learn of the history of the invention of what I – from our modern perspective – regarded as so 'obvious' that at first I could hardly believe that there was ever a time when humankind lacked the concept: a symbol for the number zero. But history tells us that not only was the symbol late in coming, so too was the very concept of zero's being a number. Using a symbol for zero was a monumental breakthrough in the history of mathematics. But it took generations of mathematicians laboring away at arithmetic before a symbol for zero came to be widely adopted; so too for representing numbers themselves with digits whose *place* indicated powers of a so-called base. Notice that in antique Roman numerals, the symbol, for example, for the number eight "VIII" is twice as long as that for nine "IX" and four times as long as that for one hundred "C". In modern (Hindu-Arabic) notation, no number has a longer symbolic representation than a larger number, but this 'obvious', and exceedingly useful (for computational purposes), device took *thousands* of years to emerge. Having been reared on it, we take it to be 'natural'. But it is not 'natural', it was not there in Nature to be 'read off'; it was an invention of genius. And we flatter ourselves in the extreme if we think that any ordinary one of us could have or would have invented it had we not already found it in the world into which we were born.

It took more than three billion years[1] for life on this planet to evolve from the bacterial form to a primate. That it did run this course seems

1. 1 billion = 1,000,000,000 = 10^9.

to border on the miraculous, for it is easy to imagine any number of 'accidents' which could have prevented it. Recall, the dinosaurs died out. But conditions suitable for the emergence of a primate are only part of the story.

That human beings, intelligent, rational, language-using, symbol-using creatures who have invented mathematics, physics, chemistry, have tamed the Earth and the seas and the air, should exist at all is – just on the basis of probability – tantamount to a miracle: a miracle of blind Nature or a miracle ordained by God, but a miracle in either case. But once there walks on the face of the planet an intelligent, language-using creature, what happens next? From the evidence, the answer seems to be: not much. The greatest part of human history, save for the last few thousand years, seems pretty much of a piece. Only comparatively recently did human beings plant and irrigate fields, create cities, track the stars, count and multiply, refine ores, and teach themselves to read and write.

As anthropologists have spread out across the globe they have discovered 'primitive' or 'stone age' tribes living here and there, in pockets isolated from civilization, subsisting as did our common ancestors of tens of thousands of years ago. These primitive tribes had not enjoyed (if that is the right description) the progress of most of European and Asian societies. Some of these tribes, at the time of their discovery, had not yet reached the invention of the wheel. Most had no written language. Many had not learned to craft metals. Some knew little or nothing of agriculture or animal husbandry and survived by hunting and gathering.

The point is that human progress should not be regarded as a historical inevitability. It takes the right ecological conditions, of course. But it also requires something more: it requires an act of creativity, either technological (making a wheel, hammering metal, melting sand, etc.) or intellectual (placing a symbol – on a cave wall, or clay tablet, or on some such thing – of not just a scene but an *idea* or a *fact*, inventing words for abstract concepts [*one*, *two*], etc.). There is nothing inevitable about the occurrence of such breakthroughs. They may, but they need not, occur. The primitive tribes which have survived into the atomic age are evidence that these breakthroughs need not occur. Had these tribes not been discovered by explorers from civilization, one might speculate, not unreasonably, that they might have persisted in their static state indefinitely, perhaps for tens of thousands of years more, perhaps, even, forever.

Science, mathematics, philosophy, music, technology, medicine, commerce, etc. are all products of the creative genius of countless persons whose names have been forever lost to us. We shall never know the name of the man or woman who first attached a sharpened rock to a wooden shaft, or created a bow and arrow, or tried to write a sentence, or carried a bunch of counting stones to reckon numbers with, or deliberately lit a fire, etc.

There is no inevitableness in our having an arithmetic, in our having a geometry (many of them in fact), in our having calculus, in our having physics, chemistry, or biology. There is no inevitableness, either, in our formulating theories of personhood, in our codifying logics, in our exploring the bases of morality, or in our wondering about the validity of our senses. Science and philosophy both – like music – are the products of creative imagination. There was no more inevitability in humankind's enjoying Newtonian physics than there was in its being the beneficiary of Beethoven's creative genius.

Persons who study political history see certain kinds of events, such as wars, movements of populations, and political alliances, constantly repeated. Focusing on *these* sorts of phenomena one might well come to believe that there is a certain inevitability in history. Certain kinds of events are 'destined' to occur, not just once but time and time again.

