Editorial

EVOLUTION

Medical schools do not teach the principles of evolution as part of the curriculum and thus only a few doctors understand the mechanisms by which human life, anatomy, physiology and biochemistry originated and became developed and refined over the years. This is unfortunate because an evolutionary approach allows a better insight and integration of knowledge, and an expectation and awareness of some potential future problems.

Evolution requires entities with fairly stable patterns of inheritance but with an emergence of occasional variations in the genetic material (mutations), different rates of survival, and thus reproduction potential, of the entities, and sorting pressure (natural selection) exerted by changing environments which ensured the supremacy and thriving of the more 'beneficial' variations. Natural selection sorted successful individual organisms, and thereby selected their genes, to survive in the longer term. Evolution can be observed down microscopes: bacterial variants with their underlying genetic mutations are being selected out all the time by their environments (specifically antibiotic environments) to develop antibiotic resistance. Over time cumulative natural selection occurs.

Evolution, *unlike natural selection*, is irreversible because it would be most unlikely that a genetic variant could mutate back to the original form. Contrary to popular thought natural selection usually *restrains* evolution, which would otherwise happen at the mutation rate, by weeding out those mutated variants which would cope less well. Had environments differed slightly then present successful life forms could have been very different (for example dinosaurs and not man might have been the survivors).

It is tempting to claim that certain features were evolved to fulfil a specific purpose. For example, many believe that the thumb evolved to allow tools to be grasped yet no one would believe that the thumb evolved to press the space bar on a computer keyboard. The truth is that no organism ever chose to mutate or evolve itself actively for any purpose, but rather the more successful were selected: the more successful variants were passive victims of their success or failure.

The definition of what constitutes life is ethereal and difficult to define, and it may be that life does not come into existence at a particular point, except in human classifications. The interaction between environments and self-replicating, occasionally mutating, chemical entities may select life. There may well be a series of evolutionary transitions from quarks to carbon-based life forms.

Since there are an estimated 100 billion billion planets in the Universe it seems unlikely that life only happened on one. Why is there no evidence of life elsewhere in the Universe and, if life does exist elsewhere, why have we not been visited by civilisations as, or more advanced than ours? There are five possible answers. Firstly, interstellar space flight is impossible (this seems unlikely). Secondly, aliens for some reason do not wish to visit us (no comment!). Thirdly, alien civilisations are rare, do not exist, or destroy themselves (scientists are performing experiments in particle accelerators to determine what may have happened at the Big Bang. *This is worrying*). Fourthly, the distances (and thus the time) involved make interstellar travel unlikely (the nearest star system is 4.5 light years away). Fifthly, alien life forms that might visit us would be too intelligent to bother; if they had the technology for interstellar travel what would they have to gain from studying our primitive achievements? Perhaps we have been lucky not to have been visited because the history of evolution suggests that more developed life forms tend to displace, or at least exploit, less developed life forms.

In any event or classification, life developed on earth.

Unicellular organisms could only be small, as nutrients could not diffuse into bulky single cell; whereas multicellularity enabled feeding to be more efficient, facilitated the development of distinct cell types which (we have about 126 types of cell) reduced the need for intracellular specialisation, facilitated movement, aided dispersal and enabled avoidance of predators. Multicellularity required both slow and fast internal communication systems, and the endocrine and nervous systems were selected which gave their possessors survival value.

When natural selection acts on organisms that produce variations by shuffling *two* genetic packs of cards (sexual reproduction) then evolution proceeds faster than by non-sexual reproduction which only involves variation in *one* genetic pack of cards. Thus, sexually reproducing organisms were at an advantage.

Our more remote ancestors came from the oceans, almost certainly via fresh water in estuaries (we are left with some remnants of our ancestry in that we have diving reflexes, partial webbing of the fingers and we can hold our breath under water for several minutes).

Eventually organisms invaded the land, but any organism that evolved to be mobile on the land would have to be reasonably large, and this created problems of scale because, if an organism doubles the length of one of its dimensions, the surface area increases with the square of that dimension, and the volume (and usually the weight) with the cube of that dimension. The surface area available for certain functions (such as gas exchange and absorption by the gut) has to be in proportion to the body weight to be supplied. Cumulative selection of mutations occurred which increased surface areas such as our honeycombed lungs, and multiple projections of the absorptive surface on both the macroscopical and microscopical scales in the gut.

Natural selection favoured warm-bloodedness in some land-based animals as it allowed chemical reactions within the organism to be more predictable, reliable, quicker, and independent of variable environmental temperatures. Ice ages would select for intelligent warm-blooded life forms that could keep themselves warm (unless they happened to live in the tropics where there were less extremes of temperature).

