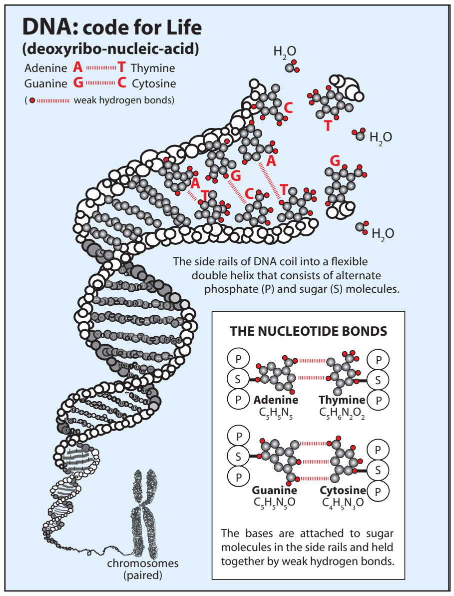
THE DIARY OF YOU

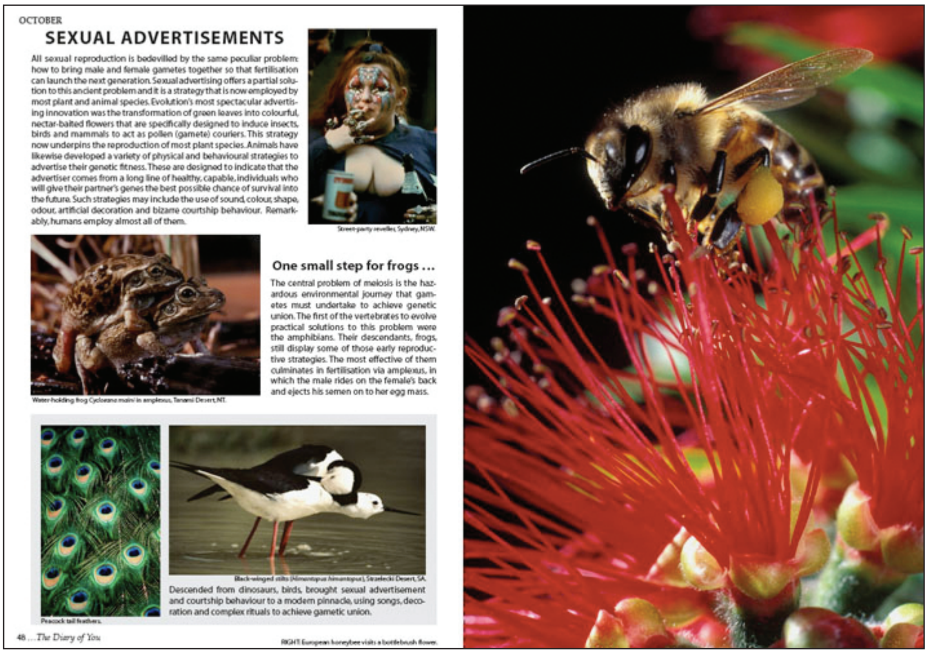
Four billion years of human evolution

Reg Morrison

As a by-product of genetic evolution, the birth of our species is inextricably linked to the evolution of the planet's biosphere and its dazzling biota. *The Diary of You* unfolds this sequence of biological mile-stones as a uniquely personal narrative.

The 4.6 billion-year life of the planet has also been matched here against a one-year calendar and divided into twelve individual 'months' in order to transpose the passage of geological time into proportions that we can readily grasp. According to this diary time-scale Earth was born at midnight on January 1, and 'You' were conceived in a genetic sense about 600 million years later, in mid February. Meanwhile, evidence archived in the biota and within cells of your body suggests that although You remain typically bacterial, you are nevertheless unique.




OCTOBER

SEXUAL ADVERTISEMENTS

All sexual reproduction is bedevilled by the same peculiar problem: how to bring male and female gametes together so that fertilisation can launch the next generation. Sexual advertising offers a partial solution to this ancient problem and it is a strategy that is now employed by most plant and animal species. Evolution's most spectacular advertising innovation was the transformation of green leaves into colourful, nectar-baited flowers that are specifically designed to induce insects, birds and mammals to act as pollen (gamete) couriers. This strategy now underpins the reproduction of most plant species. Animals have likewise developed a variety of physical and behavioural strategies to advertise their genetic fitness. These are designed to indicate that the advertiser comes from a long line of healthy, capable, individuals who will give their partner's genes the best possible chance of survival into the future. Such strategies may include the use of sound, colour, shape, odour, artificial decoration and bizarre courtship behaviour. Remarkably, humans employ almost all of them.