But focusing on intellectual history, an entirely different sort of picture emerges. Here there is not repetition but novelty. Here there is not inevitability, but uniqueness, creativity, imagination, and genius. It was not inevitable that a number system would evolve; it was not inevitable that grammarians would appear; it was not inevitable that humankind would figure out the relationship between the sides of triangles in a Euclidean space; it was not inevitable that humankind would figure out the relationship between the sides of triangles in non-Euclidean spaces; it was not inevitable that Locke (chapter 6) would concern himself about the personality of a prince being transferred into the body of a cobbler; it was not inevitable that Bach would write the Chaconne; it was not inevitable that Newton would invent the concept of *mass*.

Far too much has been made of a few cases where one piece of goods, either a material invention or an intellectual invention, was simultaneously created by two or more persons. Cases often cited are Newton's and Leibniz's independent invention of the calculus; Edison's and Cros's invention of the phonograph; Benz's and Daimler's invention of the gasoline engine; Gauss's and Lobachevsky's invention of non-Euclidean geometries. One must not lose perspective, however.

Non-Euclidean geometries arose out of a critical examination of Euclid's geometry created some two thousand years earlier. It took, that is, two thousand years before Euclid's geometry was understood well enough so that variants became possible. But if it took that long just to *understand* Euclid's geometry, is it reasonable to suppose that someone or other, other than Euclid, would have invented his geometry had he not done so? The very fact that it took so long to create a non-Euclidean geometry attests, I would like to suggest, not so much to the inevitability of someone's creating that geometry, but instead to the extraordinary intellectual novelty it was. If the creating of geometries were anything like being 'obvious', non-Euclidean geometries should have occurred not in the nineteenth century AD, but in the first century BC. Then, too, although Leibniz may be regarded as the co-inventor of the calculus, there is nothing in history to suggest that he, or any contemporary, was simultaneously co-inventing mechanics along with Newton. Leibniz had not conceived of *mass*; Leibniz had not conceived of the planet Earth accelerating toward a falling body; Leibniz had not conceived of universal* gravitation; and Leibniz had not conceived that for every action there was an equal and opposite reaction.

There are also a few cases cited within biology itself, not just within recent human intellectual development, which have been used to argue for a certain goal-directedness operative in Nature. The phenomenon of so-called 'convergent' evolution (along very different phylogenetic paths) of, for example, the eye of the mammal and the eye of the octopus has sometimes been offered as evidence of goal-directedness in evolution. (See, for example, [80], 198.) And from the supposition of this directedness, it has been further argued that evolution would probably (or inevitably) produce a creature whose mathematics and physics would resemble ours. But forbidding problems are found in this argument when it is dissected. First is the fact that convergent evolution is a relatively rare phenomenon, providing only weak evidence – at best – of a goal-directedness in evolution itself. Second is the fact that even if one were to posit a goal-directedness in evolution as an explanation of convergent evolution, that goal-directedness would be toward the development of similar physiological structures. It is only on an *analogy* that one moves beyond a goal-directedness of physiological structure to a goal-directedness of rational thought. Formally, i.e. its particular content aside, the argument thus begins with citing a fact about a relatively rare phenomenon and then proceeds in a series of steps each of which is itself of significantly low probability.

The cumulative effect is to make the probability which the factual premise confers on its speculative conclusion no more than very small. It is one thing to argue that something *could* be so (i.e. has a nonzero probability) and quite another to provide solid grounds for believing it *is* so (i.e. has a high probability [greater than 50%]). In short, the argument – which moves from the detected similarities in physiology between the octopus eye and the mammalian eye to the conclusion of the inevitableness of someone or other producing the geometry and physics of Euclid and Newton – is far too weak to justify its conclusion.[2]

Neither occasional instances of co-invention nor irregular occurrences of convergent evolution provide a strong base on which to posit a goal-directedness or historical determinism in Nature pointing toward the probable (still less the inevitable) unfolding of our own particular intellectual history.

