Which is the chicken, and which the egg?

THE reductionists' agenda cannot be complete until we know, in general terms, how life began. Nor will it be possible to conduct a meaningful search for where else in the Galaxy life might be found without knowing more about the circumstances under which terrestrial life began.

Unfortunately, there is as yet not much that is tangible to report. More accurately, there have been many pointed investigations since the Second World War, many of them with great intrinsic interest, but there is not yet an unambiguous pointer to the mechanisms that may have led to the emergence of living organisms in the fossil record of 3.5 billion years ago.

Sinclair Stammers/SPL

Light micrograph (magnification ×94) of a thin section of Gunflint chert from Ontario, Canada, showing fossil remains of the first Precambrian life-forms to be discovered, dating from two billion years ago. The sample includes a mixture of organic detritus, filaments resembling the modern day blue-green algae, and colonies of algae (spikelets). These primitive plants gained energy through photosynthesis, releasing free oxygen into the environment as a by-product. This had far-reaching consequences for the subsequent history of the environment.

Some features of the problem to be unravelled are nevertheless clear. First, the atmosphere of the early Earth was probably a reducing atmosphere in which molecules such as methane (CH_4) and ammonia (NH_3) would have been prominent. That belief rests on the predominance of hydrogen among the constituents of the solar nebula and on the observation that present-day eukaryotic cells require detoxifying systems for their survival.

But on the common assumption that the first self-replicating organisms would be unicellular, and that they would also have been photosynthetic, oxygen would have had to be present in the early atmosphere as CO_2. Experiments by Harold Urey and Stanley Miller at Chicago in the early 1950s, in which electric discharges were passed through mixtures of CH_4, H_2, NH_3 and H_2O, yielded small quantities of the simpler amino acids, suggesting that they may have been produced from the early atmosphere.

A second general principle in the search for the origin of life is that subsequent events must have followed an evolutionary path selected from among many alternatives by environmental circumstances. For that reason (among many others), there has recently been great interest in what is called 'molecular evolution' — the use of artificial selection pressures to select products with particular properties from systems of chemical reactions using random mixtures of molecules as substrates. Their relevance to the origin of real life is to demonstrate that selection does, unsurprisingly, function at the molecular level.

Much also can be (and has been) learned from the presence in extant organisms of macromolecules with particular functions which are also highly conserved in their structure across species. Thus, on the basis of comparisons of ribosomal RNA (rRNA) species, C. Woese has argued that extant unicellular organisms can be divided into no more than three groups. But the inference that the elements of rRNA structure that are common to the three groups are truly primaeval is not unavoidable; the common elements could have evolved in parallel, in changing but common circumstances.

That is not to say that the biochemistry of extant life-forms has nothing unambiguous to say about the origin of life. On the contrary, there are many features of the present diversity of life that could (and should) be more systematically exploited to create a chronologically based taxonomy of extant organisms. But it is unlikely that molecular taxonomy in itself, invaluable though it has proved to be in demonstrating the evolutionary relationships between closely related organisms, will be sufficient to identify a set of biochemical reactions that could be regarded as the minimum requirement of primitive organisms.

One speculation, for example, is that the long gap of about two billion years between the first appearance of microorganisms in the fossil record and the rapid radiation of multicellular organisms in the early Cambrian period was spent in the evolution of the intercellular signalling systems and the genetic mechanisms of cell differentiation necessary for the functioning of multicellular organisms.

The obvious difficulty is that the genes responsible for the intercellular-signalling molecules (and their receptors) in primitive organisms are probably adaptations of pre-existing genes with a continuing role in the metabolism of cells. Even so, a more systematic and extensive comparative study of extant organisms which appear on general grounds to have links with the primaeval should eventually yield some kind of picture of what the most primitive unicellular organisms were like.

Sadly, that is not the origin of life. □

RNA in primaeval genetics

SINCE the discovery in the early 1980s that RNA molecules may have catalytic properties (as in the splicing of messenger-RNA molecules in cell nuclei), there has been a revival of interest in the possibility that RNA was the Earth's first self-replicating molecule, although the 'RNA world' was first inspired by the high degree of conservation of the sequence structure of ribosomal RNA (see above).

There are three arguments in favour of RNA as the first biomolecule[1]. First, being a polymer of alternative nucleotides, it can carry genetic information (as if it were DNA). Second, there is laboratory evidence that the polymerization of HCN (probably a constituent of the primitive atmosphere) can lead to the formation of purines, including two of the components of modern RNA molecules, adenine and guanine. (The hydrolysis of polycyanogen can have similar results.) Third, simple chemicals related to nucleotides are ubiquitous in extant life-forms, as coenzymes and also as ATP.

Unfortunately, there are also difficulties, not least the source of the pyrimidine nucleotides that are components of RNA, cytosine and uracil, as well as the source of the ribose with which they are specifically (and stereochemically) linked in modern RNA. The problem with the sugars is not the likelihood of their occurrence on the primitive Earth (formaldehyde, CH_2O, is a potential source) but that of specificity; why the link with ribose, when other sugars may have been equally abundant?

Several ways of circumventing those