Street-party revellers, Sydney, NSW.

One small step for frogs ...

The central problem of meiosis is the hazardous environmental journey that gametes must undertake to achieve genetic union. The first of the vertebrates to evolve practical solutions to this problem were the amphibians. Their descendants, frogs, still display some of those early reproductive strategies. The most effective of them culminates in fertilisation via amplexus, in which the male rides on the female's back and ejects his semen on to her egg mass.

Water-holding frog Cyclorana maini in amplexus, Tanami Desert, NT.

Black-winged stilts (Himantopus himantopus), Strzelecki Desert, SA.

Descended from dinosaurs, birds brought sexual advertisement and courtship behaviour to a modern pinnacle, using songs, decoration and complex rituals to achieve gametic union.

Peacock tail feathers.

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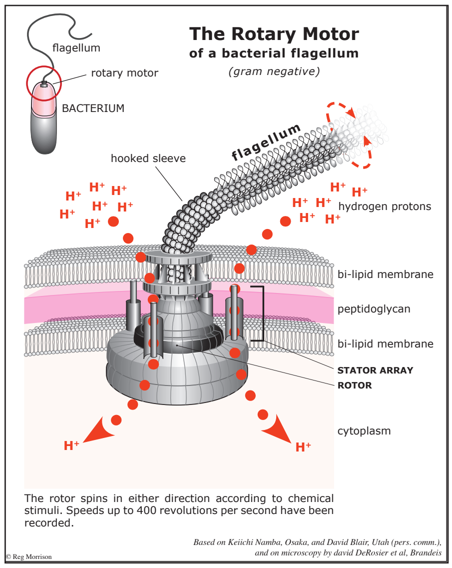
RIGHT: European honeybee visits a bottlebrush flower.



The red glow of cosmic hydrogen.

Three species: one African, two Australian.

CONTENTS

This 64-page book has been developed as a resource for High School biology teachers and students in years 11 and 12. The author has been advised at various times by many Australian academics including professors Malcolm Walter and Michael Archer of the University of NSW, Michael Gillings of Macquarie University, Andrew Glikson of the ANU and Dr Arthur Hickman of GSWA, as well as Distinguished Pofessor Lynn Margulis of Massachusetts University.

For syllabus dot points (NSW and WA), study aids, and further information go to:
www.regmorrison.id.au

MARCH

(~3.86—3.47 billion years ago)

Life's first signature

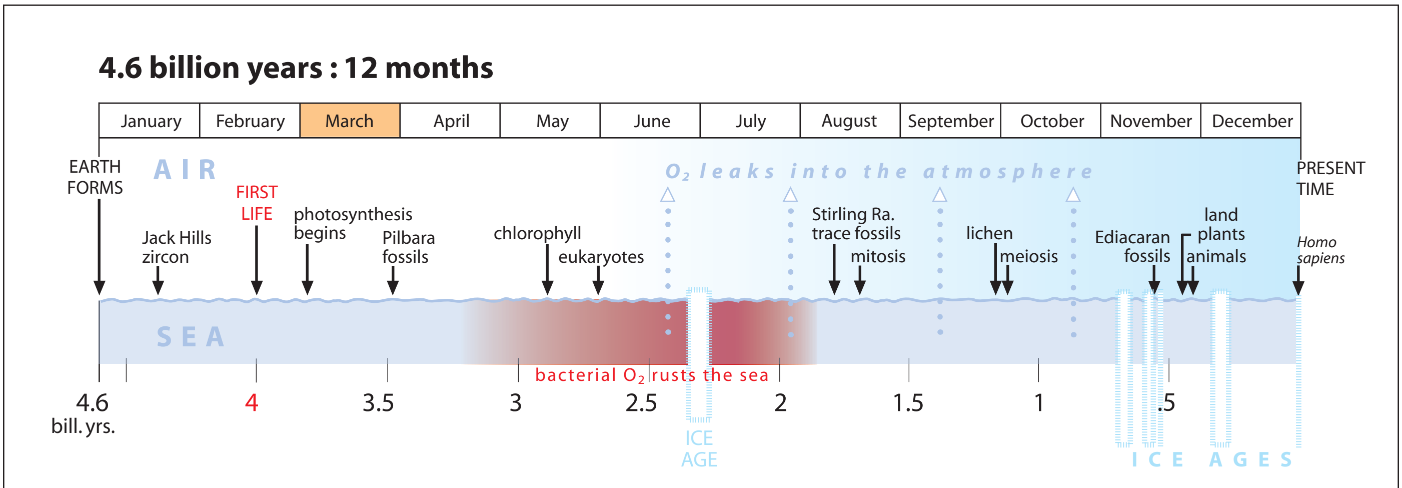
During the early part of this diary month genetic evolution produces a wide diversity of bacterial forms, but in the savagely unstable primordial environment the Darwinian process of natural selection quickly resolves this diversity into two highly successful evolutionary streams: the archaebacteria (commonly called archaea), and eubacteria or 'true' bacteria. The third branch on the tree of life, the eukaryotes, will not begin to evolve for another billion years, and even they will be a combination of the two primary forms. In short, planet Earth is a bacterial planet, and nothing will alter that fact in the next three billion years. Bacteria will help to erode the rocks and alter the composition of the atmosphere, mainly by the addition of their waste gases. During those three billion years bacteria will dramatically reshape the biosphere, cooling the planet and creating the physical environments and weather systems that we see around us today.

