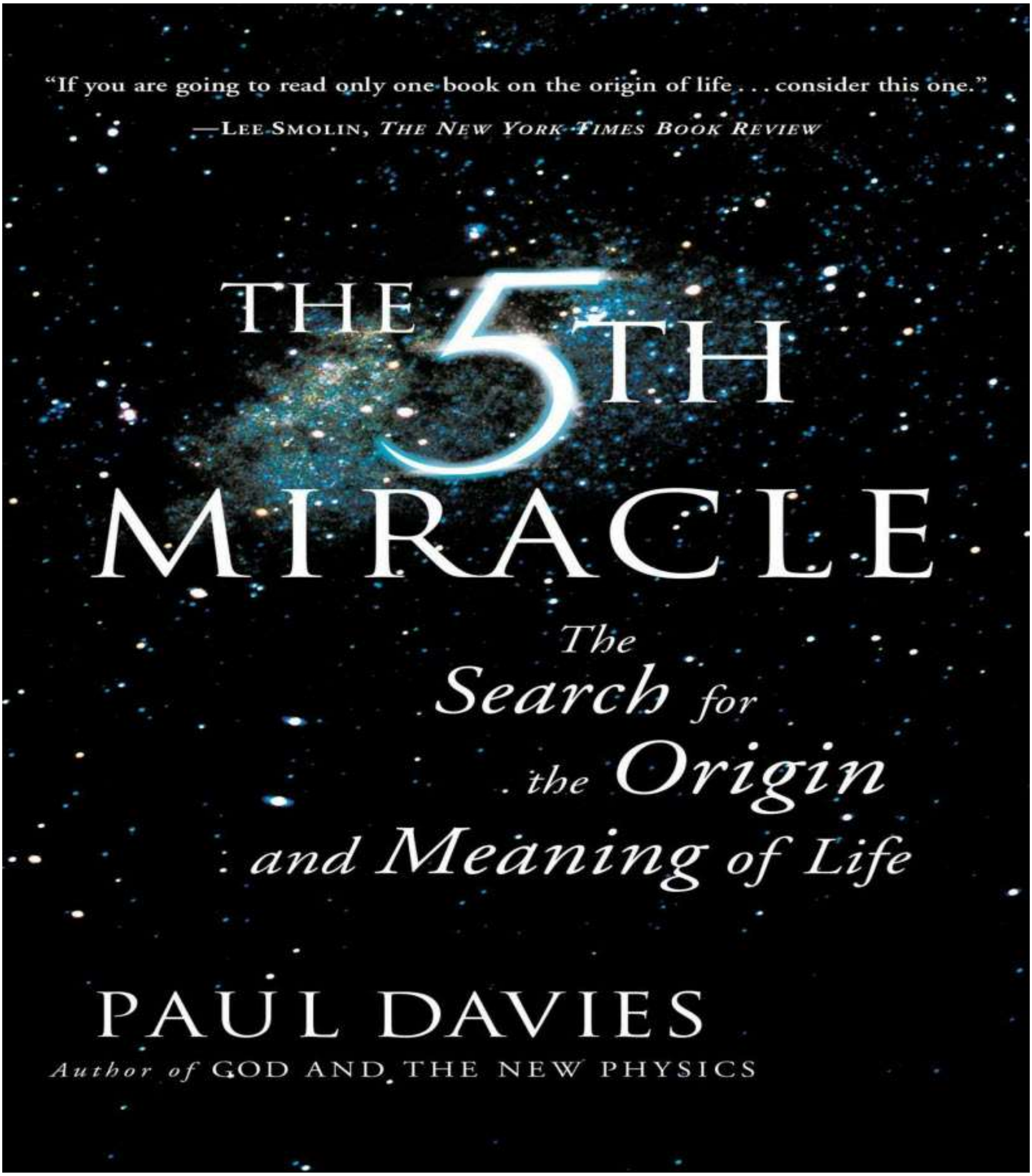
بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

The Fifth Miracle

The Search for the Origin and Meaning of Life

By: Paul Davies



- In August 1996, the world was electrified by news that an ancient meteorite may contain evidence for life on Mars. President Clinton himself conveyed the story to the public and a startled scientific community. The momentous implications of the discovery, if such it was, were expressed in appropriate superlatives. This memorable event marked one of the few occasions when a scientific result had a direct impact on the public. Yet the plaudits and the banter glossed over the true significance of the findings. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص. 17]
- The problem of how and where life began is one of the great outstanding mysteries of science. But it is more than that. The story of life's origin has ramifications for philosophy and even religion. Answers to such profound questions as whether we are the only sentient beings in the universe, whether life is the product of random accident or deeply rooted law, and whether there may be some sort of ultimate meaning to our existence, hinge on what science can reveal about the formation of life. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص. 41]
- The origin of life appears . . . to be almost a miracle, so many are the conditions which would have had to be satisfied to get it going.[Francis Crick, Life Itself: Its Nature and Origin (New York: Simon & Schuster, 1981), p. 88] [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.42]
- One of the principal ways in which life distinguishes itself from the rest of nature is its remarkable ability to go "against the tide" (in the above example literally) and create order out of chaos. By contrast, inanimate forces tend to produce disorder. There is in fact a very basic law of nature at work here, called the second law of thermodynamics. To understand how life began, we first need to know how it copes with the vagaries of this law. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.72]
- In essence, the second law of thermodynamics forbids the creation of a perfect machine, or perpetuum mobile. It acknowledges that all large-scale physical

processes are less than 100 percent efficient: there is inevitable waste, or degeneration. Steam engines, for example, do not use all the energy liberated by the coal that is burned; much of the heat from the boiler radiates away uselessly into the environment, and some of the kinetic energy is lost to friction in the moving parts. A good way to characterize this waste is in terms of order and disorder, or useful and useless energy. The motion of the steam locomotive along the track represents ordered or useful energy; the waste heat is disordered or useless energy. Heat is disordered energy because it is the chaotic motion of molecules. It is useless because it is randomly distributed. The second law describes the inevitable and irreversible trend from ordered to disordered forms of energy. Without a supply of fuel, or useful energy—often called "free" energy—the steam locomotive would soon run out of puff. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.73]