5.2 Listening and probing for extraterrestrial intelligence

Once humankind had reconciled itself to the fact that the Earth is not the center of the universe, that not even the Sun is the center of the universe, that there are billions of galaxies in the vastness of the universe, and each galaxy in its turn contains billions of planets, the question naturally arises: Is there intelligent life elsewhere in the universe? In the last thirty years, centuries of speculation have at last turned into active empirical research. The United States government has from time to time funded the program SETI (Search for Extra-Terrestrial Intelligence) (albeit sometimes unwittingly[3]) and has even lofted (1972) into the heavens, on a flight beyond the solar system, a gold-anodized aluminum plate bearing an engraving of a man and a woman along with a (crude) star map of Earth's position among the planets orbiting the Sun. The hope motivating this project has been that somewhere, some time, this disk might be intercepted by alien intelligences and something of our own appearance and accomplishments would then

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2. For more on convergent evolution and the emergence of intelligence, see Mayr [133], 28, and Raup [166], 35-7.

3. In 1978 Congress terminated funding for SETI. NASA, however, continued SETI without publicity under its exobiology* program, spending $1.5 million on SETI in 1980-1. But in 1981, Congress discovered the subterfuge and explicitly forbade any further expenditures by NASA on SETI ([190]).

be made known beyond our own tiny speck of a planet. Radio telescopes – although not funded by NASA – daily scan the skies searching among the countless sources of radio waves for some telltale traces of an origin, not in some natural process, but in a deliberate, contrived, intelligent broadcast ([59], 70).

But how reasonable is this hope that there is intelligent extraterrestrial life with whom we might communicate? The arguments motivating the modern empirical search for such intelligent life conceal a host of metaphysical assumptions worthy of close philosophical scrutiny.

It is notoriously difficult to assign a probability to the existence of intelligent extraterrestrial life. And I must confess to being mildly bemused by the attempts other persons have made to actually calculate the probability of there being intelligent life elsewhere in the universe.[4] The assumptions on which these calculations are based seem to me to be so tenuous and so numerous as to undermine any reasonableness whatever of the conclusions reached. I, for one, find it premature, at the current level of scientific knowledge, to try to assign a numerical value to the probability of intelligent life arising in a waterless or carbonless world. What conditions are necessary for life? Certainly those on Earth have proved ideal. But how far can conditions depart before life of any form is physically impossible?[5] Is water needed? Is carbon needed? Is starlight (sunlight) needed or might the radiating heat of a planet's molten core do as a substitute? What temperature range? What atmosphere, etc.?

It is altogether improbable that evolution on other planets will have produced a human being. Intelligent life elsewhere in the universe,

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4. The standard approach to this problem is currently via the Drake equation (see e.g. [80], 345-51), devised by the astronomer Frank Drake. Carl Sagan gives a slightly variant version ([183], 12-24). Typically, the probability of there being civilizations in our own galaxy with whom we can now communicate is figured as the product of several independent factors, usually seven in all, including such things as the fraction of planets per planetary system having conditions ecologically suitable for the evolution of life, the fraction of planets where life actually develops, and the fraction where life progresses to the stage of technology.

5. For a detailed examination and criticism of the assumptions made by exobiologists and cosmologists in trying to determine the numerical values of the terms in the Drake equation, see [129], esp. 80-6.

almost certainly, will be nonhuman. These nonhumans may lack eyes or have light-sensitive organs very different from our own; they may lack ears or have auditory organs quite unlike ours; they may have senses we lack; they may lack senses we have; their emotional responses may be very dissimilar to our own, perhaps even incomprehensible to us; etc.[6] What – given all these myriads of possible differences in our biologies – can we expect to share in common? What subject matter should we choose when we try to establish communication? How shall we communicate with an alien life-form?

Steven Spielberg gave one answer, of a sort, in his film *Close Encounters of the Third Kind* (1977). Many newspaper and magazine reviews of the movie were extravagant in their praise of Spielberg's using music as the medium for communication between aliens and ourselves. But as one thinks about it critically, surely the praise for that particular aspect of the film is undeserved. Music is hardly a universal medium for communication. It is certainly not a language: while it may evoke emotions, it cannot be used to state facts. But even more important, for our purposes, is the fact that music must, to a far greater extent than a language, be tailored to fit the peculiar biology of a species.

