PSYCHOLOGY Live **SERIES**

USER'S GUIDE

Evolutionary Theories
EVOLUTION BY NATURAL SELECTION

This Guide is designed to be read before viewing and an overview of the content and structure of the programme is given to assist with planning and lesson preparation. It is written to support the teaching of psychology and will be particularly helpful for those new to this subject. The DVD includes a menu linking to sections within the programme. The default setting is to play the DVD through automatically. To select a section highlight the relevant heading using the arrows on your remote control and press 'ENTER'. The chosen section will then play through and return to the menu for your next choice.

Running time: 48 minutes (1997)

We hope you find this programme a useful teaching tool.

Introduction

This programme is designed to be watched in small parts with frequent breaks for consolidation. It contains too much information to be useful if viewed from start to finish in one sitting. Ideally a suitable section will be watched in one session, making liberal use of the pause or stop button for discussion and/or note taking.

We have included six breaks for thought, discussion or activities and details of these are listed in this Guide. A 'Pause The Video' screen is shown for several seconds during each break to allow time for those watching on video to pause, or turn off and switch on again.

The study of evolution is a topic which students always enjoy discussing. We hope that information and ideas in the programme and Guide stimulate debate and offer ideas for further study.

Syllabus links

AQA A2 (A) Mod 4 13.5 Comparative Psychology Evolutionary explanations of behaviour
Mod 5 14 Perspectives Approaches (b) Evolutionary Psychology
13.5 Determinants of animal behaviour
AQA AS (B) Mod 1 The Biological Approach 10.2.1 Evolution and Human Behaviour

Timing and Content of the programme

00.00 Introduction

03.00 An Alternative Theory of Evolution

04.30 Charles Darwin

18.00 The Theory of Natural Selection

20.30 Problems with the Theory

22.00 Evidence to Support the Theory

24.00 Altruism or Selfishness?

32.30 Explaining Human Behaviour

Timing and Content of the Breaks

Break 1 Why did Darwin wait 20 years before publishing his theory?

Break 2 How did Natural Selection change the colour of the peppered-moth?

Break 3 How can the theory of Natural Selection explain the increased length of giraffes' necks?

Break 4 Write down the height of your ideal partner of the opposite sex and your own height.

Break 5 How can we explain the finding that step-parents are statistically more likely to harm their step-children than their biological children?

Break 6 Why should the majority of step-parents care for their step-children even though there is no genetic advantage in doing so?

Extra information

Our scriptwriter Dr Pauline Bird, whose area of expertise this is, has provided much interesting information for this Guide. Some of the theories and ideas described will not be found in student textbooks but will fascinate students and enhance their understanding and written work. Articles could be given to students for discussion or private study to expand the readily available knowledge of evolution.

Articles

- The Aquatic Ape Theory
- The Story of Alfred Wallace
- Steven Gould and Adaptation
- Mutation
- The Problem of the Eye
- Has Language Evolved?
- How Did Life Begin on Earth?
  - i The Primeval Soup Theory
  - ii The Inorganic Mineral Theory
- Altruism and Selfishness Revisited

The Aquatic Ape Theory

At the beginning of the programme, we saw that the first creatures to stand upright were the Australopithecines. The generally accepted explanation is that this change in stature came about when apes came down from the trees and became hunters on the plains of Africa. This theory is dismissed by Elaine Morgan, a self-taught science writer (Morgan, 1997). **She suggests that humans learned to walk upright by wading through water, developed blubber as a means of keeping warm, and learnt to talk by using breath control initially adapted to enable them to dive underwater**. These aquatic apes supposedly lived on the shores of an island about seven million years ago. It was formed by the flooding of the area that is now Ethiopia.

> *'There is no other theory currently accepted which offers a unified explanation of why we are naked, vocal and bipedal*," writes Morgan. *"When scientists examined the pollen from areas where they found bipedal remains it was not consistent with us having lived on the plains. Many of the places where they have found fossils were watery, lakeside spaces and any ape living in those conditions would have to stand up and wade on two legs."*

Morgan illustrates her point with examples of animals that currently walk upright. The proboscis monkey of Borneo, for example, lives in habitat consisting of trees, land and water and regularly crosses stretches of water on two legs, in order to move from one feeding ground to the next. The theory also explains our nakedness.

> *'The most effective way of insulating a body in air is a coat of fur, but that does not work in water. We have a much higher proportion of fat than any other mammals because the more effective method of insulation for aquatic mammals is a lining of fat.'*

According to Morgan, this watery existence was responsible for the development of vocal communication among humans. *"We are able to talk because we have conscious breath control which is found in all diving animals. The reason an ape cannot speak is not because there is anything wrong with its tongue or its throat; it's because it cannot control its breath."*

The aquatic ape theory was first aired in 1960 by Sir Alister Hardy, Professor of Marine Biology at Oxford University. It was greeted with dismay by evolutionary anthropologists, many of whom have been trying to ignore the idea ever since. This theory is not met with acceptance by the established scientific community, perhaps because the non-aquatic theory is fully entrenched in all the scientific literature, and partly because Elaine Morgan is an amateur. Some scientists, including Daniel Dennett (see *Darwin's Dangerous Idea*) agree that there is nothing inherently wrong with the idea, it is just not sufficiently convincing to counteract the arguments against it.

