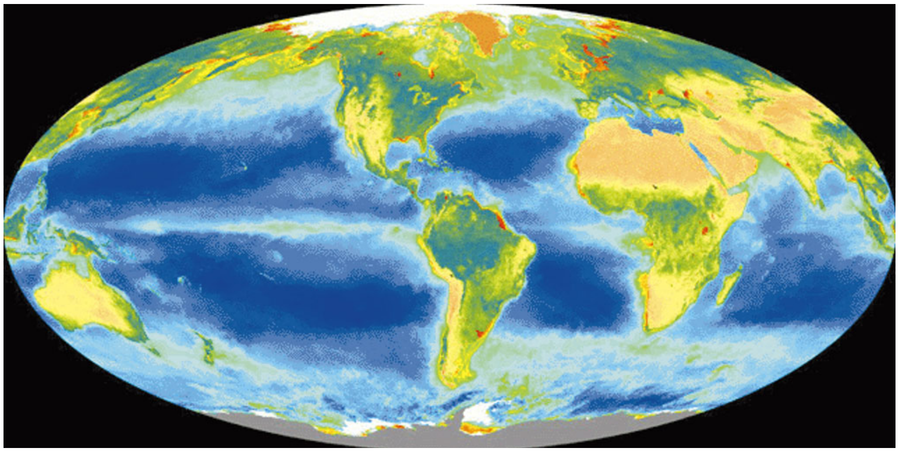

Figure 1 **The biosphere from space. This composite image, based on data from the SeaWiFS project (showing the geographical features of the ocean's plankton system) and the average terrestrial vegetation index (estimated from data provided by a separate sensor), identifies regions where most of the Earth's biological production takes place. SeaWiFS data are represented by a rainbow colour scheme, with dark blue for the lowest phytoplankton levels and orange and red for the highest. See ref. 5 for further details.**

subtropical gyres; and the intense production on continental shelves and in certain high-latitude regions.

Results presented at San Francisco reflected the improved quantitative abilities of SeaWiFS, as well as a broadening of the environmental topics addressed. Progress has been made in developing local algorithms with better precision for regions such as the California Current and the Southern Ocean. These modified algorithms do a better job correcting for regional atmospheric properties and Sun angle than does a generalized, single algorithm. Measurements of spectral absorption and backscatter ratios in Southern Ocean waters suggest that the optical properties differ from those assumed in previous models. Work also continues on ways to link chlorophyll estimates and photosynthetic parameters to estimate productivity rates as well as standing crop[4].

In an apt demonstration that one man's noise is another's signal, the SeaWiFS visible and near infrared bands have been used to track aeolian dust. Such aerosols are thought to transport trace metals (such as iron) needed for phytoplankton growth from land to open ocean regions, where they occur in very low concentrations. Ironically, the aerosol signal is part of the atmospheric correction made before estimating chlorophyll.

The obscuring effect of clouds remains a problem, one which is being tackled by combining SeaWiFS data with cloud-penetrating, active sensors such as imaging radar. Although radar returns an indirect index of phytoplankton levels based primarily on organic matter in surface waters, it may help fill in blind spots in productive high-latitude regions that are often hidden by clouds. The success of new sensors in clarifying ocean carbon flow will probably depend on improved numerical models to estimate the export of phytoplankton from surface waters. Several examples were discussed, most of them using ocean colour data to validate results of a phytoplankton–zooplankton–nitrogen biological model embedded in a physical representation of ocean dynamics. This work has provided increased resolution of the temporal variations in phytoplankton levels related to ocean dynamics along the Equator, and to regional changes in the Atlantic.

Finally, SeaWiFS data are being analysed statistically to identify the characteristic spatial scales in which patches of higher production occur. As data become available, this study will also address the temporal scales on which these patches form and disperse. Such analyses are becoming ever more rigorous and go hand-in-hand with the improved sensor capabilities. Together they will make the next decade a productive one for understanding the ecological dynamics of the sea. □

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erratum

In Christopher Chyba's article "Origins of life: Buried beginnings" (*Nature* 395, 329–330; 1998) the proposal that life could have originated at hydrothermal vents, because of the chemical reducing power of iron and nickel sulphides present at such sites, should have been attributed to G. Wächtershäuser, *Microbiol. Rev.* 52, 452–484 (1988).