If we ever do succeed in making contact with the members of an alien civilization, we certainly would not expect to find pianos in their homes. Pianos are designed in their keyboards and pedals to fit the anatomy of a human being: ten fingers, two feet, and upright posture. And the piano's equal tempering, i.e. being tuned in a certain fashion, indeed its even producing fundamental tones in the audible range of 33 Hz to 4000 Hz, is tailored to the atmosphere of the Earth and the

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6. For a minority, dissenting, opinion, see Bieri [29]. The guiding assumption of Bieri's argument is that the actual route which evolution has followed on Earth is the route which would be followed on virtually any planet. Given such a premise, his conclusions are not improbable. But that initial assumption needs powerful independent justification, and Bieri does not offer it. In its finer details, his argument is of this sort: "Strong arguments can be advanced for the presence of only two eyes for binocular vision and two ears for binaural hearing" ([29], 456). Unfortunately, Bieri leaves it at that; he offers not even a hint as to what these "strong arguments" might be. And he gets more specific still, being convinced, for example, that humanoids on other planets will not have green skin (457). But again, he offers no argument whatsoever for his assertion.

auditory mechanism of human beings. We can expect few, if any, of these necessary* conditions for our having created a piano to be replicated on other planets.

But even putting aside the purely physical means of producing music, ought we to expect the music itself of alien civilizations to resemble our own? I think there is no good reason to suppose that it would. Given the inordinate number of factors which fuel the evolution of a species, it strikes me as highly improbable that the nervous systems of extraterrestrials would develop in a manner parallel to that of human beings on Earth. It is far more likely that the aesthetic experiences of extraterrestrials, if indeed they have aesthetic experiences at all, would be totally inaccessible to ourselves. Aliens may not, for example, be capable of sorting out the separate lines in a piece of polyphonic music, may be insensitive to color or to geometrical perspective, etc. Their own aesthetics, in turn, may be as incomprehensible and as unmoving to us as our own best accomplishments, e.g. Michelangelo's Sistine Chapel or Schubert's String Quintet, apparently are to cats and dogs.

But if our aesthetic goods are not to be exchanged with alien intelligences, might intellectual goods? Leaving Hollywood behind, and turning to the scientific and philosophical literature, we find that many writers do believe that there are at least some intellectual goods we would share in common with any technologically advanced life-forms: mathematics and science. The idea is that mathematics and science are 'objective', that mathematics will be the same throughout the universe, and that science will be as well, provided, of course, in this latter instance, that the laws of physics are the same throughout the universe.

> What, then, can we hope to communicate with any 'technological' species? It appears that purely symbolic constructs which can be reduced to a postulational system, for example, mathematics (which might include much of physics as well as even basic rules of social organization), can be communicated. Surely a preliminary phase of communicating simple axioms to educate the alien intelligence and let them educate us in basic concepts is first required. However, it seems unlikely that we could share ideas which involve affect and emotions; for example we would be unable to communicate the feel rather than the abstract description of perceiving something. (Arbib [9], 76)

> Our main hope for interstellar communication is based on the belief that a technological civilization must have numbers. It is hard to conceive of a psychology which could do technology without being able to count, and add, and multiply. To do the geometry necessary to describe the motion of planets it must have some theory like conic sections or calculus. Thus one might expect such things to be in the repertoire of a scientist in any technological culture. … One might expect (though Drake's ideas on neutron stars may suggest a counterexample) that Newton's laws hold anywhere as a reasonable first approximation, so that any scientist would eventually begin to recognize that you are talking about Newton's laws. After a while, you have a language in which you can describe the motion of particles, no matter what the senses of the creature are, or whether he perceives these motions by vision, x-ray, touch, or another method. (Arbib [9], 77)

Arbib's optimism is based on a very great number of unarticulated presuppositions. Many of these I regard as highly dubious. I am not at all confident about the possibility of an alien life-form, indeed another human being for that matter, understanding the symbolism of our physics without our already sharing a common natural language. That is, Arbib and many others who have promoted the search for extraterrestrial intelligence believe that two creatures who do not share a common natural language can recognize, just by the passing back and forth of symbols, not only that the symbols are being used to express science and mathematics, but more specifically that the science is Newtonian physics and the mathematics is ordinary arithmetic. It strikes me that altogether too much credit is being given to the power of the message itself, and far too little to the need of a prior commonality of the languages and thought-structures of the would-be communicators.