- The second law of thermodynamics is not restricted to engineering. It is a fundamental law of nature; there is no escaping it. The British astronomer Sir Arthur Eddington regarded it as occupying the supreme position among the laws of nature. He once wrote, "if your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation."[A. S. Eddington, The Nature of the Physical World (Cambridge: Cambridge University Press, 1928), p. 74.] It is easy to find everyday examples of the second law at work, cases where order surrenders to chaos. The destruction of sand piles and footprints I have already mentioned. Think also of a melting snowman or a breaking egg. All these processes produce disordered states of matter from relatively ordered ones. The changes are irreversible. You won't see the tide create a footprint or the sunshine make a snowman. And even the king's horses and men were unable to put Humpty Dumpty together again. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.73-74]
- Physicists measure the loss of useful energy in terms of a quantity termed entropy, which roughly speaking corresponds to the degree of chaos present

in the system. When a physical process occurs, such as a piston-and-cylinder cycle in a steam engine, it is possible to compute how much entropy is produced as a result. Armed with the concept of entropy, we can state the second law as follows: In a closed system the total entropy cannot go down. Nor will it go on rising without limit. There will be a state of maximum entropy or maximum disorder, which is referred to as thermodynamic equilibrium; once the system has reached that state it is stuck there. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.74]

- To make these principles clear, let me illustrate them with a simple example concerning the direction of heat flow. If a hot body is put in contact with a cold body, heat passes from hot to cold. Eventually the two bodies reach thermodynamic equilibrium—i.e., a uniform temperature. The heat flow then ceases. Why is this a transition from order to disorder? The uneven distribution of heat at the start can be regarded as a relatively more ordered, hence lower-entropy, state than the final one, because in the final state the heat energy is distributed chaotically among the maximum number of molecules. In this example, the second law demands that heat flow from hot to cold, never the other way. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.74]
- When the laws of thermodynamics are applied to living organisms, there seems to be a problem. One of the basic properties of life is its high degree of order, so, when an organism develops or reproduces, the order increases. This is the opposite of the second law's bidding. The growth of an embryo, the formation of a DNA molecule, the appearance of a new species, and the increasing elaboration of the biosphere as a whole are all examples of an increase of order and a decrease of entropy. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.74-75]
- Some eminent scientists have been deeply mystified by this contradiction. The

German physicist Hermann von Helmholtz, himself one of the founders of the science of thermodynamics, was one of the first to suggest that life somehow circumvents the second law.[A. I. Zotin, “The Second Law, Negentropy, Thermodynamics of Linear Processes,” in I. Lamprecht and A. I. Zotin, eds., Thermodynamics of Biological Processes (New York: de Gruyter, 1978), p. 19.] Eddington likewise perceived a clash between Darwinian evolution and thermodynamics, and suggested either that the former be abandoned or that an “anti-evolution principle” be set alongside it.[A. S. Eddington, “The End of the World: From the Standpoint of Mathematical Physics,” Nature 127(1931):447.] Even Schrödinger had his doubts. In his book What Is Life? he examined the relationship between order and disorder in conventional thermodynamics and contrasted it with life’s hereditary principle of more order from order. Observing that an organism avoids decay and maintains order by “drinking orderliness” from its environment, he surmised that the second law of thermodynamics may not apply to living matter. “We must be prepared to find a new type of physical law prevailing on it,” he wrote.[Erwin Schrödinger, What Is Life? (Cambridge: Cambridge University Press, 1944), p. 81.] [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
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- The second law can also be applied to biological evolution. The appearance of a new species marks an increase in order, but Darwin’s theory identifies the price that is paid to achieve this. To evolve a new species requires many mutations, the vast majority of which are harmful and get eliminated by the sieve of natural selection. For every successful surviving mutant, there are thousands of unsuccessful dead ones. The carnage of natural selection amounts to a huge increase in entropy, which more than compensates for the gain represented by the successful mutant. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.77]
- As such a weak force, it is hard to see how gravitation could play a direct role in biochemical processes. However, suggestions have been made along those lines. Roger Penrose, an Oxford mathematician and a world expert on

gravitation theory, has speculated that gravity may affect biomolecules through quantum processes. [Roger Penrose, The Emperors New Mind (Oxford: Oxford University Press, 1989), and Shadows of the Mind (Oxford: Oxford University Press, 1994).] Mathematical physicist Lee Smolin has also compared the subjects of life and gravitation in his recent book The Life of the Cosmos. He develops an analogy between the behavior of ecosystems and spiral galaxies. Drawing inspiration from computer models of self-organization, Smolin finds close parallels in the processes of feedback and pattern formation in star clusters and biology. He believes that life is part of a "nested hierarchy of self-organized systems that begins with our local ecologies and extends upwards at least to the galaxy." [Lee Smolin, The Life of the Cosmos (Oxford: Oxford University Press, 1997), p. 159.] [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.92]

- Thus, both quantum mechanics and relativity suggest that information is a global rather than a local physical quantity. You cannot simply inspect a location in space and detect information. What you see—a particle, for example—becomes information only in an appropriate global context. Yet whether or not the particle does represent information is not a trivial or purely semantic matter. It may have dramatic physical consequences, as the bomb example graphically demonstrates. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.94]
- How does all this relate to the origin of life? It suggests that we will not be able to trace the origin of biological information to the operation of local physical forces and laws. In particular, the oftrepeated claim that life is written into the laws of physics cannot be true if those laws are restricted to the normal sort, which describe localized action and proximate forces. We must seek the origin of biological information in some sort of global context. That may turn out to be simply the environment in which biogenesis occurs. On the other hand, it may involve some nonlocal type of physical law, as yet unrecognized by science, that explicitly entangles the dynamics of information with the dynamics of matter. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999,

p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.95]

- A thousand years of history is about forty generations. Each of us had two parents, four grandparents, and eight great-grandparents. For every generation one goes back, the number of ancestors doubles. Using this rule, it seems that forty generations ago I would have had 2^{40} or about a trillion ancestors. That is much more than all the people on Earth who have ever lived, so something must be wrong with the arithmetic. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.99]
- The mistake is to assume that human ancestry spreads out forever into the past, as family trees suggest. In reality, at some point as you trace a family tree back in time, the lines start to cross and recross. Genes, and royal blood, diffuse across the planet, making us all distant cousins. I too have royal blood in my veins; it's just that, unlike Lord Mountbatten, I don't have the necessary documentation to prove it. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.100]
- Searching the fossil record might be described as a top-down approach to the investigation of biogenesis. Starting with what is known about life today, we try to follow its evolutionary path back in time, and down in size, to the simplest organisms and the earliest traces, until the record peters out in obscurity. Some time prior to 3.5 billion, and quite possibly earlier than 3.8 billion years ago, the very first terrestrial organism dwelt somewhere on our planet. But where? And what was it like? I shall address these questions when I return to the top-down route in chapter 6, but now I should like to turn to the alternative, bottom-up, approach. The idea here is to ask what we know about the conditions on the young Earth, and then try to reconstruct the physical and chemical events that sparked the beginning of life all those years ago. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.100]
- As it happens, belief in the spontaneous generation of life has a long history,

dating back at least to Plato. In the seventeenth century, it was widely believed that many sorts of living creatures could be generated de novo under appropriate conditions. Adult mice, for example, were said to appear from a heap of sweaty underwear and wheat.[Gerald Feinberg and Robert Shapiro, Life Beyond Earth (New York: William Morrow, 1980), p. 113.]Other favorite recipes were old socks and rotting meat from which lice, flies, and maggots might duly emerge. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.117]