Daedalus

Ultra-light glazing

Glass-blowing only works because the viscosity of molten glass rises as its temperature falls. If a section becomes too thin, it cools and becomes more viscous; the hotter regions around it stretch preferentially, and soon match it in thickness. The principle also works in the drawing of very fine glass fibres; but fails, sadly, in the drawing of thin glass sheet. Adequate thermal uniformity cannot be maintained over its width.

In this connection Daedalus recalls the wonderful stability and uniformity of a simple soap film. If a region is suddenly thinned, its surface tension rises, and hauls it back to a safe thickness. So Daedalus is seeking a 'soap' for molten glass. To have the right surface activity, its molecules must combine a glass-loving grouping with one that is incompatible with glass. A silicate or charged silicone moiety should have the thermal stability for the first role; a good candidate for the second is buckminsterfullerene. Like graphite, it must be utterly incompatible with glass; it has a high (indeed, unknown) melting point; and it can carry side-chains for coupling to the silicon unit. DREADCO's chemists are now at work on the project.

Detergent-laden molten glass will be tricky to handle. Opticians, for whom even tiny bubbles in the melt are a headache, will be horrified by its tendency to froth and foam. (Insulation engineers, however, will welcome glass froth as a product in its own right.) From a free surface of the melt, ultra-thin glass film will simply be pulled between fast-running parallel wires. It will set to a uniform thickness governed by the molecular interaction between its faces, probably a fraction of a micrometre. Thin glass films are amazingly flexible and tenacious, and Daedalus is confident of many new uses for his product. Books with glass pages and fired-in print will endure down the ages, and ultra-thin glass cells will transform chemical spectroscopy. Two-dimensional glass lasers and optical conductors will open new areas of photonics and communications; tough interference filters, beam-splitters, anti-reflection layers and photographic film will invade optics. But the major use will be for glazing. Laminated to both faces of a tough polycarbonate sheet, glass film will give a splendid window material — transparent, hard and smooth as glass itself, unscratchable and unbreakable. Windows, the Achilles' heel of modern houses, shops, offices and vehicles, will be safely armoured at last.

David Jones

Sutton *et al.* observed a number of salt bridges between syntaxin and SNAP-25 in their core SNARE complex structure, but only two between synaptobrevin and these two t-SNAREs. They speculate that such interactions lend extra stability to pairing between the t-SNAREs. Previous studies have shown that pairing within coiled coils can be prevented by ionic repulsion between the residues next to the hydrophobic heptad positions[6]. Do repulsive interactions at these positions contribute to interaction specificity of the core fusion complex, or might selectivity be determined in a different way from previously characterized coiled coils? Unfortunately, the authors have not listed the ionic interactions or discussed their conservation, so it is difficult to assess the potential contribution of these residues to specificity.

It is possible that formation of SNARE complexes provides affinity and is a driving force behind bilayer fusion, but that other factors determine the specific organization of membrane compartments. Certainly, the work of Sutton *et al.*[1] and Poirier *et al.*[2] defines many new questions, and ushers in a new era of high-resolution studies of intracellular membrane fusion. ☐

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Origins of life

Buried beginnings

Christopher Chyba

Did life begin on Earth near the surface, where the abundant free energy of sunlight could be directly harvested? Or were there instead crucial advantages to be had at subsurface hydrothermal systems? The paper by Brandes *et al.* on page 365 of this issue[1] hints that contributions from both environments might have been required. It increases our appreciation of the opportunities for life offered by crustal and oceanic hydrothermal systems, and raises the possibility that they affected the surface climate.

The possibility that terrestrial life had a subsurface origin will shape the exploration of the Solar System in the next few decades. The science of exobiology has been reborn largely by the discovery of Earth's 'deep, hot biosphere'[2] — the microbial communities that live beneath the oceans and within the crust — and because of evidence that subsurface liquid water may exist today on Mars and Europa and possibly other bodies[3].