We still know relatively little about either branch of those original bacteria at this early stage of evolution, but one of their most spectacular innovations has been incorporated into the structure of our eyes. It is the reddish pigment rhodopsin, produced by the highly sensitive rod cells embedded throughout the retina but especially round its fringes. Even dim light changes the shape of the rhodopsin molecule, and so we, like many modern creatures, use it to see in semi darkness. Several features in your rod cells suggest that they are indeed bacterial in origin and this is confirmed by the bacterial DNA that manages each cell. So it seems that You owe your night vision to about 125 million modified descendants of purple sulfur bacteria that live on, in a sense, within your eyes.

Rhodopsin was originally incorporated into archaea (archaebacteria) more than 3.5 billion years ago, probably for the same reason some purple sulfur bacteria still find it useful—because rhodopsin yields a small amount of energy when it reacts to light and changes its shape.

Scattered across several crumbling ridge lines in north-western Australia there are fragments of a seabed that has monumental significance for us. The region's extraordinary stability for the past 3.5 billion-years has preserved even the ripples in its once-muddy surface, so you can't help but notice the curious, bubble-like eruptions that puncture it. Each puncture reveals the tip of a pile of limey waste left by a colony of microscopic bacteria that once lived there. Run a finger over those crumbling layers and you are tracing out life's oldest tangible signature on the face of the Earth.

We now know exactly what the fossils represent because you can wade waist deep among very similar piles of bacterial waste in the shallows of Hamelin Pool in Shark Bay, some 800 kilometres to the south-west. Their builders are the descendants of the bacteria that built the 3.5-billion-year-old fossils. But these ones are giants by comparison, for this is the oldest and largest population of 'living' stromatolites in the world.



Stromatolites at high tide, Shark Bay, WA.

STROMATOLITES: The upper surface of each stromatolite column is inhabited by a dense mat of light-sensitive organisms that are often mistakenly called blue-green algae because of their chlorophyll content. They are in fact bacteria, or more precisely, cyanobacteria. Using sunlight as a power source and chlorophyll as a catalyst, they manufacture their own nutrient from carbon and other elements in the seawater. Their wastes include a small amount of oxygen gas and some limey (carbonate) minerals. Silt particles adhere to this sticky deposit throughout the day and build up during the night, burying the dormant bacteria. When dawn breaks, the bacteria extricate themselves and migrate to the surface to resume their photosynthetic feeding. Several kinds of bacteria acquired the ability to live together in colonial mats and to run their matabolism via photosynthesis, and so several kinds may help to build a single stromatolite. Stromatolites have been growing in Shark Bay for several thousand years and some are more than a metre tall.