Suppose the tables were turned. Suppose it were we who were the recipients, rather than the senders, of such a message. The message contains a series of marks which we take to be written in an attempt to establish communication by the senders instructing us in the rudiments of arithmetic and physics. The trouble is that there is no single way, or even just a few ways, to axiomatize either arithmetic or Newtonian physics. Any number of different ways exist to axiomatize arithmetic, some doubtless containing concepts we have never even imagined, perhaps even concepts which we are incapable of having.[7] Similarly for Newtonian physics. Must one have a concept of mass, for example, to do Newtonian mechanics? We might at first think so, since that is the way it was taught to most of us. We have been taught that there were, at its outset, three 'fundamental' concepts of Newtonian mechanics: mass, length, and time. (A fourth, electric charge, was added in the nineteenth century.) But it is far from clear that there is anything sacrosanct, privileged, necessary, or inevitable about this particular starting point. Some physicists in the nineteenth century 'revised' the conceptual basis of Newtonian mechanics and 'defined' mass itself in terms of length alone (the French system), and others in terms of length together with time (the astronomical system).[8] The more important point is that it is by no means obvious that we would recognize an alien's version of 'Newtonian mechanics'. It is entirely conceivable that aliens should have hit upon a radically different manner of calculating the acceleration of falling bodies, of calculating the path of projectiles, of calculating the orbits of planets, etc., without using our concepts of mass, length, and time, indeed without using any, or very many, concepts we ourselves use.

Their mathematics, too, may be unrecognizable. In the 1920s, two versions of quantum mechanics appeared: Schrödinger's wave mechanics and Heisenberg's matrix mechanics. These theories were each possible only because mathematicians had in previous generations invented algebras for dealing with wave equations and with matrices. But it is entirely possible that advanced civilizations on different planets might not invent both algebras: one might invent only an

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7. Again, see Thomas Nagel [140].

8. James Maxwell (1831-79) introduces the topic by writing: "We shall call the unit of length [*L*]. … We shall call the concrete unit of time [*T*]. … We shall denote the concrete unit of mass by the symbol [*M*] in treating of the dimensions of other units. The unit of mass will be taken as one of the three fundamental units" ([132], 3-4). But then he immediately proceeds to explain that it is not necessary to take mass as fundamental: "When, as in the French system, a particular substance, water, is taken as a standard of density, then the unit of mass is no longer independent, but varies as the unit of volume, or as $[L^3]$. If, as in the astronomical system, the unit of mass is defined with respect to its attractive power, the dimensions of $[M]$ are $[L^3T^{-2}]$" ([132], 4). See also Lord Kelvin (William Thomson 1824-1907) [109].

algebra for wave equations, the other only a matrix algebra. Were they to try to communicate their respective physics, one to the other, they would meet with incomprehension: the receiving civilization would not understand the mathematics, or even for that matter understand that it was mathematics which was being transmitted. (Remember, the plan in SETI is to send mathematical and physical information before the communicating parties attempt to establish conversation through natural language.) Among our own intellectual accomplishments, we happen to find an actual example of two different algebras. Their very existence, however, points up the possibility of radically different ways of doing mathematics, and suggests (although does not of course prove) that there may be other ways, even countless other ways, of doing mathematics, ways which we have not even begun to imagine, which are at least as different as are wave mechanics and matrix mechanics.

My point is not so much to worry about the possibility of our actually ever communicating with extraterrestrial intelligences, but to expose the metaphysical presuppositions of the kinds of scientific, epistemological,* and metaphysical views which inform much of the current discussion. So very much of this contemporary discussion strikes me as being premised on a naive view that mathematics and science can be of only one sort and that any 'successful' mathematics or science must be recognizable as such and translatable into our own. These views, in their turn, seem to me, ultimately, to be traceable back to the naive Baconian idea that Truth can be 'read off' of Nature, that ultimately there can be only one science, because – once the hypothesizing and the testing are done – Truth will be manifest. I cannot prove that these modern views are incorrect. But I am sure – and this is the important point – that they cannot be proven to be true.

As a species, we are faced with something of a methodological dilemma. If we do not assume that communication is possible, if we do not assume that mathematics and physics will be the same and will be recognizable for other technologically advanced civilizations, then we shall never succeed in finding intelligent life elsewhere in the universe by listening to radio signals. That is, these particular, unprovable metaphysical assumptions are a necessary condition for our finding what we seek. But they are not sufficient* conditions. They may be wildly wrong. There may be intelligent life in the universe which has devised mathematics and science, and has managed admirably to cope with its environment, in ways totally unimagined, indeed unimaginable, to us. If so, we will not find them with our technology. Making the assumption that mathematics, science, and technology will inevitably and universally be recognizably similar to our own is our only route to success, just as our hoping that there is to be found (invented) a cure for cancer is our only hope of ever finding (inventing) such a cure. But the hope is no guarantee of success; it is merely a psychologically and politically necessary condition for getting on with the job.