- Today these stories seem ridiculous, but it took a scientist of the caliber of Louis Pasteur to settle the matter. In 1862, under the incentive of a public prize, Pasteur performed a series of careful experiments to demonstrate that living organisms come only from other living organisms. A truly sterile medium would, he claimed, remain forever sterile. Pasteur declared triumphally: "Never will the doctrine of spontaneous generation recover from the mortal blow of this simple experiment!" [Charles Thaxton, Walter Bradley, and Roger Olsen, The Mystery of Life's Origin (New York: Philosophical Library of New York, 1984), p. 12.] . [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.118]
- Important though this demonstration was, Pasteur's conclusion came into direct conflict with Darwin's theory of evolution. Darwin's celebrated tome On the Origin of Species, which had been published just three years before Pasteur's experiments, sought to discredit the need for God to create the species by showing how one species can transmute into another. But Darwin's account left open the problem of how the first living thing came to exist. Unless life had always existed, at least one species—the first—cannot have come to exist by transmutation from another species, only by transmutation from nonliving matter. Darwin himself wrote, some years later: "I have met with no evidence that seems in the least trustworthy, in favour of so-called Spontaneous Generation."[Bendall, ed., Evolution from Molecules to Men, p. 128.]Yet, in the absence of a miracle, life could have originated only by some sort of spontaneous generation. Darwin's theory of evolution and Pasteur's theory that only life begets life cannot both have been

completely right. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.118]

- At that time, the very notion that life might spring into being spontaneously from a nonliving chemical mixture was greeted with fierce criticism from theologians, and even from some scientists. The eminent British physicist Lord Kelvin dismissed the whole idea as "a very ancient speculation," opining that "science brings a vast mass of inductive evidence against this hypothesis." He stated unequivocally, "Dead matter cannot become living without coming under the influence of matter previously alive."[11. Quoted in Svante Arrhenius, Worlds in the Making (London: Harper, 1908), p. 216.] This left only two alternatives: either life has always existed or its origin was a miracle. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.119]
- Theorizing about the origin of life seemed altogether too speculative in the 1920s, and few people paid much attention to the ideas of Oparin and Haldane. One person who did take notice, however, was Harold Urey, an American chemist who would one day win the Nobel Prize for the discovery of deuterium. Urey realized that it might be possible to test the theory of the primordial soup in the laboratory. Many years later, in 1953, he set out to do just that. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.122]
- Two major obstacles stand in the way of further progress towards life in a primordial soup. One is that in most scenarios the soup is far too dilute to achieve much. Haldane's vast ocean broth would be exceedingly unlikely to bring the right components together in the same place at the same time. Without some mechanism to concentrate the chemicals greatly, the synthesis of more complex substances than amino acids looks doomed. Many imaginative suggestions have been made on how to thicken the brew. For example, Darwin's warm little pond may have evaporated to leave a potent scum. Or perhaps mineral surfaces like clay trapped and concentrated passing chemicals from a fluid medium. However, it is far from clear whether any of

these suggestions is realistic in the context of the early Earth, and no souplike state has been preserved in the rocks to guide us. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.124-125]

- The other obstacle is even deeper and goes back to the second law of thermodynamics. Recall how this law describes a natural tendency towards degradation and corruption, and away from increasing order and complexity. The synthesis of complex biomolecules therefore runs "against the tide," thermodynamically speaking. At first sight this seems to lead to a contradiction, because amino acids form readily under a wide range of conditions. In fact, there is no conflict with the second law. As I explained in chapter 2, order can appear in one place as long as a greater quantity of disorder, or entropy, is delivered to the environment. This is what happens when a crystal forms from a solute. The crystalline solid is a more ordered arrangement of atoms than a liquid, so it has less entropy. However, the formation of a crystal is accompanied by a release of heat into the environment, which raises the entropy. The second factor outweighs the first. The same applies to amino-acid synthesis, which, like crystal formation, is thermodynamically favored. The reason for this concerns the role of free energy. If a process lowers the energy of a system,—i.e., if it goes "downhill"—then it has the second law's blessing. By contrast, an "uphill" process defies the second law. Water runs downhill, not uphill. You can make water go uphill, but only if you work for it. A process that happens spontaneously is always a downhill process. Amino-acid production has this character of being a downhill process, which is why amino acids are so easy to make. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.125]
- To be sure, there would have been no lack of available energy sources on the early Earth to provide the work needed to forge the peptide bonds, but just throwing energy at the problem is no solution. The same energy sources that generate organic molecules also serve to destroy them. To work constructively, the energy has to be targeted at the specific reaction required.

Uncontrolled energy input, such as simple heating, is far more likely to prove destructive than constructive. The situation can be compared to a workman laboriously building a brick pillar by piling bricks one on top of another. The higher the pillar goes, the more likely it is to wobble and collapse. Likewise, long chains made of amino acids linked together are very fragile. As a general rule, if you simply heat organics willy-nilly, you end up, not with delicate long chain molecules, but with a tarry mess, as barbecue owners can testify. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.127-128]