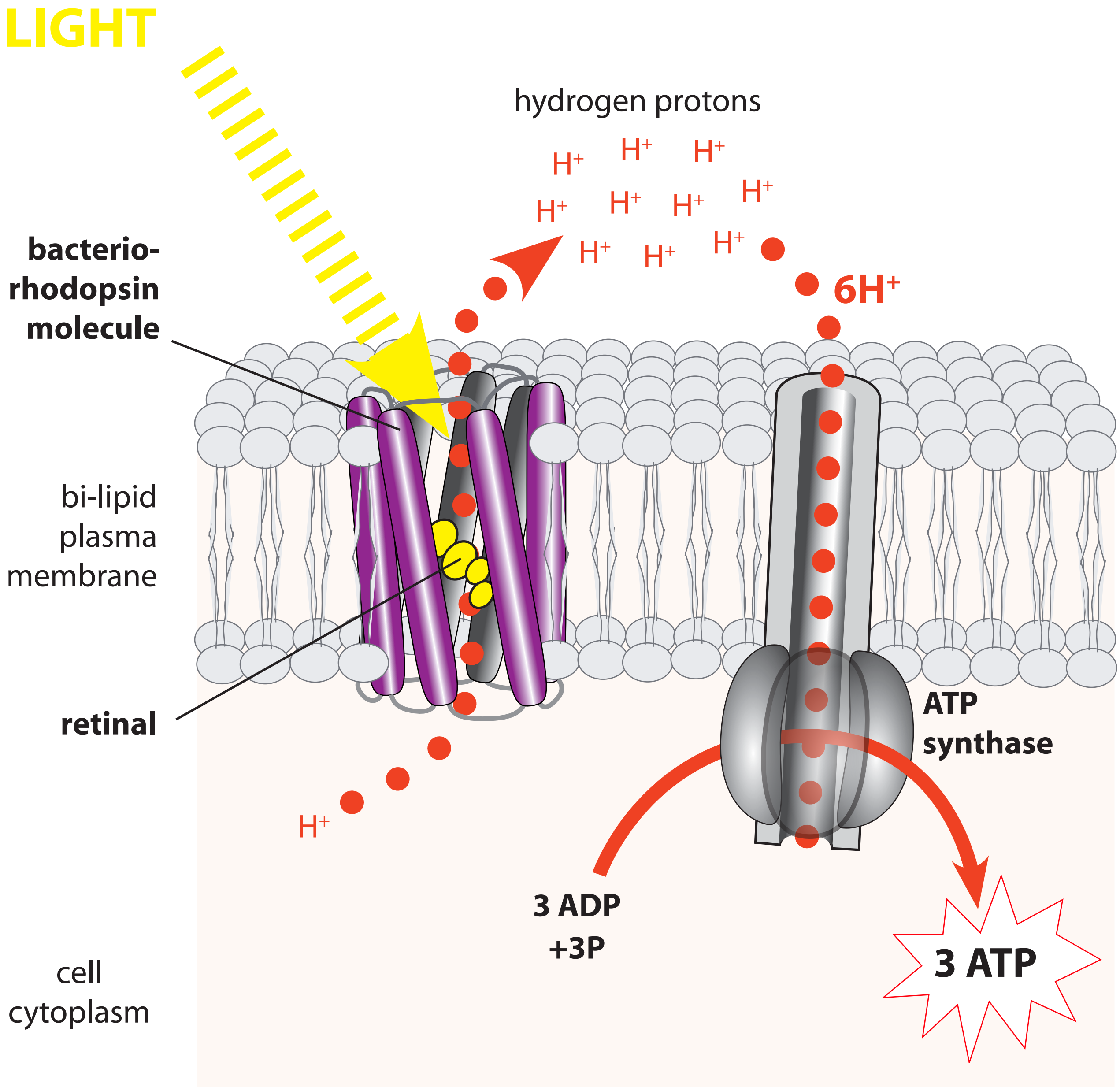
Stromatolite fossils, Pilbara, WA.

ABOVE: These two fossilised stromatolites are about 3.49 billion years old and represent the oldest tangible trace of life on Earth. The separated column (centre) is 3.5cm. tall. There is a second one beside it.

Stromatolites at dawn, Shark Bay, WA.

