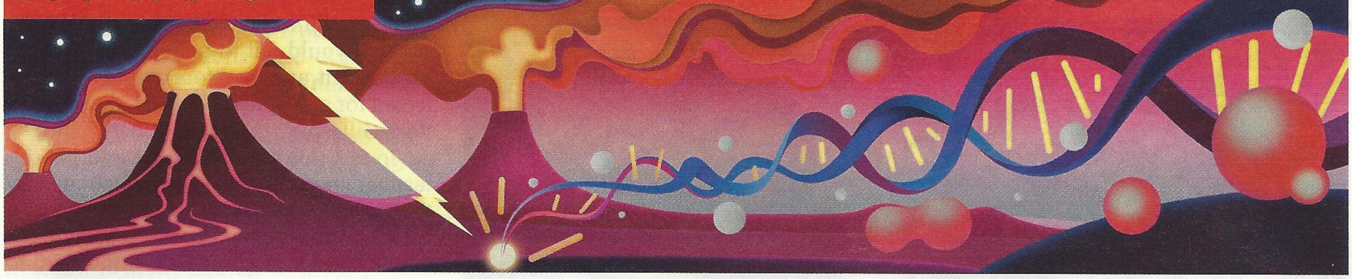


How did biology begin?

# Life story

**In the first of a series of six briefs looking at unsolved scientific mysteries we ask how living things got going and whether they exist elsewhere than Earth**

ON ONE wall of *The Economist*'s science office is a picture taken by *Hubble*, an American space telescope. It is called the Extreme Deep Field. Looking at it is a good way to get a visceral appreciation of the sheer scale of the universe. The image shows a patch of sky less than 1/150th the size of a full moon. This speck of space contains more than 5,000 galaxies. Multiply that across the heavens and you realise that the visible universe contains somewhere north of 150 billion galaxies. Each of those, in turn, contains billions of stars.

Anyone who has pondered such immensity will surely have wondered whether, somewhere else in the vastness of the cosmos, other forms of life might be crawling, flying or hopping around—perhaps pondering exactly the same question themselves. No one knows. But in 1961 Frank Drake, an American astronomer, came up with a good way to think about the problem. He pointed out that the number of life-bearing planets must be a function of how many stars are available to host them, how many planets have actually formed around those stars, what fraction of those planets are suitable for life, on what proportion life has actually begun, and so on. The Drake equation (see chart on following page) codifies this intuition. Gather enough information and extrapolate it to the universe at large and you could come up with an answer.

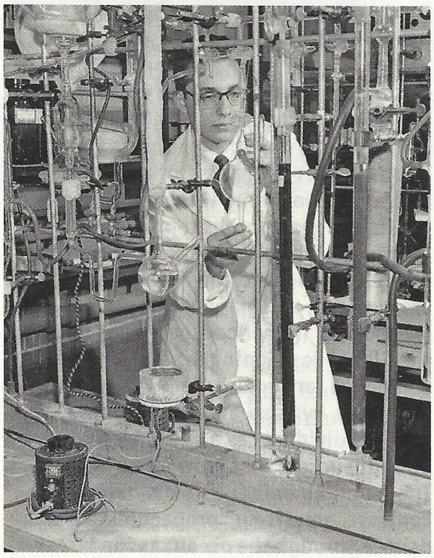
The physical terms of the equation are fairly easy to fill in. Thanks to pictures like the Extreme Deep Field, researchers have a good idea how many stars exist. The study of exoplanets—those that orbit stars other than the sun—has more recently armed them with data about planets, too. Extrapolating from the 2,000 or so known exoplanets suggests that most stars have them. Estimates of how many are habitable are less certain, mainly because of arguments about the definition of "habitable". But even the lowest are of the order of billions of such worlds in the Milky Way alone.

Filling in the biological parts of the equation is much harder. Science has but a single example—that of life on Earth—to extrapolate from. But if researchers can work out how life gets going, they will acquire an idea of how likely or unlikely that process is, and what sorts of conditions might be needed for it to happen. That would be progress. And the question of how life got started on Earth is an important one in its own right.