- It is true that the second law of thermodynamics is only a statistical law; it does not absolutely forbid physical systems from going "the wrong way" (i.e., uphill). But the odds are heavily weighted against it. So, for example, it is possible, but very unlikely, to create a brick pillar by simply tipping a pile of bricks out from a hopper. You might not be surprised to see two bricks ending up neatly on top of one another; three bricks would be remarkable, ten almost miraculous. You would undoubtedly wait a very long time for a ten-brick column to happen spontaneously. In ordinary chemical reactions that take place close to thermodynamic equilibrium, the molecules are jiggled about at random, so again you will likely wait a very long time for a fragile molecular chain to form by accident. The longer the chain, the longer the wait. It has been estimated that, left to its own devices, a concentrated solution of amino acids would need a volume of fluid the size of the observable universe to go against the thermodynamic tide and create a single small polypeptide spontaneously. Clearly, random molecular shuffling is of little use when the arrow of directionality points the wrong way.[Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.128]
- One possible escape route from the strictures of the second law is to depart from thermodynamic-equilibrium conditions. The American biochemist Sidney Fox has investigated what happens when a mixture of amino acids is strongly heated. Driving out the water as steam makes the linkage of amino acids into peptide chains much more likely. The thermal-energy flow

generates the necessary entropy to comply with the second law. Fox has produced some quite long polypeptides, which he terms “proteinoids,” using this method. Unfortunately, the resemblance between Fox’s proteinoids and real proteins is rather superficial. For example, real proteins are made exclusively of left-handed amino acids (see here), whereas proteinoids are an equal mixture of left and right. .[Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.128]

- There is a more fundamental reason why the random self-assembly of proteins seems a nonstarter. This has to do not with the formation of the chemical bonds as such, but with the particular order in which the amino acids link together. Proteins do not consist of any old peptide chains; they are very specific amino-acid sequences that have specialized chemical properties needed for life. However, the number of alternative permutations available to a mixture of amino acids is superastronomical. A small protein may typically contain a hundred amino acids of twenty varieties. There are about 10^{130} (which is one followed by 130 zeros) different arrangements of the amino acids in a molecule of this length. Hitting the right one by accident would be no mean feat.[Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.128-129]
- Let me spell out what is involved here. I have already emphasized that the complex molecules found in living organisms are not themselves alive. A molecule is a molecule is a molecule; it is neither living nor dead. Life is a phenomenon associated with a whole society of specialized molecules, millions of them, cooperating in surprising and novel ways. No single molecule carries the spark of life, no chain of atoms alone constitutes an organism. Even DNA, the biological supermolecule, is not alive. Pluck the DNA from a living cell and it would be stranded, unable to carry out its familiar role. Only within the context of a highly specific molecular milieu will a given molecule play its role in life. To function properly, DNA must be part of a large team, with each molecule executing its assigned task alongside the others in a cooperative manner. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion

productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.130]

- You might get the impression from what I have written not only that the origin of life is virtually impossible, but that life itself is impossible. If fragile biomolecules are continually being attacked and disintegrated, surely our own bodies would rapidly degenerate into chemical mayhem spelling certain death? Fortunately for us, our cells contain sophisticated chemical-repair-and-construction mechanisms, handy sources of chemical energy to drive processes uphill, and enzymes with special properties that can smoothly assemble complex molecules from fragments. Also, proteins fold into protective balls that prevent water from attacking their delicate chemical bonds. As fast as the second law tries to drag us downhill, this cooperating army of specialized molecules tugs the other way. As long as we remain open systems, exchanging energy and entropy with our environment, the degenerative consequences of the second law can be avoided. But the primordial soup lacked these convenient cohorts of cooperating chemicals. No molecular-repair gangs stood ready to take on the second law. The soup had to win the battle alone, against odds that were not just heavy but mind-numbingly huge. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.131-132]
- In the previous section I presented the fantastic odds against shuffling amino acids at random into the right sequence to form a protein molecule by accident. That was a single protein. Life as we know it requires hundreds of thousands of specialist proteins, not to mention the nucleic acids. The odds against producing just the proteins by pure chance are something like 10^{40000} to 1. This is one followed by forty thousand zeros, which would take up an entire chapter of this book if I wanted to write it out in full. Dealing a perfect suit at cards a thousand times in a row is easy by comparison. In a famous remark, the British astronomer Fred Hoyle likened the odds against the spontaneous assembly of life to those for a whirlwind sweeping through a junkyard and producing a fully functioning Boeing 747. [Fred Hoyle, The Intelligent Universe (London: Michael Joseph, 1983), p. 19.] [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion

productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.134]

- I often give public lectures on the possibility of extraterrestrial life. Invariably, someone in the audience will remark that there must be life on other planets because there are so many stars offering potential abodes. It is a commonly used argument. On a recent trip to Europe to attend a conference on extraterrestrial life, I flipped through the airline's in-flight entertainment guide, only to find that the search for life beyond Earth was on offer as part of their program. The promotional description said "With a half-trillion stars wheeling through the spiral patterns of the Milky Way Galaxy, it seems illogical to assume that among them only one world supports intelligent life."[Omnia (British Airways in-flight magazine), September-October 1997, p. 26.] The use of the word "illogical" was unfortunate, because the logic is perfectly clear. There are indeed a lot of stars—at least ten billion billion in the observable universe. But this number, gigantic as it may appear to us, is nevertheless trivially small compared with the gigantic odds against the random assembly of even a single protein molecule. Though the universe is big, if life formed solely by random agitation in a molecular junkyard, there is scant chance it has happened twice. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.134-135]
- As a simple-minded physicist, when I think about life at the molecular level, the question I keep asking is: how do all these mindless atoms know what to do? The complexity of the living cell is immense, resembling a city in the degree of its elaborate activity. Each molecule has a specified function and a designated place in the overall scheme so that the correct objects are manufactured. There is much commuting going on. Molecules have to travel across the cell to meet others at the right place and the right time in order to carry out their jobs properly. This all happens without a boss to order the molecules around and steer them to their appropriate locations. No overseer supervises their activities. Molecules simply do what molecules have to do: bang around blindly, knock into each other, rebound, embrace. At the level of individual atoms, life is anarchy—blundering, purposeless chaos. Yet somehow, collectively, these unthinking atoms get it together and perform

the dance of life with exquisite precision. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.143]

- Can science ever explain such a magnificently self-orchestrating process? Some people flatly deny it.1 They believe that the living cell is just too elaborate, too contrived, to be the product of blind physical forces alone. Science may give a good account of this or that individual feature, they say, but it will never explain the overall organization, or how the original cell was assembled in the first place. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص. 143]
- Proteins are a godsend to DNA, because they can be used both as building material, to make things like cell walls, and as enzymes, to supervise and accelerate chemical reactions. Enzymes are chemical catalysts that "grease the wheels" of the biological machine. Without them metabolism would grind to a halt, and there would be no energy available for the business of life. Not surprisingly, therefore, a large part of the DNA databank is used for storing instructions on how to make proteins. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص. 151]
- When the protein synthesis is complete, the ribosome receives a "stop" signal from the mRNA "tape" and the chain cuts loose. The protein is now assembled, but it doesn't remain strung out like a snake. Instead it rolls up into a knobbly ball, rather like a piece of elastic that's stretched and allowed to snap back. This folding process may take some seconds, and it is still something of a mystery how the protein attains the appropriate final shape. If it is to work properly, the three-dimensional form of the protein has to be correct, with the bumps and cavities in all the right places, and the right atoms facing outwards. Ultimately, it is the particular amino-acid sequence along the chain that determines the final three-dimensional conformation, and therefore the physical and chemical properties, of the protein. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion

productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص. 153-154]