Bacterial Rhodopsin

(bacteriorhodopsin)



Bacterial membranes rich in bacteriorhodopsin form an emergency power source that can keep an organism's life cycle going when other nutrients are scarce. Molecules of bacteriorhodopsin change their shape slightly when hit by photons of light and during this process they "pump" hydrogen protons across the membrane, transporting them out of the cell. This creates a charge potential across the membrane, and where other ion channels allow re-entry, the inflow of hydrogen protons enables the cell's phosphatic enzymes to build adenosine diphosphate (ADP) into its energy-rich triphosphate form (ATP). Rhodopsin molecules are commonly present in the membranes of archaebacteria (archaea) that live in extreme environments such as boiling volcanic pools, or in alkaline, acid, or very salty waters, especially the latter. This is why some brine lakes are characterised by their pinkish water.

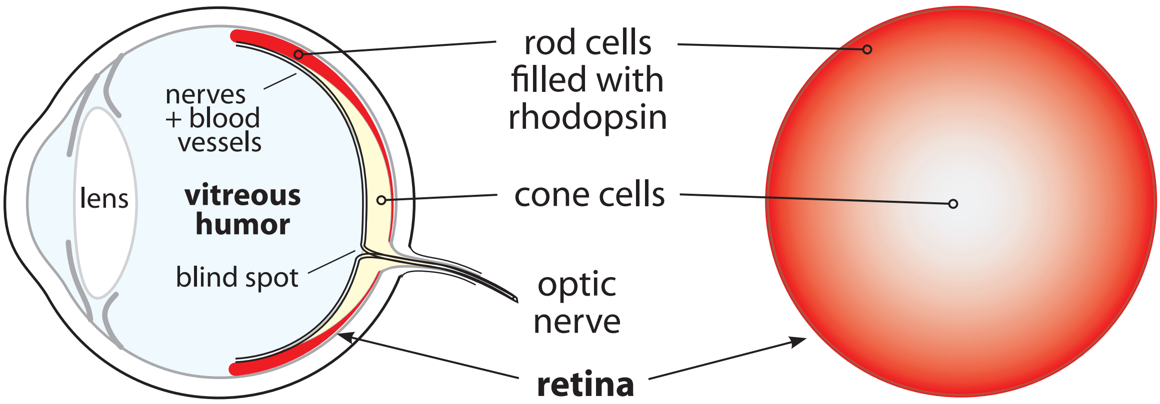
RHODOPSIN

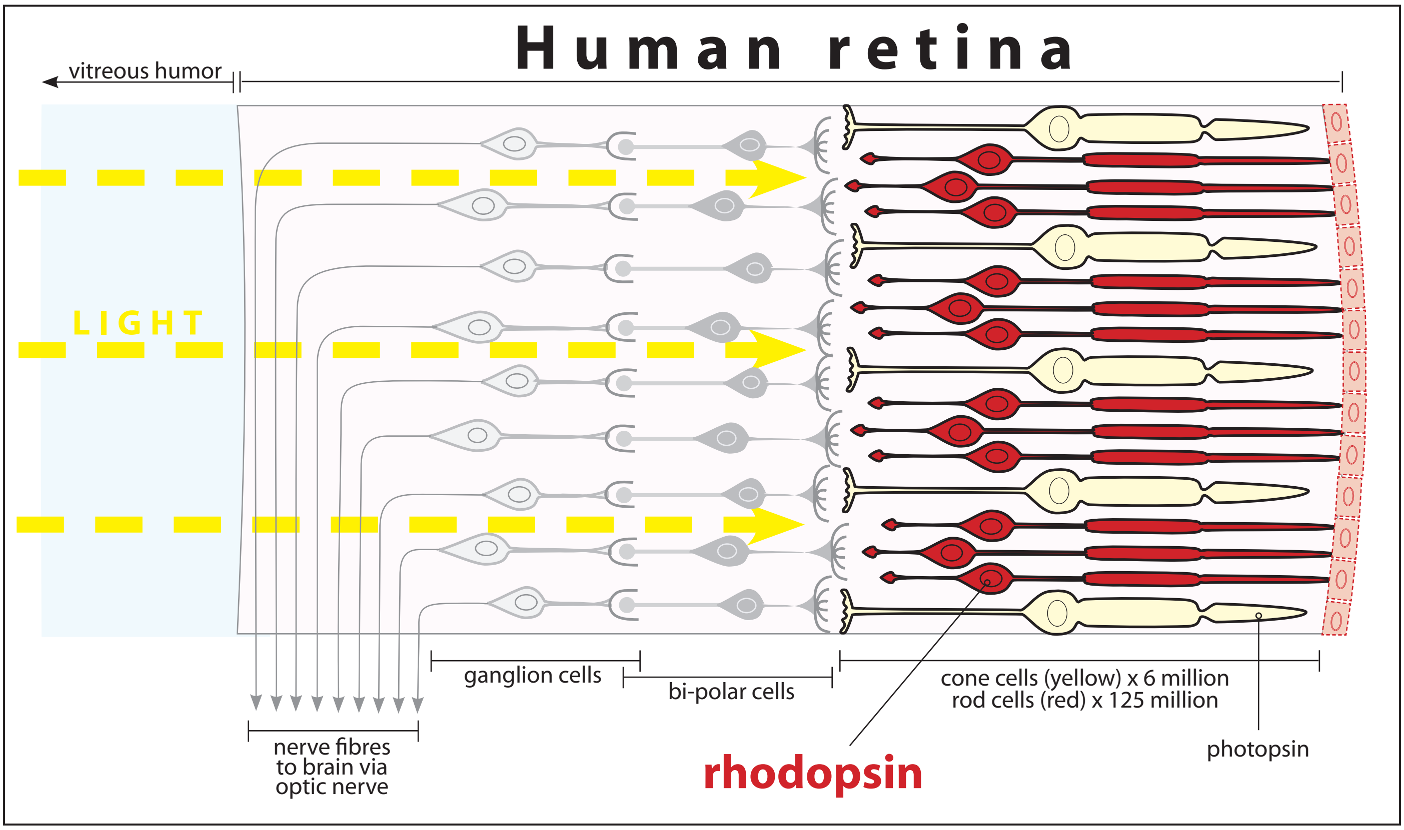
Net-casting spider (*Dinopis subrufa*), Sydney, NSW.