## Meet the ancestors

There are two ways to answer this question. One is to work up from basic chemistry. The other is to work down from existing cells.

Modern cells rely on long strands of DNA to encode their genetic information, shorter strands of RNA to carry that information around, and proteins, made using that information, to run the chemical reactions they require to live. It is implausible that such a trifold system sprang into being fully formed. However, one of its components, RNA, is able to carry out the functions of the two others, and may thus predate them. Like DNA, RNA can store genetic information in the order of its component bases. And like proteins, it can catalyse chemical reactions—including its own duplication.



Is anybody in there?

Clues within modern cells suggest they may indeed be descended from RNA-based life. Almost all possess a structure called a ribosome, a molecular factory that strings proteins together from chemicals called amino acids. The structure of something so vital is likely to have been conserved, even over billions of years. And the business end of a ribosome, the part that actually does the assembling, is a single long strand of RNA. Modern cells also sport chemicals called ribozymes—enzymes made from RNA rather than from proteins—which perform various important cellular functions. Like the ribosome, they may be biochemical fossils from the earliest era of life.

Such an "RNA" world, in which small strands of the stuff copied themselves and sometimes mutated, may be theoretically plausible. But it throws up another question—where did the RNA came from? To try to answer that, other researchers have taken the opposite approach—start with chemistry and see what you can build.

The most famous such experiment was performed in 1952 by Stanley Miller (see picture) and Harold Urey. They filled a flask with water, hydrogen, ammonia and methane—a mix of chemicals thought to be roughly representative of Earth's early atmosphere. Adding energy in the form of electrical sparks (to stand in for lightning, although ultraviolet sunlight may also have provided the necessary kick) persuaded those chemicals to combine into longer, more complicated varieties that stained the bottom of the flask with thick, tarry brown stuff. When this sludge was analysed it turned out to contain, among other things, several types of amino acid.

The "primordial soup" hypothesis Miller and Urey were testing has since fallen from favour. Critics point out that, even with enormous amounts of lightning, the rate of chemical synthesis would be agonisingly slow. Nor is it clear how the components of the soup could come together. But there are other ideas on the

IN THIS SERIES

1 **How did life begin?**
2 Is the universe alone?
3 What is the universe really made of?
4 What caused the Cambrian explosion?
5 Why does time pass?
6 What is consciousness?

menu. Michael Russell, a researcher at NASA, argues that life may have started in underwater towers called "white smokers", built by volcanically heated, mineral-laden water bubbling up from beneath the ocean floor. Such smokers have a honeycomb structure, and experiments by Nick Lane of University College, London, show that the pores in this honeycomb could act as primitive cells, concentrating organic material inside themselves, and even setting up electrical gradients like those which power modern cells.

With no fossils left over from the earliest era of life, such theories are ultimately arguments about plausibility. One thing researchers can do, though, is try their hands at creating simple life themselves, in a laboratory. Jack Szostak, a biologist at Harvard University, is attempting to do just that. He combines the top-down and bottom-up approaches by trying to create proto-cells which could have formed from simple precursor chemicals, but that provide an environment in which small strands of RNA can catalyse their own replication.

Dr Szostak and his team have already created proto-cells from blobs of the sorts of oily molecules, called lipids, that form the outer membranes of real living cells. These proto-cells are sufficiently robust to isolate any RNA they contain from the effects of the outside world.

### Is anybody out there?

The other way to find out how easily life can get started is to search for it elsewhere. Fifty years ago this week James Lovelock, a British scientist, published a paper in *Nature* called, "A physical basis for life-detection experiments". It was the first suggestion of how to conduct such searches from afar, and placed emphasis on looking for unstable mixtures of chemicals in planetary atmospheres.

Then, in the 1970s, a pair of American probes to Mars, the *Viking* landers, found some odd chemistry, but no clear signs of life. Some researchers nevertheless continue to hope Martian life may turn up. Though liquid water is essential for every known form of life, and modern Mars is a frozen desert, the evidence indicates it was warmer and wetter in its youth. Ancient river channels can be seen from orbit and sedimentary rocks litter the surface.