- This whole remarkable sequence of events is repeated in thousands of ribosomes scattered throughout the cell, producing tens of thousands of different proteins. It is worth repeating that, in spite of the appearance of purpose, the participating molecules are completely mindless. Collectively they may display systematic cooperation, as if to a plan, but individually they just career about. The molecular traffic within the cell is essentially chaotic, driven by chemical attraction and repulsion and continually agitated by thermal energy. Yet out of this blind chaos order emerges spontaneously. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص. 154]
- The genetic code, with a few recently discovered minor variations, is common to all known forms of life. That the code is universal is extremely significant, for it suggests it was used by the common ancestor of all life, and is robust enough to have survived through billions of years of evolution. Without it, the production of proteins would be a hopelessly hit-or-miss affair. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص. 157]
- Questions abound. How did such a complicated and specific system as the genetic code arise in the first place? Why, out of the 10^{70} possible codes based on triplets, has nature chosen the one in universal use? Could a different code work as well? If there is life on Mars, will it have the same genetic code as Earthlife? Can we imagine uncoded life, in which interdependent molecules deal directly with each other on the basis of their chemical affinities alone? Or is the origin of the genetic code itself (or at least a genetic code) the key to the origin of life? The British biologist John Maynard Smith has described the origin of the code as the most perplexing problem in evolutionary biology. With collaborator Eörs Szathmáry he writes: “The existing translational machinery is at the same time so complex, so universal, and so essential that it is hard to see how it could have come

into existence, or how life could have existed without it.”[John Maynard Smith and Eörs Szathmáry, The Major Transitions in Evolution (Oxford and New York: Freeman, 1995), p. 81.] [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص. 157]

- An even tougher problem concerns the coding assignments—i.e., which triplets code for which amino acids. How did these designations come about? Because nucleic-acid bases and amino acids don’t recognize each other directly, but have to deal via chemical intermediaries, there is no obvious reason why particular triplets should go with particular amino acids. Other translations are conceivable. Coded instructions are a good idea, but the actual code seems to be pretty arbitrary. Perhaps it is simply a frozen accident, a random choice that just locked itself in, with no deeper significance. On the other hand, there may be some subtle reason why this particular code works best. If one code had the edge over another, reliability-wise, then evolution would favor it, and, by a process of successive refinement, an optimal code would be reached. It seems reasonable. But this theory is not without problems either. Darwinian evolution works in incremental steps, accumulating small advantages over many generations. In the case of the code, this won’t do. Changing even a single assignment would normally prove lethal, because it alters not merely one but a whole set of proteins. Among these are the proteins that activate and facilitate the translation process itself. So a change in the code risks feeding back into the very translation machinery that implements it, leading to a catastrophic feedback of errors that would wreck the whole process. To have accurate translation, the cell must first translate accurately. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.158-159]
- Viewed this way, the problem of the origin of life reduces to one of understanding how encoded software emerged spontaneously from hardware. How did it happen? How did nature “go digital”? We are dealing here not with a simple matter of refinement and adaptation, an amplification of complexity, or even the husbanding of information, but a fundamental

change of concept. It is like trying to explain how a kite can evolve into a radio-controlled aircraft. Can the laws of nature as we presently comprehend them account for such a transition? I do not believe they can. To see why not, it is necessary to dig a bit deeper into the informational character of life. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.165]

- Now, you might be thinking that, if biological organization is random, its genesis should be easy. It is, after all, a simple matter to create random patterns. Just take a jar of coffee beans and tip them on the floor. Surely nature is full of haphazard and chaotic processes that might create a random macromolecule like a genome? This is a good question, and it marks the point where we encounter the truly subtle and mysterious nature of life in the starkest manner. Fact one: the vast majority of possible sequences in a nucleic-acid molecule are random sequences. Fact two: not all random sequences are potential genomes. Far from it. In fact, only a tiny, tiny fraction of all possible random sequences would be even remotely biologically functional. A functioning genome is a random sequence, but it is not just any random sequence. It belongs to a very, very special subset of random sequences—namely, those that encode biologically relevant information. All random sequences of the same length encode about the same amount of information, but the quality of that information is crucial: in the vast majority of cases it would be, biologically speaking, complete gobbledygook. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.170]
- The conclusion we have reached is clear and it is profound. A functional genome is both random and highly specific—properties that seem almost contradictory. It must be random to contain substantial amounts of information, and it must be specific for that information to be biologically relevant. The puzzle we are then faced with is how such a structure came into existence. We know that chance can produce randomness, and we know that law can produce a specific, predictable end-product. But how can both properties be combined into one process? How can a blend of chance and law cooperate to yield a specific random structure? [Paul Davies, ***The Fifth***

Miracle: The Search for the Origin and Meaning of Life, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.170-171]

- To get some idea of what we are up against with this dilemma, it is rather like tipping out the coffee beans from a jar to make a particular random pattern. Not just any old random pattern, but a definite, narrowly specific, predetermined random pattern. The task seems formidable. Could a law on its own, without a huge element of luck (i.e., chance), do such a thing? Can specific randomness be the guaranteed product of a deterministic, mechanical, lawlike process, like a primordial soup left to the mercy of familiar laws of physics and chemistry? No, it couldn't. No known law of nature could achieve this[Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.171]
- It appears as if the information processing needed to generate a genome might also be computationally intractable. Sorting out a particular random sequence from all possible sequences looks like a problem every bit as daunting as that of a traveling salesman faced with visiting a million cities. Which casts the central paradox of biogenesis in the following terms. Given that it requires a long and arduous computation (i.e., a sequence of information-processing steps) to evolve a genome from microbe to man, could the (already considerable) genome of a microbe come into being without a comparably long and arduous process? How, in the phase before Darwinian evolution kicked in, could a very particular sort of information have been scavenged from the nonliving environment and deposited in something like a genome? [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.172-173]

CHAPTER 5: The Chicken-and-Egg Paradox

- All known life revolves around the cozy accommodation between DNA and proteins: the software and the hardware. Each needs the other. So which came first? We have already encountered this sort of chicken-and-egg paradox in chapter 2, concerning the so-called error catastrophe that limits the number of copying mistakes in genetic replication, but the problem is much more general. There seems to be an enigmatic circularity to life, a type of irreducible complexity that some people regard as utterly mysterious. [See, for example, Michael Behe, Darwin's Black Box (New York: Free Press, 1996).] [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.178.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.]