Australia's net-casting spiders are visual hunters and depend entirely on a pair of huge hunting eyes. These are so light-sensitive that the spiders are able to hunt easily by starlight. They can do this because their hunting eyes are lined entirely with bacterial relics that are loaded with the light-sensitive pigment, rhodopsin. The only drawback is that rhodopsin is de-activated by strong light, so the spiders drain the rhodopsin from their hunting eyes each morning and replenish their light receptors each night.

The human eye also has rhodopsin-filled bacterial cells (rods) that are adapted for night vision, but they are protected from the full intensity of daylight by being concentrated around the fringes of the retina, leaving the central area dominated by less sensitive cone cells—the cells that register light's three primary wavelengths, red, green and blue.

The human eye





JULY

(~2.32–1.93 billion years ago)

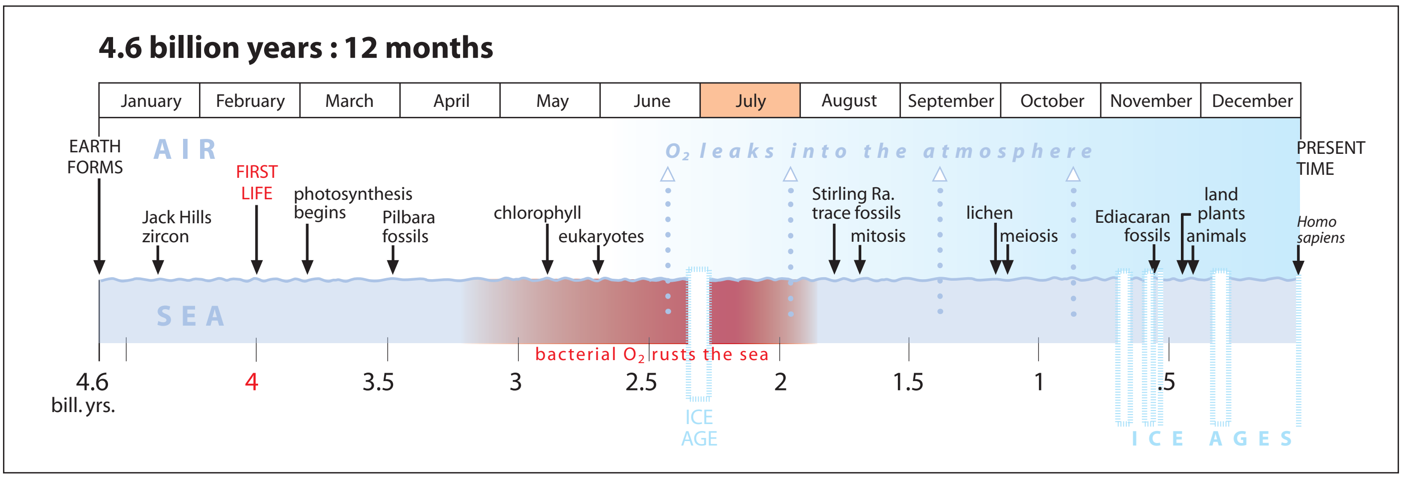
Earth's mid-life crisis

The accumulation of free oxygen has by this time forced a wide range of bacterial defence strategies, including oxygen tolerance in some cases. But by far the most revolutionary of these innovations is the partnership that has developed between some stout-walled archaea (archaebacteria) and a few strains of predatory eubacteria. Instead of plundering their hosts' genetic material and then leaving, a few bacterial invaders find refuge inside their host's doubled walls and become what are known as endosymbionts—internal parasites that earn their keep by providing goods or services that contribute to the survival of their hosts, and thereby, of themselves. The result is a chimera, a composite form that incorporates elements from both branches of the bacterial tree of life. Known as eukarya, this branch will one day evolve a corporate form that will include 'You'.

Most of the internal structures—organelles—of modern eukaryotes seem to have originated as endosymbionts. Each cell has a number of internal powerhouses known as mitochondria that appear to have evolved from oxygen-tolerant purple sulfur bacteria. These must have taken refuge inside their archaeal hosts at some time in the distant past, and then repayed their hosts by mopping up any stray oxygen and re-packaging its dangerously reactive atoms in a benign, but energy-loaded form known as adenosine triphosphate, or ATP. Cells can can dismember ATP at will—whenever energy is needed for growth, repair or replication. Your body cells each house a number of mitochondria, and it is their prodigious production of ATP that maintains your cellular functions during every moment