If life can only begin on the surface, then Mars might still host a subterranean biosphere. Life could have originated at its surface when conditions were more clement than today, or spread there from Earth. But Europa, whose ocean[4] (if it exists) has probably been buried beneath kilometres of ice throughout the history of the Solar System, would be barren.

On the other hand, if life can begin in the near or total absence of sunlight, then the putative Europan ocean is highly intriguing. The US space agency NASA intends to launch an orbiter to Europa in 2003 to test the existence of the ocean and, should it exist, to begin characterizing it[5]. Later missions should then search for prebiotic and biological signatures.

So can we yet make an educated guess as to which of these ideas is right? Unfortunately, it is not clear whether any of the life under Earth's surface is truly independent of surface photosynthesis. Although it is claimed[6] that one subterranean methanogen (a bacterium) derives its energy from hydrogen generated from iron-rich basalt, that claim has now been questioned[7]. We have only begun to sample the subsurface biosphere, and to understand its organisms and metabolic diversity.

But our understanding of the role of hydrothermal vent systems continues to advance. Such vents are attractive sites for the origin of life, owing to the protection they would have afforded against the comets and asteroids that bombarded the early Earth[8], and the presence of chemical reducing power in the form of minerals such as iron and nickel sulphides[9].

Brandes *et al.*[1] have taken advantage of this reducing power, experimentally demonstrating the mineral-catalysed reduction of molecular nitrogen and oxides of nitrogen to ammonia at temperatures between 300 and 800 °C. These results suggest that hydrothermal environments and their surrounding waters would have been the most ammonia-rich environments in the prebiotic world, making them potential oases for early life.

Moreover, vents could have made an important contribution of ammonia to the atmosphere. Provided atmospheric ammonia was partially shielded against ultraviolet photodestruction (by a high-altitude haze, for example), an atmospheric mixing ratio of only 10^{-5} of ammonia might have been maintained, providing enough greenhouse warming to keep surface temperatures above freezing[10]. (The Sun was appreciably fainter than it is now, and it is uncertain why the Earth was so warm.) So the reducing power of vent environments may have had a global influence on the surface environment, and this sort of coupling between surface and subsurface environments may have been important for the origin of life. ▶

Earth science

Melting moments


A. R. PHILPOTTS

This 1-cm cube of rock provides a persuasive explanation for a common feature of basalts, a type of igneous rock. When basalts form from magma, horizontal sheets of coarser grain segregate out as the magma cools and crystallizes.

As they describe elsewhere in this issue (*Nature* 395, 343–346; 1998), Philpotts *et al.* have examined the process by heating samples of basalt to temperatures of around 1,100 °C, and then quenching and examining serial sections of them. As shown here, the cube retains its shape even when largely melted. The authors think that in the reverse process, crystallization, a three-dimensional crystal network in the basalt starts to maintain its integrity when the surprisingly low level of 25% crystallization is reached. At 35% crystallization, that network becomes strong enough to resist compaction from overlying material. But in between the two values, it is weak and permeable ('mushy'), and in this interval liquid can be expelled — as is evident from the drop in the photograph. It is this liquid that forms the coarser-grained sheets characteristic of many occurrences of basalt. **Tim Lincoln**

NATURE

100 YEARS AGO

Suppose I toss a penny, and let it fall on the table. You will agree that the face of the penny which looks upwards is determined by chance, and that with a symmetrical penny it is an even chance whether the "head" face or the "tail" face lies uppermost. For the moment, that is all one can say about the result. Now compare this with the statements we can make about other moving bodies. You will find it stated, in any almanac, that there will be a total eclipse of the moon on December 27, and that the eclipse will become total at Greenwich at 10.57 p.m.; and I imagine you will all feel sure on reading that statement, that when December 27 comes the eclipse will occur; and it will become total at 10.57 p.m. It will not become total at 10.50 p.m., and it will not wait until 11.0 p.m. You will say, therefore, that eclipses of the moon do not occur by chance. What is the difference between these two events, of which we say that one happens by chance, and the other does not? The difference is simply a difference of degree in our knowledge of the conditions. The laws of motion are as true of moving pence as they are of moving planets…

From *Nature* 22 September 1898.

