ALAMY

How could today's complex life forms have been created by the blind forces of evolution? Emily Singer reports on the scientists filling in the gaps

Relic hints at primal force

AN ENZYME still toiling away in modern bacteria contains signatures of the prebiotic world, suggesting that it originated in the very earliest cells. The enzyme unlocks energy from a simple molecule called pyrophosphate, and its discovery bolsters the idea that this was how primitive life first got its energy.

The universal energy currency in modern cells is a molecule called ATP. It contains a high-energy bond between two phosphate groups that supplies energy when it is broken. But ATP is a complex organic molecule, and scientists wondered how primitive cells struggling to function as life emerged could have developed such a complicated mechanism.

Almost 40 years ago, Fritz Lipmann, the scientist who first worked out the role of ATP, suggested that the original energy carrier might instead have been pyrophosphate. This molecule, found in cooling lava, consists simply of two phosphate groups joined with a high-energy bond. Some photosynthetic bacteria still use pyrophosphate as a secondary energy source. They absorb phosphate from their environment and use sunlight to create a phosphate bond, linking the molecules into pyrophosphate. Breaking the bond provides the organism with energy when and where in the cell it is needed. If this simple mechanism came first it could have paved the way for ATP.

There was no way to test the idea. But now Herrick and Margareta Baltscheffsky, biochemists from the University of Stockholm, Sweden, have identified and analysed the sequence of the enzyme that makes and breaks that pyrophosphate bond. They found that the active sites of the enzyme, which tend to be very highly conserved throughout evolution, have unusually high concentrations of glycine, alanine, valine and aspartic acid. These are the four amino acids thought to have arisen first in the prebiotic world, suggesting that the enzyme dates from that time.

Did phosphates from lava feed the first life forms?

"This could be an ancient enzyme," says Herrick Baltscheffsky, adding that phosphate compounds in lava may have been important for the first life forms. "Sometimes we stumble on what appears to be a relic of the primitive age," agrees Doron Lancet, a biologist from the Weizmann Institute in Israel. "This simple molecule could be elaborated to create ATP." ●

Instant evolution

A TINY genetic change can transform the function of an enzyme, scientists who captured the forces of natural selection in a Petri dish have shown. Their experiment is the first demonstration of how families of genes can evolve within living organisms.

Inside every cell is a complicated metabolic factory where specific proteins act as enzymes, converting available molecules into compounds vital for the life of the cell. A key question for evolutionary biologists is how this complicated machinery arose.

One theory is that genes in the simple genomes of early life forms duplicated, leaving the second copy of the gene free to take on a new function. If a mutation occurred that helped the organism survive, the new gene would be adopted and preserved. Scientists believe that related gene families are the result of this process happening over and over again, generating new and specific metabolic pathways.

No one had ever shown this happening in living organisms, but now scientists at the University of Florence, Italy, have proved just how easy it is for enzymes to take on new identities. Renato Fani and Matteo Brilli started with two related genes that produce enzymes involved in different stages of the synthesis of histidine, an amino acid crucial for bacteria to function. They knocked out one gene, so the bacteria could survive only if given histidine from an outside source Then they took away the histidine. "The cells either mutate or die," says Fani.

By adding a spare copy of the functional gene, the scientists gave the bacteria a way to cheat death. If a mutation allowed this copy to perform the function of the gene that was knocked out, the bugs would recreate their ability to synthesise histidine.

Some bacteria did survive.

"The research shows that an enzyme can spontaneously mutate back to what it was," comments bioinformaticist William Collis. "It's amazing that one point mutation can change the structure and function of an enzyme."

Fani and Brilli are now checking the exact mutations that saved the bacteria. Preliminary tests have ruled out any major changes, narrowing it down to single amino acid changes or tiny insertions or deletions in the gene. ●

Life in a ball of fat

WERE little balls of fat the precursors for life on Earth? These chubby balls can reproduce and evolve all by themselves in computer simulations, and can even help form the long chains of RNA that are vital for life as we know it.

The most popular theory for how life originated is the "RNA world", which says self-replicating RNA molecules started the process off. But how did complex chains of RNA arise from simple organic molecules floating in the primordial soup?

One possibility is that nucleotides – building blocks of RNA – could stick to the surface of clay particles. This would concentrate the molecules, helping them join together. Others believe lipid membranes enclosed groups of simple molecules into tight compartments, allowing them to connect.

But Doron Lancet, a biologist at the Weizmann Institute of Science in Israel, is proposing a radical alternative – the "lipid world". He argues that balls of detergent-like molecules provide a simpler way to kick-start replication and evolution, as well as explaining how the first RNA molecules formed.

These balls, known as micelles, are well known to chemists. They consist of lipid molecules, which have a water-loving head attached to a water-hating tail. In solution, the hydrophilic heads form the surface of a ball, tucking their hydrophobic tails inside. This is all that was needed for the first steps towards life, says Lancet. "We think a ball like this can grow and split and give rise to an almost identical copy."

While RNA molecules encode information in their sequence of bases, micelles carry it in the ratios of different types of heads in the ball, Lancet explains. What's more, some of these heads behave like catalysts, converting other heads from one type into another. When Lancet simulated these balls in a computer model, complex webs of reactions took place inside them. Sometimes a micelle formed that was able to split into two new micelles with the same composition of molecules as the original – forming a self-replicating, slowly evolving ball.

At some point in the lipid world, RNA must have arrived. Lancet envisages micelles made of a mixture of molecules – some with catalytic heads and some with heads made of nucleotides. As the hydrophobic tails form a ball, the heads are forced into close proximity. The catalytic heads can then join the nucleotides into more complex molecules. Add in molecules with heads made of amino acids and the same process could make proteins, suggests Lancet. "Such amino-acid-bearing lipids exist even today, so the idea is not so far-fetched."

