The RAS Science Writing Competition

Sue Bowler announces the results of the competition for students, and introduces the winning piece.

One of the aims of the RAS Science Writing Competition is to encourage students to write about the subjects that interest them in a lively and entertaining way, making their specialist interests accessible to the wider audience that enjoys science magazines and television programmes. This is a valuable exercise in itself: no-one can explain complex issues at this level without a clear understanding of the fundamentals. But it also comes in useful in later life, whatever your chosen career.

Science fiction is often the starting point for expositions of science fact, as the winning piece by **Lewis Dartnell** (UCL) so ably demonstrates. He takes as his starting point the scene in *Star Trek* when the USS Enterprise approaches an uncharted planet and, swiftly, almost magically, works out whether it holds life or not. How exactly we, rather than the Enterprise crew, might detect such lifesigns is the theme of Dartnell's piece.

The runner up, **Elizabeth Tasker** (Oxford University), started from a different point, the question in the pub: "What do you do, then?" As she's a theoretical astrophysicist, the answer "I build universes" tends to bring the sort of silence that usually accompanies the villain in a western. Tasker goes on to explain how and why she attempts such a weird thing. With her imaginary – and increasingly tipsy – audience firmly in mind, she goes through the steps that bring her worlds alive, staying both entertaining and informative throughout.

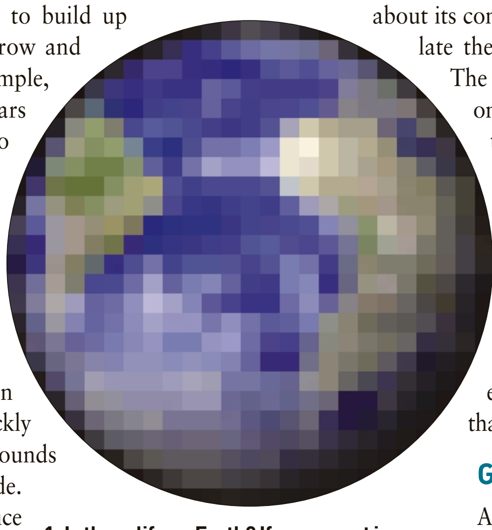
The winning and runner-up entries can be read in full on the RAS website at http://www.ras.org.uk/, where you will also find details of how to enter the next round, closing date 31 July.

It's life, Jim...

Lewis Dartnell wonders how astronomers find life on this and other planets. After all, they do it on *Star Trek* with just a scanner...

The USS Enterprise drops out of warp and slips into a parking orbit around an uncharted alien planet. The Captain orders a scan for lifesigns and, within seconds, he is told exactly what lifeforms are present, including the pre-industrial humanoids on the southern continent. How feasible is this, really?

The possibility of detecting life across the vastness of interstellar space was first suggested in 1965 by James Lovelock, who also proposed the Gaia theory. The most fundamental definition of "life" involves the extraction of energy from the environment in order to build up complex molecules, grow and reproduce. For example, human cells use sugars and amino acids to build up the large biomolecules that make up their DNA, enzymes and membranes. To do this, life forces chemical reactions against their normal direction. Oxygen is very reactive and quickly forms oxidized compounds such as carbon dioxide. When plants produce oxygen during photosynthesis they are putting energy from the Sun into reactions to drive them backwards. So one of the signs of life is that it changes the chemistry of its surroundings in ways that would not otherwise have happened.



1: Is there life on Earth? If we can get images such as this of extrasolar planets, which is the promise of planned technologies, we have the techniques to analyse them for signs of life.

Furthermore, no organism is isolated from the world around it, but participates in an enormous food web. The Sun's energy is harvested by plants and passed on through levels of herbivores, predators and, eventually, decomposers. The raw materials of life (carbon, nitrogen, oxygen and water) are recycled through the rocks, oceans and air of the planet itself. This is the basis of the Gaia theory; not only is every organism inextricably linked with all others, but the biotic and abiotic spheres also interact.