of your life. In short, those ancient bacterial invaders now power every beat of your heart, every move that You make and every thought that You have. To put it in its full evolutionary context, your present existence was essentially midwifed by the explosion of photosynthetic bacteria in Earth's iron-loaded seas between 3 billion and 1.8 billion years ago, and your oxygen-fuelled life still depends on its bacterial energy suppliers, mitochondria.

Memorials to this milestone in the evolution of You lie scattered about the planet in the form of iron-rich deposits known as banded iron formations (BIFs), and the greatest of these memorials is the Hamersley Ranges in north-western Australia. This gigantic deposit is up to 2.5 kilometres thick in places and is the accumulated fallout from a billion years of oxygen pollution by cyanobacteria. The Hamersley Ranges also commemorate the greatest pollution crisis that life has ever faced, a crisis that resulted in the greatest mass extinction ever inflicted on the biota by life itself.

But invariably, environmental stress is evolution's spur, and the biological catastrophe also nurtured the newest branch on the bacterial tree of life. This chimeric third branch, the eukarya, now dominates much of the the planetary surface and is still characterised by the intimately collaborative process that originally rescued surface life from extinction. It also provided the key to the evolution of fully integrated corporations of cells, including multicelled giants like You.



Hamersley Range, WA.

ABOVE: Massive deposits of oxidised iron, like those that form the Hamersley Ranges in Australia's north-west, helped to sweep the world's oceans free of soluble iron by 1.8 billion years ago. In some places this rusty seabed is almost 2.5 kilometres thick. It is thought that the sediment accumulated to this depth because the seabed gradually sagged under the growing weight of iron that washed from the Pilbara landmass and became oxidised by the vast blooms of photosynthetic bacteria that lived in the Hamersley Basin.

BELOW LEFT: Repeatedly shaved down by sheets of ice, the Hamersley Ranges have, in recent time, been carved into a maze of gorges and slot canyons by creeks such as this one in Hancock Gorge.
*BELOW RIGHT: Growing out of the iron oxide that commemorates life's greatest crisis, a Western Snappy gum (*Eucalyptus leucophloia*) epitomises the balance that life has achieved between oxygen production via chlorophyll and oxygen consumption via mitochondria and ATP.*

Waterfall, Hancock Gorge, Hamersley Range,, WA.

Western Snappy gum, *Eucalyptus leucophloia*, Hamersley Ra., WA.