Do triffids dream

Australian scientists are taking on nature with an innovation that could turn sunlight into energy. **Richard Corfield** looks at the technology and cautionary tales from science fiction

'Commerce is our business here at Tyrell, Mr Deckard. More human than human is our motto.' With these words the chilling Dr Tyrell in Ridley Scott's film noir classic *Blade Runner* introduced the concept of replicants, artificial humans created by the Tyrell Corporation's genetic engineers sometime in the 21st century.

When *Blade Runner* was made in the early 1980s the concept of artificial humans seemed all but inconceivable, but today we are catching up to the future with frightening speed. Within the past month, researchers at the University of Sydney, Australia, have announced that they have found a way to emulate the oldest evolutionary trick of all, the ability to turn sunlight into energy. The idea is about 3bn years old and is called photosynthesis.

Around 3.8bn years ago, the Late Hadean Bombardment of the inner solar system finished. Soon afterwards, life began, as nucleic and amino acids began to synthesise in an atmosphere continuously boiled and tormented by lightening strikes. Sometime after that — in the long evolutionary dawn known as the Age of Bacteria — a free-living single-celled organism, whose DNA was not organised into a subcellular nucleus (a prokaryote), discovered how to synthesise complex carbohydrate molecules from sunlight. It was one of the most important evolutionary innovations of all time because the waste product of this reaction is oxygen, a molecule we all have reason to be grateful for because it allowed the development of multicellular life.

The crucial innovation that made photosynthesis possible was the combination of a porphyrin with a metal ion, in this case magnesium, to form chlorophyll. Porphyrins are pigments composed of a group of pyrrole rings joined together by carbon/hydrogen (methine) bridges. Their ability to bind with metals makes them crucially important in biochemistry. For example, when combined with iron, porphyrin makes up the respiratory protein haemoglobin.

The chlorophyll molecule starts the process of energy capture by absorbing light energy by losing an electron. This initiates a cascade of electron loss in a

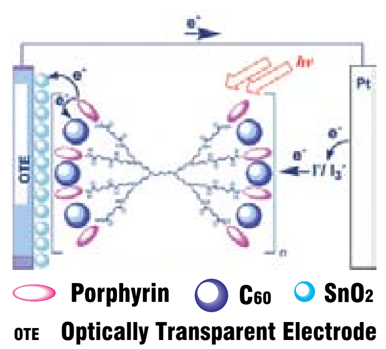


Figure 1: Conversion of solar energy into usable electrical energy by synthetic organic solar cells

In brief

- **Scientists in Sydney believe they have found a way to simulate photosynthesis**
- **Photosynthesis, the ability to turn sunlight into energy, took billions of years to evolve**
- **Synthetic porphyrins surround a dendrimer to mimic natural photosynthetic systems**
- **The technology could be used for solar power**

# of electric sap?

chain of other molecules until a stable high energy carbohydrate compound is formed. The entire process is highly complicated but the outcome is incredibly simple: stored energy.

Imagine if we could do the same thing but produce energy in the form that is most useful to us – electricity. This is the achievement of Max Crossley and his team working within the University of Sydney's molecular electronics group. They have done it by combining synthetic porphyrins with C_{60} buckyball molecules and coating the mixture onto a tin dioxide monolayer itself deposited on an optically transparent electrode (see Figure 1).

The synthetic porphyrins capture energy from sunlight in the form of photons, just like naturally occurring chlorophyll, and enter an excited state. An electron is lost by the porphyrin and transferred to the electron-accepting buckyballs, which then inject these electrons into the tin dioxide monolayer.