Manipulating climate

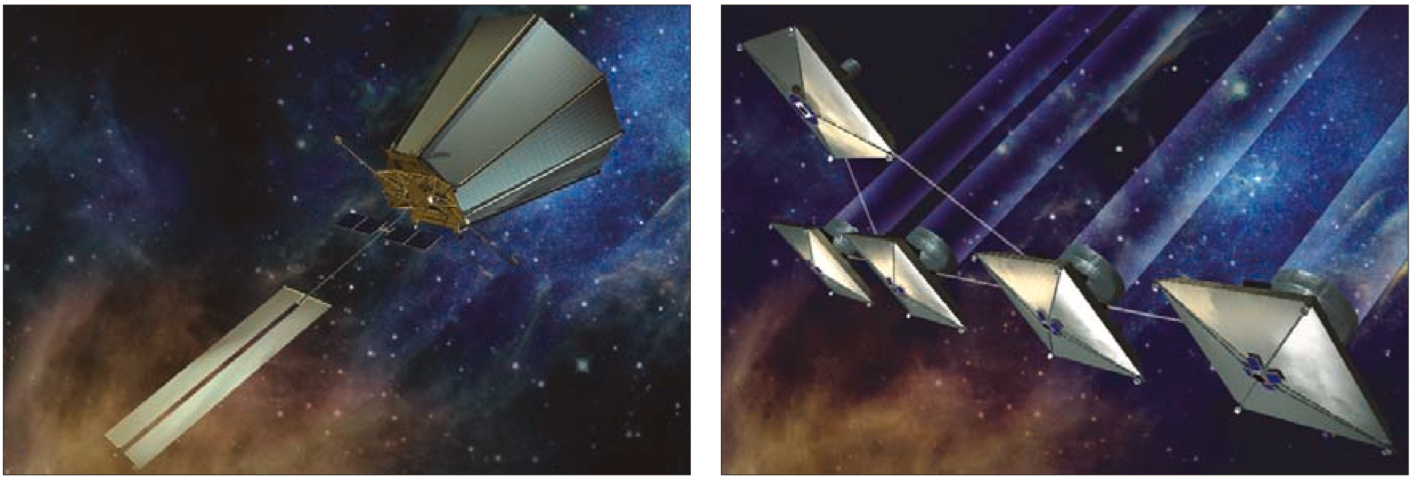
The oxygen concentration and surface temperature of a planet largely dictate what life can survive there, but by modifying the amount of carbon dioxide and water vapour in the air, life manipulates the climate. These interactions regulate each other, and so both life and the global chemistry are mutually stabilized. The planet can be thought of as a single organism striving to keep itself balanced. In this way, biological processes can have effects on a global scale, and transform the conditions and composition of an entire planet. For example, the high level of oxygen in our air is only maintained by the constant action of photosynthetic organisms.

As Lovelock describes it: "Almost everything about its composition seems to violate the laws of chemistry ... The air we breathe ... can only be an artefact maintained in a steady state far from chemical equilibrium by biological processes." In general then, biospheres are always far from chemical equilibrium, and this gives an excellent biosignature, that astronomers can seek.

Good indicator

An oxygen-rich atmosphere would be a good indicator of life on an alien planet. But that in itself is not enough because some inorganic processes can produce the same result. High levels of oxygen, together with the presence of reducing gases (which react rapidly with oxygen) would, however, be an almost-sure sign of life. In order to keep pace with their destruction, reducing gases must be constantly produced afresh by the backwards-running reactions indicative of life. Methane, for example, is quickly oxidized to carbon dioxide and water. To maintain the levels in Earth's atmosphere so far from equilibrium, over a billion tonnes of it must be released every year. That's why the methane found in the martian atmosphere by ESA's Mars Express has such significance: it means active volcanoes or life.

Of course, we know virtually nothing about what sort of biochemistry alien life might employ, or even the sorts of environments it could survive in. Alien bacteria might thrive in



2: Artist's impression of the Terrestrial Planet Finder mission, comprising a visible-light coronagraph (left), and an infrared interferometer. (NASA/JPL)

seas of ammonia rather than water, or the upper cloud layers of Saturn might conceal herds of floating filter-feeders. But looking for evidence of the general action of life – pushing the environment away from equilibrium – makes no assumptions about the specifics. Even if life lurks far underground, it will still transform the atmosphere and so can potentially be detected.