- In recent years, attempts have been made to build small and simple replicator molecules in the lab, and to subject them to environmental stresses to see if they evolve into better replicators. [Julius Rebek, "Synthetic Self-Replicating Molecules," Scientific American 271, no. 1 (1994):34.] Modest success has been claimed. However, these experiments do not demonstrate molecular evolution in nature. They have yet to show that the sort of small replicators that have been painstakingly designed and fabricated in the laboratory will form spontaneously under plausible prebiotic conditions, and if they do, whether they will replicate well enough to evade the error catastrophe. In short, nobody has a clue whether naturally occurring mini-replicators are even possible, let alone whether they have got what it takes to evolve successfully. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.190.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.]
- Where might all this have taken place? Oparin envisaged his coacervate cells in some pond or sea, but if life started on or beneath the seabed, as recent evidence suggests, then oily blobs may not be the answer. The porous basalt rock of the sea floor provides a natural network of tiny tunnels and cavities which could trap large organic molecules. The mineral surfaces might also act as convenient catalysts and serve to concentrate the organic material. Unfortunately, rock cavities can't multiply by fission. Euan Nisbet of the University of London has suggested that perhaps membranes might form within cavities, like creatures trapped in tiny caves, to be liberated in due course by some geological upheaval.[E. G. Nisbet, The Young Earth (London: Allen & Unwin, 1987), chap. 8.] [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]

[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.193]

- Another imaginative idea for a primitive cell has been proposed by Mike Russell of the University of Glasgow. [Michael Russell, Roy Daniel, Allan Hall, and John Sherringham, "A Hydrothermally Precipitated Catalytic Iron Sulphide Membrane as a First Step Toward Life," Journal of Molecular Evolution 39(1994):231. For a popular account, see Michael Russell, "Life from the Depths," Science Spectra 1(1996):26.] His theory focuses on regions of the seabed somewhat removed from volcanic vents, where water seeps gradually into the rock to a depth of several kilometers. Convection eventually returns it to the surface, rich with dissolved minerals. The emerging water is alkaline, and very hot—perhaps reaching two hundred degrees Celsius under high-pressure conditions. By contrast, the overlying ocean would have been acidic, on account of dissolved carbon dioxide, and much cooler. Russell has found that the conjunction of the two fluids triggers the formation of a colloidal membrane made of iron sulfide. As we shall see, iron and sulfur are two chemicals strongly implicated in early life. Moreover, the membrane is semipermeable: it lets through some chemicals but not others, just like a living cell. Russell has managed to grow large cell-like bubbles in the laboratory, and has found evidence for similar structures fossilized in Irish rocks. He believes that osmotic and hydraulic pressure would inflate the bubbles and make them divide. A bonus of his theory is that the juxtaposition of acid-membrane-fluid acts like an electrical battery, which could have provided the initial power source to drive early metabolism. In modern cells there is also a small voltage across the membrane. So maybe electricity was, after all, the original life force! [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.193-194]
- A completely different theory for the origin of life has been given by the British biochemist Graham Cairns-Smith, also from the University of Glasgow, who shares the belief that nucleic acids came late in the piece. [A popular account of his theory is given in A. G. Cairns-Smith, Seven Clues to the Origin of Life (Cambridge: Cambridge University Press, 1985).] In fact, as far as the chicken-and-egg (or nucleic-acids-and-proteins) argument goes,

he thinks that life started with neither. Cairns-Smith begins by reminding us that nucleic acids function primarily as software—the repositories of genetic information. That being so, their specific chemical form is irrelevant. Just as we can store the same digital information on magnetic tape or floppy disk, so genetic information could be contained in physical structures other than RNA or DNA. Perhaps life started with information encoded in some other manner, and only at a relatively late stage was the genetic function entrusted to nucleic acids. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.194]

- So what can be concluded from these various speculations about life's origin? They all share one assumption. Once life of some sort had established itself, the rest was plain sailing, because Darwinian evolution could then take over. It is therefore natural that scientists should seek to invoke Darwinism at the earliest moment in the history of life. As soon as it kicks in, dramatic advances can occur with nothing fancier than chance and selection as a driving force. Unfortunately, before Darwinian evolution can start, a certain minimum level of complexity is required. But how was this initial complexity achieved? When pressed, most scientists wring their hands and mutter the incantation "Chance." So, did chance alone create the first self-replicating molecule? Or was there more to it than that? [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.196-197]

Self organization: something for nothing?

- Life is but one example of complexity found in nature. Many other examples occur in the world about us. We see complexity in the spangled pattern of frost on a window, in the intricate wiggles of a coastline, in the filigrees and whorls that adorn the surface of Jupiter, and among the jostling eddies of a turbulent river. Life is not haphazard complexity, it is organized. Disorganized complexity is found all over the place, from the spatter of raindrops on the ground to the tea leaves at the bottom of the cup. But organized complexity, though scarcer, is by no means restricted to biology. A spiral galaxy, a rainbow, and a diffraction pattern from a laser beam are

both complex and organized. Yet they form without any genes to specify them or any Darwinian evolution to create them. If nonliving systems can generate organized complexity spontaneously, just by following the laws of physics, why can't life do it that way, at least in the beginning? [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.198]

- Some people think it can. The Belgian chemist Ilya Prigogine has given examples of chemical mixtures that behave in a lifelike manner, forming elaborate spirals or undergoing rhythmic pulsations. [Ilya Prigogine and Isabelle Stengers, Order Out of Chaos (London: Heinemann, 1984), chap. 5.] The hallmark of these reactions is that they take place far from thermodynamic equilibrium, and require a continual throughput of matter and energy—as does life. The spontaneous ordering doesn't clash with the second law of thermodynamics because the systems are open; entropy is exported into the environment to pay for the increase in order. Characteristic of such self-organizing systems is their tendency to reach critical "bifurcation" or indecision points, where their behavior is unpredictable. They may leap abruptly to a new state of greater complexity and stabilize, or descend into chaos. Prigogine and his many devotees envisage a sequence of self-organizing transitions, where matter driven by an energy flow jumps to higher and higher levels of organized complexity, until it is truly living. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.198]
- Attractive though self-organization may seem, it faces two major obstacles when it comes to the origin of life. The first is the paucity of convincing experiments. So far, most of the "experiments" have been computer simulations rather than the real thing. This has earned the subject of complexity theory something of a bad name in biology. In a now famous put-down of Kauffman's ideas, John Maynard Smith once described them, somewhat harshly, as "fact-free science."[John Maynard Smith, "Life at the Edge of Chaos?," New York Review of Books, March 2, 1995, p. 28.] [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]