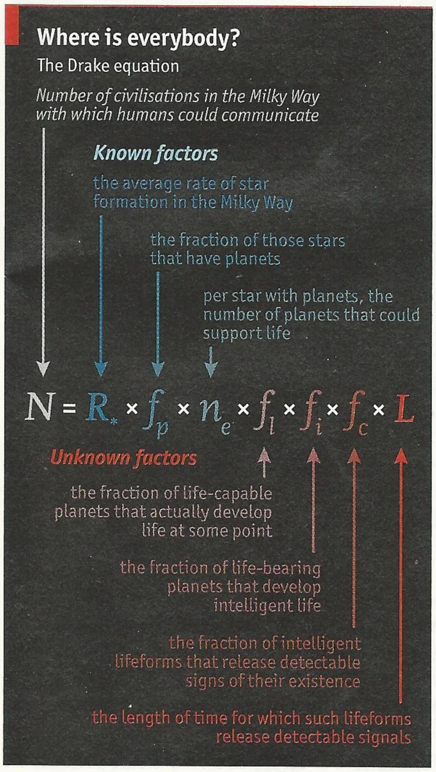
If life on Earth did begin in a primordial soup—or, for that matter, a white smoker—their Martian equivalents may have offered odds that were as good as terrestrial ones. And it is just about conceivable that Martian creatures cling to existence today, buried in places where small reservoirs of liquid water remain. Indeed, with a whole planet to hide on, it is hard to see how the idea of reclusive Martian bugs could ever be comprehensively refuted.

Alien hunters might, though, have better luck elsewhere in the solar system, at places that still have water in abundance. Two such are Europa and Enceladus, moons of Jupiter and Saturn respectively. Both are icy worlds that seem to have vast underground oceans, kept warm by heat generated as they are kneaded by the gravity of their parent planets.

Enceladus sports plumes of water that spray out into space. In 2008 *Cassini*, a probe belonging to NASA, flew through those jets and reported that they contained carbon-based molecules (the sort known to chemists as "organic", regardless of whether their origin is biological). Enceladus, then, has all the basic building blocks of life—water, organic chemicals and energy. Various robotic missions are now being discussed, that might take a closer look.

**Where is everybody?**

The Drake equation



$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Even if the solar system does prove barren, though, it may soon be possible to detect life—or at least, heavy hints of it—in other solar systems altogether. Most planets in such systems are spotted by looking for the tiny dimming of a star's light that happens as one of its planets moves between it and Earth. When this occurs an even tinier fraction of starlight passes through the planet's atmosphere. The gases therein will absorb specific parts of the starlight, leaving holes (which show up as black lines) in its spectrum. That pattern of lines would reveal the atmosphere's composition.

A gas of particular interest is oxygen. In the solar system, only Earth has much free oxygen in its atmosphere, because life—or at least, the bacteria and plants that engage in photosynthesis—generates enough of the stuff to match the rate at which it is removed from the air by reactions with other gases, such as methane. If an alien planet had both oxygen and methane in its atmosphere the mixture would have Dr Lovelock's crucial property of instability. This would suggest something there was generating a fair amount of oxygen, and it is hard to see how any process other than photosynthesis could do this over long periods.

Conclusive proof, though—as opposed to highly suggestive evidence from atmospheres—will be hard to come by. The only definitive demonstration of life's existence would be to see it in the flesh (as might happen with microbial Martians) or, if it is intelligent, to detect any deliberate communications, something that a project called the Search for Extraterrestrial Intelligence has been trying for decades with no luck.

Perhaps Earth really is unique—an improbable conjunction of circumstances that spawned an improbable, self-replicating chemistry unknown elsewhere. But the measurable terms of the Drake equation make that unlikely. Just because alien life has not yet been detected does not mean it does not exist. Perhaps it will be there in the next star system to be studied. Or perhaps, one day, Dr Szostak will walk into his laboratory and see something that was not there the day before swimming around in one of his flasks. ■