I see no good reason to believe that if we ever manage to detect life on other planets (e.g. by manned or unmanned probes), then we will find that the life-forms there will have succeeded in replicating our own history to the point where they too will have had a Newtonian revolution. Quite the contrary, it strikes me that the probability of other 'intelligent' life-forms throwing up a Newton is of the same order as their throwing up a Beethoven. I no more expect alien life-forms to have duplicated our physics and mathematics than I expect some one of them to have duplicated the *Waldstein* Sonata. And I see no inevitability, either, in any other course of evolution ever producing a Plato or an Aristotle or a Hume or a Kant.

Galileo, Brahe, and Kepler paved the way for Newton. But it was Newton alone who made the breakthrough of conceiving not of the Earth attracting the falling object, but of both the Earth and the falling object attracting one another. No one before Newton ever imagined that an object's falling and accelerating toward the Earth was reciprocated by the Earth's accelerating (but so minutely as to be imperceptible) toward the falling object. This was no minor change in a longstanding theory. Newton's rethinking the situation was breathtaking in its audacity. It was not even remotely to be conceived as being 'read off' of Nature. And it is by no means clear that *anyone* else ever would have replicated Newton's conjecture had Newton himself not authored it. Newton had been born prematurely; as an infant his head had to be supported by a cervical collar; he was a sickly youth ([49]). Had he not lived to adulthood, the modern scientific/industrial era may not have come into being.

Of course I cannot prove that no one but Newton could have figured out what we now call "Newtonian mechanics". All I can do is to reveal the differing metaphysical views we bring to such speculations. I, for one, am especially struck by the fact that so many other persons, working away at the same problems, from ancient times right up to Newton, did *not* conceive of the world the way he did. I am struck by the singularity of his accomplishment. Others, in looking at precisely the same historical data, will interpret it differently. These others will see in that data a steady intellectual evolution and will come to regard Newton's accomplishments as something of a historical necessity. They see the emergence of Newtonian mechanics as something which was bound to happen, if not exactly at the hands of Newton, then at least by somebody or other. We have already seen something of this attitude implicit, I believe, in the paragraphs above from Michael Arbib. To date, the debate between those, including myself, who believe that mathematics, science, philosophy, art, etc. are more of an accident than an inevitability and those who take the contrary view remains speculative. We each will cite the same historical data but will draw glaringly different conclusions.

That the same body of data can be, and often is, interpreted in radically different ways, indeed often in ways inconsistent with one another, is a pervasive fact virtually guaranteeing differences in our worldviews. We find another example, rather akin to the current one about the inevitability of something like Newtonian mechanics emerging eventually in the intellectual history of an intelligent race of creatures, in the debate over the existence in evolution of a goal or purpose. Religious-minded persons, not necessarily creationists or persons opposed to the evolutionary account, looking at the same history as evolutionists and seeing in it how any number of 'accidents' would have derailed its arriving at its present stage, find in that history clear evidence of the hand of a guiding God. The empirical data of evolution may be agreed upon by both atheist and theist. Yet where one sees merely life adapting to a changing environment, the other notices the contingency of all of this so much so that he or she cannot conceive of its having happened at all except as having been guided by something or someone supernatural.

If SETI is successful, if our radio telescopes succeed in finding within the radio noise of the universe signals which bear the unmistakable mark of intelligent origin, those who take the contrary view from me, those who believe that other civilizations can and will progress to radio communication, will have won the day. If diligent search, however, does not lead to success, my view will not have been proven correct; the debate will remain inconclusive.

What is the upshot? It is simply this: I see the development of mathematics, of science, of philosophy, of art, etc. all fairly much of a piece, i.e. as the product of creative genius. But if we are to discover intelligent life elsewhere in the universe we shall have to assume the contrary, namely that extraterrestrial mathematics and science will have evolved along lines pretty similar to our own and that at some point are, or were, at the stage we now find ourselves. I find these assumptions not particularly well-founded, and they seem to me to issue from some very dubious assumptions about the manner in which intelligent beings are able to make sense of, and control, their environments. Be that as it may, I also recognize that unless we make these – to my mind, dubious – metaphysical assumptions, then our hopes of finding extraterrestrial intelligent life are pretty much doomed. The only counsel I would be prepared to make is this: let us proceed with SETI, but let us also take care that it not absorb too many resources, resources which could be better spent on more immediate and pressing needs of humankind.