[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.200-201]

- There is, however, a deeper problem of a conceptual nature. Life is actually not an example of self-organization. Life is in fact specified—i.e., genetically directed—organization. Living things are instructed by the genetic software encoded in their DNA (or RNA). Convection cells form spontaneously by self-organization; there is no gene for a convection cell. The source of order here is not encoded in software; it can instead be traced to the boundary conditions on the fluid. The flux of heat and entropy across the boundaries triggers the self-organization, and the shape, size, and nature of the boundaries determine the patterning details of the cells. In other words, a convection cell's order is imposed externally, from the system's environment. By contrast, the order of a living cell derives from internal control, from its genes, which are located on a microscopic molecule buried deep within the system that chemically broadcasts its instructions outwards. To be sure, the environment enveloping a living cell's membrane will influence to some extent what goes on within the cell, but the principal characteristics of an organism are determined by its genes. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
  [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.201]
- The theory of self-organization as yet gives no clue how the transition is to be made between spontaneous, or self-induced, organization—which in even the most elaborate nonbiological examples still involves relatively simple structures—and the highly complex, information-based, genetic organization of living things. An explanation of this genetic takeover must account for more than merely the origin of nucleic acids and their potent entanglement with proteins at some later stage. It is not enough to know how these giant molecules arose or started to interact. We also need to know how the system's software came into existence. Indeed, we need to know how the very concept of software control was discovered by nature. To revisit the analogies I gave in chapter 4, we seek an explanation for how a kite can turn into a radio-controlled plane, or a steam-engine governor can evolve into a digital data-processing electronic regulator. This is not merely a matter of adding an extra layer of complexity; it is about a fundamental transformation in the very

nature of the system. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.201-202]

- Related to the latter criticism is the need to draw a careful distinction between order and organization. In the foregoing I have used the terms interchangeably, but they often have opposite meanings. Properly speaking, order refers to simple patterns. A periodic sequence of ones and zeros—like figure 4.4 on here, for example—is ordered. Likewise, a crystal is ordered. Both are highly nonrandom and so, as I explained in the last chapter, they cannot possess the complex organization and information storage of a genome. Attempts to seek a route to life via self-organization often fall into the trap of mistaking organization with order. Cited examples of self-organization are often nothing of the sort; rather, they involve spontaneous ordering instead. For instance, chemical reactions that display rhythmic cycles are often given in accounts of self-organization,17 but periodic behavior is clearly a case of nonrandom order. Similarly, the hexagonal convection cells I described above are more reminiscent of crystalline order than of the organized complexity of biological organisms. In the absence of some new principle of self-organization that induces the production of algorithmic complexity, a crucial part of the biogenesis story has been left out. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.202-203]
- So much for the bottom-up approach to the origin of life. It has yielded some useful pointers, but it leaves many bewildering riddles. However, it is not the only approach available. We can also pursue a top-down route. The idea here is to start with extant life and follow it back in time, hoping to guess where and how the earliest organisms lived. We can then employ this knowledge to tell us something about how these organisms may have come to exist. It turns out that, to track down the first living things on Earth, we must first take a look into space. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.203]

CHAPTER 6: The Cosmic Connection

- Astronomers have confirmed from spectroscopic observations that atoms are indeed the same throughout the cosmos. A carbon atom in the Andromeda Galaxy, for example, is identical to one here on Earth. Five chemical elements play a starring role in terrestrial biology: carbon, oxygen, hydrogen, nitrogen, and phosphorus. These elements seem to be among the most plentiful in the universe. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.209]
- Carbon is the truly vital element. It qualifies for pride of place because of a unique chemical property: carbon atoms can link together to form extended chain molecules, or polymers, of limitless variety and complexity. Proteins and DNA are two examples of these long chain molecules. If it wasn't for carbon, life as we know it would be impossible. Probably any sort of life would be impossible. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.210]
- Even today a comet or asteroid could hit Earth with enough force to destroy most life. It now seems likely that massive collisions have caused several major annihilation events over geological time. The most famous mass extinction occurred sixty-five million years ago (relatively recently in geological terms), when the dinosaurs suddenly died out, along with a large number of other species. Evidence that a huge cosmic impact was responsible comes from the discovery of a worldwide layer of the rare element iridium, deposited in clay strata laid down at that time. This iridium was almost certainly delivered by the impactor. Dramatic confirmation of the theory came in 1990, with the discovery of a gigantic crater of the right age buried under limestone in Mexico. It measures at least 180 kilometers across, and was probably made by an object about 20 kilometers in diameter. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.226-227]
- Cosmic impacts are examples of what biologists refer to as contingent events.

They take no account of terrestrial biology. They just happen, out of the blue, without any causal connection to the evolution of life on Earth. They are both creative and destructive, good and bad. The origin of life on Earth—and perhaps other planets too—may well have depended on their volatile-rich material; the death of the dinosaurs served to clear the way for the ascent of mammals and, eventually, mankind. It seems we owe our very existence to a chance astronomical catastrophe. Whether mankind will someday go the way of the dinosaurs remains to be seen. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.227]

- A few years ago, Kevin Maher and David Stevenson of Caltech sought to redefine what is meant by the origin of life in the light of the bombardment scenario. [Kevin Maher and David Stephenson, "Impact Frustration of the Origin of Life," Nature 331(1988):612.] Life could be said to have started, they reasoned, when the time it took for self-replicating organisms to emerge was less than the time between sterilizing impacts. If it took, say, ten million years to make life from a primordial soup, the bombardment would have needed to leave at least ten-million-year windows in order for life to begin. Maher and Stevenson then asked how far back you could go into the bombardment era and still expect gaps of that duration. They came up with an answer of two hundred million years. So life might have arisen at any time after about four billion years ago, flourishing in the calmer periods, only to be wiped out again by the next sterilizing impact. Like the mythical Sisyphus, condemned to keep rolling the stone up the hill only to fall back again each time, life may have struggled over and over to establish itself, only to get zapped repeatedly from space. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.231]
- It is a curious thought that, if life did form anew several times, then humans would not be descendants of the first living thing. Rather, we would be the products of the first life forms that just managed to survive the last big impact in this extended stop-go series. Which raises an interesting point about the 3.85-billion-year-old rocks at Isua. A sterilizing impact could have occurred after life had transformed them. If so, the organisms that left their subtle traces in that ancient terrain may not be ancestral to our form of life at all.