Animals which had mutations which allowed them access to advantageous environments flourished. It seems that the ancestors of man (the primates) took to the trees and those attributes selected by this environment were rapid agile movements, good senses including binocular vision, a good brain which could learn new tricks, versatile limbs, balance and self awareness. The primates took to the trees, developed fingers with nails, eyes at the front (rather than the side) of the head and, by about 40 million years ago, developed forelimbs that were not weightbearing but became arms and hands, which released the mouth from its predation and defence role, and allowed the mouth to be used for communication. Positive Babinski responses were selected in tree living primates to enable reflex grasping of branches (when our central nervous system is damaged or we switch off our cortex when asleep we revert to the more primitive extensor Babinski responses).

The ancestors of man became successful because tool making, logical reasoning, ability to congregate and co-operate, language development and self-awareness were naturally selected. Tool use was obviously extremely useful but the use of a tool implies that the animal concerned could make abstract conceptions in a mind that an object could be so designed and used. Once this had occurred then the next evolutionary leap forward was the making of tools, an ability which requires forethought and planning.

Having a body of a trillion cells almost ensures that a few cells become infected, malignant or otherwise deranged every day. Long-term survival required some means of internal house-keeping, with monitoring and controlling mutations. Immunocompetent individuals were naturally selected by the development of phagocytes and immune systems with cellular and antibody mediated arms.

Integration, computation, memory formation and retention became essential survival attributes, with the central nervous system becoming pivotal to the continued enhancement of survival potential and fuller development.

How did the brain become organised by selective pressure of successive environments? Why do nearly all nervous pathways, afferent and efferent, cross the midline? Presumably because vision (which demands crossing of the midline) is responsible. If a threat in the right visual field (derived from complementary parts of each of the two retinas) is appreciated in the left visual cortex, then *afferent crossing,* must occur and, as immediate action is required for the nearest (right side) limb to deal with the threat then *efferent crossing* is also required. Presumably most nervous pathways also had to cross to integrate and capitalise on binocular vision because it conferred great survival potential.

Why do pain and temperature fibres cross shortly after arrival in the spinal cord? In worms this occurs so that the contralateral muscles to the dangerous stimulus contract so that the worm flexes itself away from, and did not wrap itself around, the noxious stimulus. Did similar considerations cause our remote ancestors to have preferential survival?

Key dates for your calendar:

- **Big bang about 15,000 million years ago.**
- **Galaxies formed 10,000 million years ago.**
- **Sun and solar system formed 5,000 million years ago.**
- **Earth formed 4,500 million years ago.**
- **Life developed about 3-4,000 million years ago.**
- **Multicellular organisms developed about 700 million years ago.**
- **Life moved from seas to the land about 400 million years ago.**
- **Trees and forests came into being 370 million years ago.**
- **The crawl from the swamps onto land started 360 million years ago.**
- **Dinosaurs became extinct 65 million years ago.** ***We never met them.***
- **Chimpanzees (with whom we share 98 percent of our genes) split from our shared ancestors about five to seven million years ago (the common ancestor has not been fully identified: 'the missing link').**
- **The oldest hominoid was *Australopithecus* (southern ape) which first appeared about four million years ago. *Australopithecus* was about four feet high, lived in social groups, had 400 ccs of brain and was bipedal.**
- **Stone tools were being used in Africa about 2.5 million years ago.**
- ***Homo erectus* developed about two million years ago.**
- ***Homo sapiens* developed about 500,000 years ago Neanderthals were using fire about 100,000 years ago.**
- **Cro-Magnon men (and women!) were artistic and using tools extensively 40,000 years ago.**

Why are most people right-handed? William Calvin (in his book *The Throwing Madonna*) suggests that babies needed to be carried by the mother's left hand so that they could be comforted by the maternal heartbeat, and this would leave the right hand free to throw, cook etc. But what were the selection pressures that caused the heart to be predominantly left-sided? It, of course, is not impossible that a left-sided heart was genetically linked with other favourable genetically determined attributes.

Why are there two sides to the heart? The upright posture means that a high blood pressure is required to perfuse the head but such a pressure would cause pulmonary gas exchange vessels to be too thick to allow diffusion of gases, so the development of two pressure systems was advantageous. Fish, which are horizontal creatures, can function at lower blood pressures, and need only a single ventricle.

Essentially the human animal is a self-aware, intelligent, adaptable, bipedal, African ape with our nearest relative being the chimpanzees. Against all the odds each and *every one* of our ancestors reproduced before dying which makes each one of us highly unique, but not special.

EVOLUTION: THE FUTURE

Man will be in control. Organisms which, until now, have been passively evolved will become actively evolved. We will upstage natural selection by modifying and controlling our environment, and by the practice of medicine. More specifically our inherited and evolved genetic make-up will now be directly manipulated by implanting or removing genes, to augment further our capabilities (by use of 'better' genes) or to replace missing or 'poorer' genes.

Medicine is about to participate in a post-Darwinian era when we will be able to control evolution once we have the genetic capability to induce or correct mutations *for a purpose*. Such actively assisted attempts at channelling evolution have to be orchestrated carefully and assed precisely. Going by what we can observe thus far, it is likely that we will not face up to the practical or ethical implications of this unprecedented major change in biology. Already there have been examples of genetically modified plants which were released without adequate supervision. The omens are not good.