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EDITORIAL

Origins of life

The origins of life are buried in the murky past of evolutionary history. Biology's reigning paradigm, Darwinian selection, is the cornerstone of our understanding of biological evolution, providing a rationale for the extraordinary diversity of form and function that characterizes life on earth. The influence of evolutionary theory on our views of biology is succinctly captured in Theodosius Dobzhansky's famous saying: 'Nothing in biology makes sense except in the light of evolution'. Philosophers and poets have worried about life's purpose and Longfellow said it well:

> Life is real, life is earnest
> And the grave is not its goal
> Dust thou art to dust returnest
> Was not spoken of the soul.

But, while life's purpose must clearly lie outside the ambit of science, life's origins might indeed, be a legitimate subject of scientific enquiry. In an intriguingly titled book, *The End of Science*, John Horgan (Broadway Books, New York, 1996; Addison-Wesley, 1996) says: 'If I were a creationist, I would cease attacking the theory of evolution – which is so well supported by the fossil record – and focus instead on the origin of life. This is by far the weakest strut of the chassis of modern biology. The origin of life is a science writer's dream. It abounds with exotic scientists and exotic theories, which are never entirely abandoned or accepted but merely go in and out of fashion.' Darwin himself was remarkably circumspect, titling his treatise *On the Origin of Species*, avoiding speculating on life's origins. In Darwin's world, life had already been created; his concern was really with adaptation and evolution, his purpose to understand the imperatives that give rise to the spectacular diversity of life forms on earth. Richard Dawkins, possibly the most vigourous proponent of Darwinism, argues that the 'theory of evolution by natural selection is the only workable explanation that has ever been proposed for the remarkable fact of our existence, indeed the existence of all life wherever it may turn up in the universe. It is the only known explanation for the rich diversity of animals, plants, fungi and bacteria; not just leopards, kangaroos, Komodo dragons, dragonflies, corncrakes, coast redwood trees, whales, bats, albatrosses, mushrooms and bacilli that share our time, but the countless others – tyrannosaurs, ichthyosaurs, pterodactyls, armour-plated fishes, trilobites and giant sea scorpions – that we know only from fossils but which in their own aeons, filled every cranny of land and sea. Natural selection is the only workable explanation for the beautiful and compelling illusion of "design" that pervades every living body and every organ' (Dawkins, R., in the foreword to *The Theory of Evolution*, Maynard Smith, J., Cambridge University Press, Canto edition, 1993).

Biological evolution is a slow process and organisms have had plenty of time. The earth itself is a little less than 5 billion years old. The earliest life forms, precursors of the simplest bacteria, may have originated 4 billion years ago. Eukaryotes, nucleated cells, are estimated to have appeared only a billion years ago. Present-day biological theories provide little light on what might have happened in the long years of prebiotic evolution. The major stumbling block is the vast body of biochemistry that is inseparable from life. The simplest attributes of life, reproduction and the transmission of hereditary information involve formidably complex biochemical processes. Life involves sophisticated processes of energy transduction and cellular communication, which is central to the functioning of complex organisms, requires an exquisitely controlled cascade of biochemical reactions. Precise molecular organization, breathtaking spatial and temporal control of cellular chemistry and a remarkable fidelity of replication are among the hallmarks of the simplest of life forms. The evolution of life in the seething ferment of a prebiotic soup, however unlikely it may seem, appears to be a favoured view. Given the complexity and fluidity of molecular organization in biological systems, the spontaneous generation of a prototype primordial cell can only be seen as a happy 'chemical fluke'. The famous Urey Miller experiment of 1953, in which a spark discharge was passed through a gaseous mixture of methane, water, ammonia and hydrogen, conditions which purportedly mimic an 'early earth atmosphere', yielded a mixture of amino acids. It is this experiment that raised the hope that the precursor molecules of biochemistry might indeed be produced under primordial conditions. In the almost 50 years that have passed since the Urey–Miller experiment, there has been little progress; the limitations of such experiments becoming more apparent with each passing decade. Origin of lifers have had their moments of excitement, most often contrived, as in the hoopla about an 'RNA world', in the wake of the discovery of the catalytic power of ribonucleic acid (RNA). John Horgan quotes Lynn Margulis in raising doubts: 'Biochemical systems are effectively historical accumulations. So I don't think there is ever going to be a packaged recipe for life: add water and mix and get life. It's not a single step process. It's a cumulative process that involves a lot of changes. The smallest bacterium is so much more like people than Stanley Miller's mixtures of chemicals, because it already has these system properties. So to go from a bacterium to people is less of a step than to go from a mixture of amino acids to that bacterium'. Among others who have entered the origin of life arena are a diverse group of theoreticians, spouting the new buzzwords of chaos, complexity, self-organized criticality and 'toy models'. But, computer simulations and apparent mathematical sophistication of models for the analysis of complex systems have left most biologists profoundly disinterested.

Despite the debate on its origins, life has firmly taken root on Earth. Does life exist elsewhere in the Universe? Could the 'primordial soup' (a term attributed to J. B. S. Haldane) experiment be in progress elsewhere? Indeed, there have always been adherents of the theories of panspermia, where life on earth was seeded from outer space. Lord Kelvin and Svante Arrhenius were among the early proponents, but the most vigorous campaigners for 'the case for life as a cosmic phenomenon' have been Fred Hoyle and Chandra Wickramsinghe (cf. *Nature*, 1987, **322**, 509). In an 'Opinion' piece these authors argued for an apparent correlation between sunspots and influenza epidemics, raising the picturesque possibility of strains of viruses arriving on earth, borne by solar winds, travelling across the barren reaches of space (*Curr. Sci.*, 2000, **78**, 1057). For a long time scientists, who worried about life's origins or the existence of life elsewhere in the Universe, have worked on the fringes of science; generating hypotheses with little hard data, toiling on the borders of fact and fiction.

While many assessments of origins of life research are pessimistic, those who search for life beyond Earth may take heart from the special feature produced recently by the *Proceedings of the US National Academy of Sciences* (*PNAS*, January 30, 2001). An introductory note defines the field – 'Astrobiology is not an autonomous or self-sustaining discipline. Rather it is a hybrid subject emerging at the crossroads of astronomy, geology, paleontology, physics and biology' (Coughlin, B. C., *PNAS*, 2001, **98**, 796). Notably, chemistry, which is central to the evolution of molecules, cells and organisms is conspicuous by its exclusion; presumably a Freudian slip to which even editors are prone. In focussing attention on the search 'for an alien haven in the heavens', this issue of *PNAS* also records famously dismissive views of astrobiology. Jacques Monod magisterially declared that the 'unfeeling immensity of the Universe' must necessarily lead to the conclusion that biological organization emerged alone on earth. Many evolutionary biologists, Ernst Mayr amongst them, have felt that the search for extraterrestrial life, astrobiology, is an activity popular with some groups of physical scientists; the conglomeration of circumstances that led to life on earth being a highly improbable event. But, the recent focus in *PNAS* on the search for extraterrestrial life highlights many important aspects of the problem; the universal nature of biochemistry and state-of-the-art instruments for detecting extraterrestrial molecules and by extension, signs of life elsewhere in the solar system. In analysing the physical limits of life and the constraints of organic and biochemical processes, Norman Pace concludes: 'In principle, life, regardless of where it arose, could have survived interplanetary transport and seeded the solar system wherever conditions occur that are permissible to life'.

Origins of life research has had a chequered history and has a long way to go; but it is a welcome sign that the field still appears to be stirring.

P. Balaram