They may have belonged to an earlier, alternative biology that was totally wiped out by the cosmic bombardment. The rocks of Greenland may thus contain evidence for what is, in a sense, an alien life form. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.231]

- From what we know of the early history of the solar system, the Earth's surface was a hazardous place for a living organism to be for at least several hundred million years after the planet's formation. Even the bottom of the ocean would afford little protection against the violence of the larger impactors. The heat pulses from these cataclysms would have been lethal to a depth of tens or even hundreds of meters into the Earth's crust itself. Hardly a Garden of Eden. Where, then, would one expect the earliest life forms to have taken up residence? What refuge existed that might have spared the first faltering ecosystem wholesale annihilation by vaporized rock? The answer would seem to be: somewhere deep. Somewhere below ground. But what on Earth can live there? [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.232]

CHAPTER 7: Superbugs

- A basic question about these deep-sea organisms is: how do they make a living? Biologists long supposed that all life on Earth depends ultimately on the Sun for energy. Plants won't grow without light, and animals must eat plants (or each other) to survive. However, that far beneath the sea it is pitch-black. [Actually, it may not be completely dark. There can be an eerie glow around the vents caused by some as yet ill-understood process. Some scientists have conjectured that photosynthesis might have started from this faint submarine light, rather than from sunlight. See Ruth Flanagan, "The Light at the Bottom of the Sea," New Scientist, December 13, 1997, p. 42.]No sunlight penetrates. This isn't a problem for the crabs and worms, because they scavenge for food among the smaller creatures on the seabed. But something must lie at the base of the food chain. It turns out that microbes act as primary producers, obtaining their vital energy directly from the hot chemical broth vomiting from the volcanic depths. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion

productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.241-242]

- Organisms that don’t eat organic matter but manufacture their own biomass directly are known as autotrophs (“self-feeders”). Plants are the most familiar autotrophs; they use the energy of sunlight to turn inorganic substances like carbon dioxide and water into organic material. Autotrophs that make biomass using chemical energy rather than light energy have been dubbed chemoautotrophs, or chemotrophs for short. The discovery of true chemotrophs was a pivotal event in the history of biology. Here was the basis of a completely independent life chain, a hierarchy of organisms that could exist alongside familiar surface life, yet without being dependent on sunlight for its primary energy source [Most of the organisms living near black smokers are indirectly dependent on sunlight, either by making use of dissolved oxygen (a byproduct of photosynthesis) or by eating organic scraps that descend from the surface. Thirty years ago the biologist George Wald wrote: “It may form an interesting intellectual exercise to imagine ways in which life might arise, and having arisen might maintain itself, on a dark planet; but I doubt very much that this has ever happened, or that it can happen.” See “Life and Light,” Scientific American 201, no. 4(1959):92. However, Wald was wrong. Chemotrophs that are truly independent of surface life are known.] For the first time it became possible to conceive of ecosystems free of the complexities of photosynthesis. Scientists began to glimpse a vast new biological realm that has lain hidden for billions of years. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.242]
- It is clear from these recent discoveries that Earth possesses a pervasive living underworld, the vast extent of which is only just being revealed. There must be a huge amount of biomass in total down there. If bacteria proliferate to a depth of half a kilometer or more, as the surveys suggest, then, totted up over the whole planet, they would account for a tenth of the Earth’s biomass. Even this could be an underestimate, because some types of microbe live happily at yet greater depths. If 110 degrees Celsius is as hot as they can stand, the microbial realm might go as deep as four kilometers under the ground and

seven kilometers beneath the ocean floor. And if Parkes is to be believed, the top temperature might be as high as 170 degrees Celsius, and the habitable zone would go even deeper. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.248]

- An obvious question to ask is how living organisms got to be in such deep locations in the first place. Did they infiltrate the rocks from above, swept along in the groundwater? Or did they get trapped long ago, when the sediments were first formed? It seems likely that both routes have been followed to some extent. However, these explanations proceed from the assumption that surface life is "normal," and subterranean life is an offbeat adaptation. Can we be sure of this? Could it be that the reasoning is literally upside down, and that the truth is just the opposite? [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.249]
- Still unanswered is how and when the three great domains arose: archaea, bacteria, and eucarya. It seems probable that the great split in the tree of life between archaea and bacteria occurred before the invention of photosynthesis, perhaps as early as 3.9 billion or 4 billion years ago—well inside the era of heavy bombardment. The evidence points to the archaea's being the oldest and most primitive organisms, with bacteria arising somewhat later. So deep was the cleft between the archaea and the bacteria that they have never really been rivals; they still occupy different niches after several billion years of evolution. Finally, the deep rift that produced the eucarya domain probably occurred when conditions were somewhat cooler. For some reason, perhaps by being exposed to the challenges of a less stable environment, the lower-temperature eukaryotes evolved at a much faster rate. The subsequent flowering of life, its diversification into many species, and the huge rise in biological complexity stemmed directly from the branching away of eucarya on the tree of life. Without this momentous step, it is unlikely that we—or any other sentient beings—would exist on Earth today to reflect on the significance of it all. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.267-

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CHAPTER 8: Mars: Red and Dead?

- In 1977, NASA finally put the matter to the test directly, by landing two Viking spacecraft on the Martian surface. The craft were specifically designed to seek out life. By this stage, few people hoped for more than some microbes in the Martian soil. The data sent back by Viking confirmed the skeptics' opinion. The soil tests failed to find any convincing evidence for Martian microbes. To the disappointment of many, the red planet was pronounced a dead planet. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.] [بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.276]
- Concerning the possibility of life, the fact that Mars was warm and wet between 3.8 and 3.5 billion years ago is highly significant, for it means that Mars resembled Earth at a time when life existed here. This has led some scientists to conclude that Mars would have been a suitable abode for life at that time too. On its own, however, the presence of liquid water is only part of the story. What makes the prospects for life seem so good is that Mars had not only liquid water but also volcanoes. [Paul Davies, ***The Fifth Miracle: The Search for the Origin and Meaning of Life***, Orion productions, 1999, p.]
[بول ديفيز: أصل الحياة، ترجمة: منير شريف، المركز القومي للترجمة، ط.1، 2010، ص.291]

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