Proponents of the RNA world are dubious. "All life is based on DNA," points out Enzo Gallori, an RNA expert at the University of Florence. "Genetic polymers are fundamental and I think they mark the beginning of life. It's difficult to imagine another possibility."

The idea can't be tested with today's molecular tools, so for now the lipid world exists only on Lancet's computer. But he hopes that in the future, scientists will recreate and analyse it inside a test tube. ●

"Sometimes we stumble on what appears to be a relic of the primitive age"

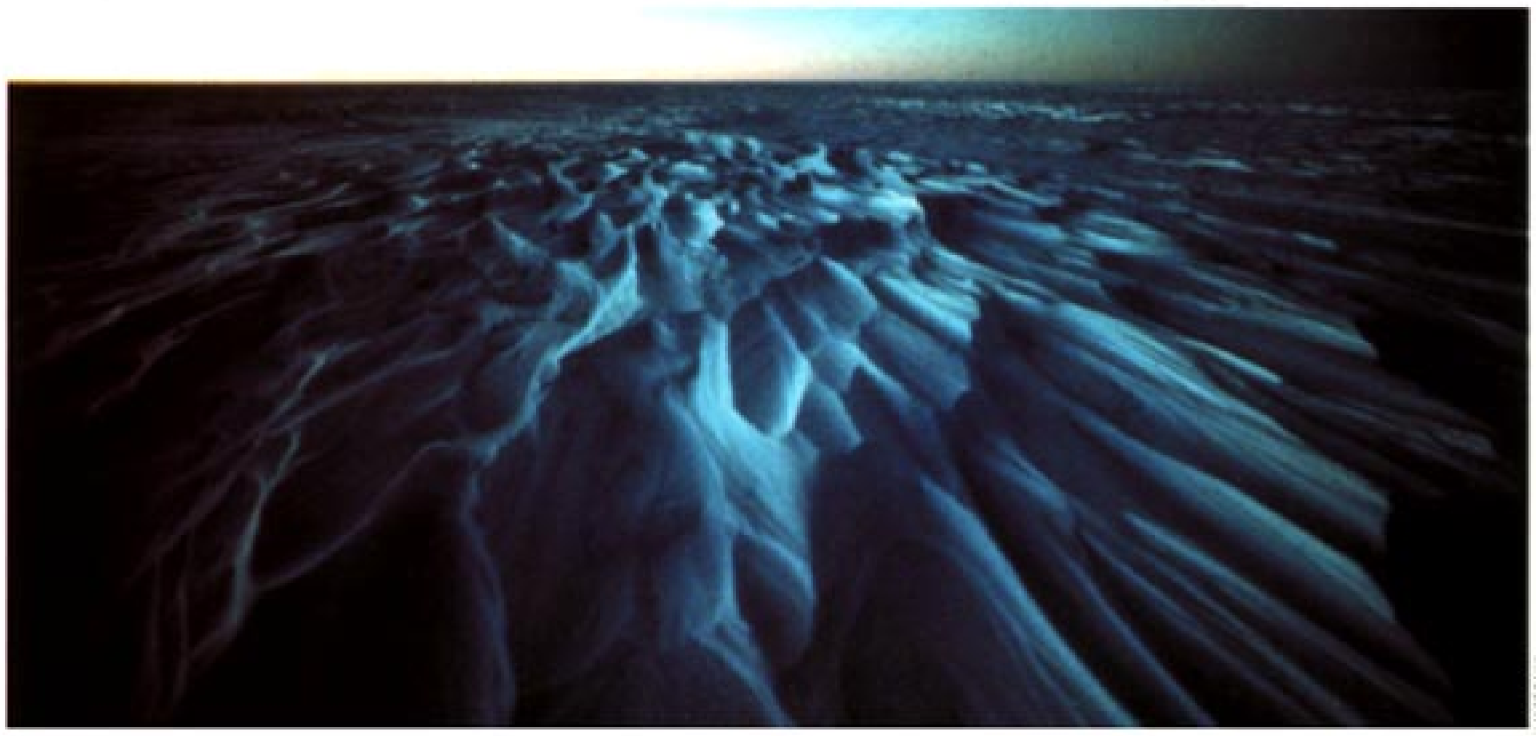
Vital clues from Europa

COULD sulphur traces on Jupiter's moon Europa be a sign of alien life? The compounds look like waste products rising from bacterial colonies living beneath the surface.

The Galileo space probe first spotted the sulphur compounds, as well as revealing that the moon almost certainly has a volcanically heated and potentially habitable ocean hiding beneath the surface layer of ice. Some scientists say the sulphur may have come from the nearby moon Io, where the compound is abundant. Or volcanic eruptions in the moon's core may have brought the sulphur to the surface.

But Aranya Bhattacherjee of the University of Pisa, Italy, and Julian Chela-Flores of the International Centre for Theoretical Physics in Trieste say the sulphur could be biological in origin. They base their idea on an Earth-based analogue of Europa – the dry valley lakes of Antarctica. The icy surface of these lakes also contains traces of sulphur compounds, excreted by bacteria in the water below. "Over a long period of time, bacteria could put substantial sulphur deposits on the surface of Europa," says Chela-Flores.

There is no way to check the idea without going to Europa, but it highlights the type of "biogenic signatures" scientists can look for when probing space for signs of life, according to Torrence Johnson of NASA's Jet Propulsion Lab in California. "It gives us an interesting idea of what to measure," he says. ●



Life is hiding under the Antarctic ice

IMAGE BANK