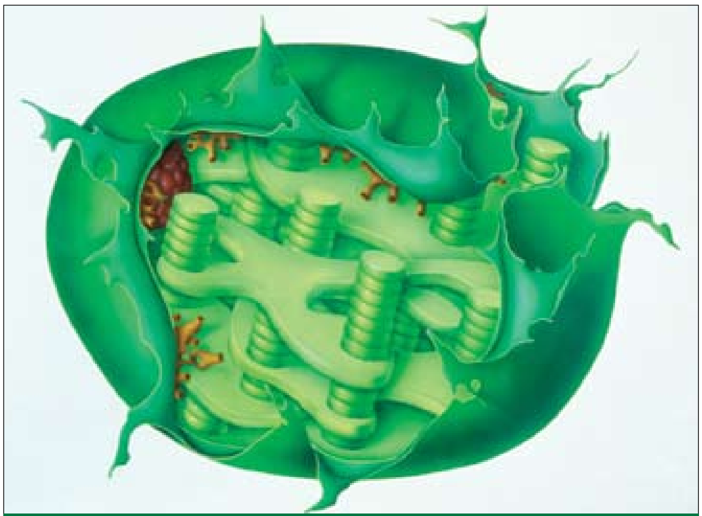
This transfer of electrons generates electrical current in an external circuit that can be used in a similar way to that in a conventional photovoltaic cell. The electron deficient porphyrin gains an electron from iodide (I3-/I-) in the electrolyte solution in the cell, and returns to its original unexcited state – allowing the whole process to repeat again.

Cellular folds

Within a plant cell, the subcellular organelle that does the heavy lifting of converting sunlight into usable amounts of energy is the chloroplast, where the chlorophyll molecules are arranged onto lipid bilayers – an even older evolutionary invention. This dates back to the time that the first nucleic and amino acids began to arrange themselves into thalkaloid membranes. These thalkaloid membranes are folded together rather in the manner of a compressed telephone cord to form structures called grana. Stacks of grana within the chloroplast make up the energy generating turbines of the chloroplast (see Figure 2).

The trick for postdoctoral researcher Deanna D'Alessandro, a new member of the Sydney team, has been to emulate nature once again and design structures that incorporate enough synthetic porphyrins to generate usable amounts of electricity. To do this, the team has arranged the porphyrins in highly branched circular structures called dendrimers, complex arrangements of porphyrin molecules. The C_{60} buckeyballs are arranged between the branches of the dendrimers.

'We have been able to construct synthetic porphyrins,' D'Alessandro explains. 'More than 100 of them can be assembled around a tree-like core called a dendrimer to mimic the wheel-shaped arrangement in natural photosynthetic systems.'



Francis Leroy, Biocosmos/science Photo Library

Figure 2: interior of a chloroplast in 3D

> *'It seems that 'replicant' plants – familiar to all from John Wyndam's* The Day of the Triffids *– may be around the corner'*

The Sydney group is working with engineers at Osaka University in Japan to combine these inorganic grana equivalents into the synthetic counterpart of a plant cell. If this stage is successful, they plan to scale up the technology to commercial scale solar panels over the next five years.

Thanks to the Sydney team it seems that 'replicant' plants – familiar to all from John Wyndham's 1951 sci-fi masterpiece *The Day of the Triffids* – may be around the corner.

Replicants: super-emulators

Like Ridley Scott's androids, the Sydney team's replicant porphyrin/buckeyball molecules are better, faster and stronger than the opposition. They are expected to be twice at efficient at capturing energy as conventional silicon based photovoltaic cells – 30-40% efficient versus 15-20% – and they are also excellent at storing energy, something that even Mother Nature's own chloroplasts don't themselves do. The Sydney team believes that its replicant molecules could one day function like mega-batteries.

Does it all sound too good to be true – a super-efficient energy capture and storage system in one molecular dendrimer basket? Both *The Day of the Triffids* and *Blade Runner* are cautionary tales. In Wyndham's novel, his genetically engineered plants almost take over the world, while at the end of *Blade Runner* Roy Batty, Dr Tyrell's most advanced replicant, turns on him in a frenzy of Frankensteinian proportions.

Although catastrophes of these dimensions are unlikely, outcomes of dendrimer development do make you think: evolution took 2bn years to perfect photosynthesis. We may have to wait a little longer for reliable electric sap.