We do have one place where we know life thrives, though, and so it makes sense to hunt for similar lifeforms in similar spots in the universe. For the moment astrobiologists are focusing their attention on carbon- and water-based life on Earth-like planets orbiting Sun-like stars. Water is currently thought to be essential as it has special properties that make it particularly benevolent towards life, including its ability to dissolve organic molecules and cushion temperature fluctuations. Water is liquid over only a limited range of temperatures, and so inhabitable planets must orbit at a particular distance from their sun – the hospitable zone. The first step towards finding life outside our solar system is to find medium-sized, rocky planets orbiting within the hospitable zone of their star.

More sensitive equipment

So far, 136 planets in other star systems have been discovered. Most of these, however, are of the "hot Jupiter" type: massive planets that orbit close to their star and are not thought able to harbour life. Our equipment is not sensitive enough to pick up Earth-like planets, but techniques are rapidly improving and there are some exciting plans for space telescopes already in the pipeline.

The Space Interferometry Mission (SIM), scheduled for launch in 2009, will be the first instrument able to detect hospitable planets. It will study the nearest 250 stars for the telltale wobble caused by an orbiting "Earth". Tantalizing as this will be, SIM will provide only a catalogue of planets that might be suitable. Astrobiologists really want to be able to analyse their atmospheres for the gas signatures of life.

The Terrestrial Planet Finder (TPF) is a fleet of telescopes that, it is proposed, will fly in formation at a Lagrangian point – an especially stable position where the Earth's and Sun's gravity cancel out. The array (figure 2) will use clever optical tricks to behave like a single massive telescope and to block out the blinding glare of the star. This will enable the TPF to look at only the light coming through the atmosphere of the target planet, peering into the chemistry of an alien world from almost 50 light years away. The physics behind this idea is simple enough. The telescope collects the light and passes it through a spectrometer. This is a gadget that spreads the light into its component wavelengths, much like water drops creating a rainbow. The broad shape of the infrared spectrum will reveal the temperature of the planet, and thus whether it could provide liquid water. Different molecules absorb infrared light at a particular wavelength, and so by looking for dips in the infrared spectrum you can infer which gases the planet's atmosphere contains. Carbon dioxide and water both give very strong signals. Oxygen itself is not easy to detect, but high in the atmosphere it is converted by sunlight into ozone, which stands out very well. The presence of both oxygen and a reducing gas such as methane would provide very strong evidence for life. We will be able to tell not only if a planet is habitable, but if it is actually inhabited.

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Biosignatures detected

In fact all of these biosignatures have already been detected in the atmosphere of a planet. In 1990 the Galileo probe swung by the Earth for a gravitational boost en route to Jupiter. As it raced away it turned its instruments back towards us, and detected the dips in the spectrum of reflected sunlight indicating oxygen and methane. The probe also saw the absorption fingerprint of chlorophyll, the complex molecule that captures sunlight during photosynthesis. All these signs taken together allowed Galileo to assert, with almost complete conviction, that the Earth did in fact harbour life. Reassuring as this is, it also has important implications for the possibility of discovering life on other planets

Ambition

Detecting the atmospheric biosignature of life would certainly be revolutionary, but astronomers have even more ambitious plans. Using the same principles as the TPF, the next generation of telescopes would fly in a formation stretching over hundreds of kilometres. The resolution of such an enormous array will be good enough to make out the surface of a planet. Figure 1 shows the pixellated sight we would get if viewing Earth through such a telescope. It may resemble a pointillist abstraction of coloured dots, but to see this amount of detail of another rocky planet would be truly spectacular. We might see continents, oceans and ice caps. If the planet is alive, we could see deserts contrasting against the colour of plains and forests (which might even be green!). We may even be able to see seasonal fluctuations in the vegetation on a continent as the hemisphere swings between summer and winter. Such a project could be working in perhaps 30 years.

Imagine that: gazing upon the very face of an alien world a mere 425 years after Galileo first turned a telescope to the heavens. ●

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Further information

The Space Interferometry Mission (SIM):
http://planetquest.jpl.nasa.gov/SIM/sim_index.html

The Terrestrial Planet Finder (TPF):
http://planetquest.jpl.nasa.gov/TPF/tpf_index.html