50 YEARS AGO

That Newton had a just appreciation of the work of Huygens and fully understood it is significant, because Huygens signally failed to comprehend Newton's full achievement, although he realized Newton's greatness as a mathematician and as an experimenter. He criticized Newton's fundamental work on colour because it did not explain the ultimate nature of colour – "Besides, if it should be true that the rays of light, in their original state, were some red, others blue, etc., there would still remain the great difficulty of explaining, by mechanical principles, in what consists this diversity of colours". He did not understand Newton's "But to examine how Colors may be explained hypothetically is beyond my purpose". Huygens himself wrote little about colour, since the problem as he conceived it, to find a mechanical explanation, seemed to him intractable. … To say this is not to disparage Huygens, whose fundamental achievements make a formidable list.

From *Nature* 25 September 1948.

Other traffic may have run in the opposite direction. For example, it is thermodynamically difficult to form peptides out of individual amino acids in the open ocean, but amino acids have been converted to peptides in experiments that are claimed to model hydrothermal settings[11]. We don't know whether amino acids themselves can form at vents, but they might have been produced copiously at the Earth's surface[12], and would also have arrived on meteorites[13]. So perhaps they were delivered from the surface to the vents, and only there linked into peptides.

But none of these possibilities should be overplayed; there is still too much we do not know. For example, nitrites and nitrates would have been created by a number of sources on the early Earth, including lightning in clouds of volcanic ash[14], and then reduced to ammonia by Fe^{2+} in the ocean[15]. These mechanisms may have produced as much ammonia as the mineral-catalysed reduction identified by Brandes *et al.*[1].

It is intriguing to ask how early terrestrial hydrothermal environments differed from the wet, organic-molecule-rich environments in the parent bodies of carbonaceous chondrite meteorites early in the Solar System's history[3]. Evidence from mineralogy and organic chemistry makes it clear that the Murchison meteorite, for example, experienced liquid water for the first 10,000 years or so of its history, during which time its amino acids were probably synthesized. Yet there is no evidence for peptides in Murchison[16], and in general it appears that prebiotic evolution in that object did not proceed beyond simple monomers. Why not? Does this cast doubt on the hydrothermal-origins hypothesis, or was something missing, or the time too short? Within the deep interiors of large asteroids, where liquid water may have persisted for a hundred million years, could prebiotic chemistry have proceeded much further[3]? This is, after all, comparable to the time available[8] for the origin of life on Earth. □

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Plant domestication

Getting to the roots of tubers

Peter D. Moore

Starch, derived from the roots of tuberous plants, is the staple dietary energy resource for the peoples of many tropical countries. These plants, such as manioc (or cassava, *Manihot esculenta*; Fig. 1) and sweet potato (*Ipomoea batatas*), are widely used, yet little is known about their origins. Undoubtedly they evolved in Central and South America, but beyond that there is little evidence of where or when they were first brought into cultivation. The main problem for archaeologists is the lack of fossils — unlike the grasses, tuberous plants have no persistent parts that survive in sites of former cultivation or food preparation. But an approach that may open up new opportunities for tracing the roots of Neotropical agriculture is now reported in the *Journal of Archaeology*. Dolores Piperno and Irene Holst[1] show that starch grains belonging to some of the plants in question have survived on the surfaces of prehistoric stone tools.

Old World archaeologists tracing the history of the cereals have many advantages over their New World colleagues. Grasses store their starch in tough seeds that are easily carbonized and preserved in an intact state, allowing them to be identified with precision to species level. The grasses also contain opal phytoliths — silica bodies with distinctive, often angular, shapes — that are relatively inert and survive after organic tissues have decomposed. Moreover, the domesticated cereals produce pollen grains with features that allow them to be separated from other grasses, providing opportunities for the history of cereal-based agriculture to be traced. By contrast, the Neotropical starch-producing root crops, such as manioc, have no identifiable phytoliths, produce few pollen grains and do not carbonize, so it has been difficult to work out their history.

Starch grains vary in size, shape and structure, and it has been claimed that they are distinctive enough to allow species determination[2]. So if starch grains could be found in a datable situation, they could provide evidence for the use of certain plants in the past — including the Neotropical root crops whose history has proved so elusive. The most obvious place to look for such starch grains is on the tools used for grinding and