In 1991, Roed et al published "The Aquatic Ape: Fact or Fiction?" – a collection of essays by a variety of experts, for and against the aquatic ape theory. If you are interested in the topic, this book would be a good place to start, after reading Morgan's book.

Morgan, E. (1997) *The Aquatic Ape Hypothesis* London: Souvenir
Roed, M., Wind, J. & Reynolds, V. (Eds) (1991) *The Aquatic Ape: Fact or Fiction* London: Souvenir,
Hardy, A. (1960) *Was Man More Aquatic in the Past?* New Scientist, 642-45
Dennett, D.C. (1995) *Darwin's Dangerous Idea* London: Penguin

Alfred Wallace

You will have heard in the film that Darwin was not the only person to have identified natural selection as the means by which new species must have evolved. Alfred Wallace had been lying ill with fever in a remote island near the western end of New Guinea when the idea 'flashed' to him. In his biography, he gave this account of how it happened.

> *I was then [February, 1858] living at Ternate in the Moluccas, and was suffering from a rather severe attack of intermittent fever (malaria), which prostrated me for several hours every day during the cold and succeeding hot fits. During one of these fits, while again considering the problem of the origin of species, something led me to think of Malthus's Essay on Population (which I had read about ten years before), and the "positive checks" - war, disease, famine, accidents, etc - which he adduced as keeping all savage populations nearly stationary. It then occurred to me that these checks must also act upon animals, and keep down their numbers; and as they increase so much faster than man does, while their numbers are always very nearly or quite stationary, it was clear that these checks in their case must be far more powerful, since a number equal to the whole increase must be cut off by them every year. While vaguely thinking how this would affect any species, there suddenly flashed upon me the idea of the survival of the fittest - that the individuals removed by these checks must be, on the whole, inferior to those that survived. Then considering the variations continually occurring in every fresh generation of animals or plants, and the changes of climate, of food, of enemies always in progress, the whole method of specific [ie species] modification became clear to me, and in the two hours of my fit I had thought out the main points of the theory. That same evening I sketched out the draft of a paper; and in the two succeeding evenings I wrote it out, and sent it by the next post to Mr Darwin.*

Darwin was mortified because it was clear that Wallace, quite independently, had also arrived at the idea of natural selection, and although Darwin had been working on the theory for twenty years, he had not established his 'right' to it by formal publication and could, therefore, not claim the theory as his own. Wallace did not mention publication but Darwin was ready to send Wallace's paper to any journal of Wallace's choice.

Darwin wrote to inform his friend, Charles Lyell, stating, "all my originality, whatever it may amount to, will be smashed." Lyell mulled over the problem and came up with the solution to the delicate situation; they should announce their discoveries jointly, with papers being submitted to the Linnean Society in London.

Darwin did not attend and Wallace, of course, was still on his travels. The papers were read by the Secretary to the 30 or so scientists present. In the event, there was little or no response from the audience. Perhaps as a result of this, Wallace felt no need to return, whilst Darwin was urged by his colleagues to hurry and expand the theory into book form. The following year, in 1859, *'The Origin'* was published. Wallace had graciously sent his approval.

At first sight, it seems strange and unfair that Wallace's achievement has been overshadowed by that of Darwin, but there was one crucial difference between them. Wallace had become deeply interested in spiritualism and psychic phenomena, and did not believe that the complexity of man's mental powers could be satisfactorily explained through natural selection. There was also a subtle difference of emphasis on how natural selection operated. Wallace emphasised the environment as eliminating the unfit, rather than a cut-throat competition among individuals. But this is merely a difference in emphasis in the manner of presenting the argument, rather than a real point of theoretical difference.

Wallace's achievement in unravelling the theory of natural selection cannot be overstated. Unlike Darwin, he was not born with a silver spoon in his mouth. He was an impoverished lawyer's son, born on the Welsh borders, and apprenticed to a builder in London at fourteen. In 1844, he took a teaching job in Leicester, and there he had the opportunity to read Malthus's Essay, as well as popular works of natural history and exploration. In the town library at Leicester, Wallace met H.W. Bates, the well-known entomologist, and in 1848 they set out for the Amazon region, on an expedition supported by an American naturalist whose acquaintance they had made in London. Their objective was to collect botanical and zoological materials for sale on their return.

Wallace stayed in South America for four years, but it was to end in disaster when the ship he was returning in was destroyed by fire, together with nearly all the specimens he had collected in the four years of work in the jungle. Wallace himself was fortunate to escape in a small boat and was later picked up by a passenger boat returning to London. He was taken in, almost penniless, by his sister, but was able to redeem his position to some degree by publishing a book on his travels. In this period, Wallace attended meetings of the Zoological Society in London and made the acquaintance of some of the leading scientists of the day.

For eight years, beginning in 1854, Wallace with the help of an assistant explored parts of the world that were then almost unknown to Western man. He sent shipments of beetles, butterflies, and bird skins to a London dealer to help pay his way. He had to pack a thousand labeled beetles per box, but it was a living.

Wallace travelled about fourteen thousand miles in this period, all the while turning over in his mind the problem of the origin of species. Like Darwin, he was able to bring to bear on the problem his very wide experience of the geographical distribution of plants and animals, acquired through his travels in Brazil and South East Asia. He kept up a correspondence with Darwin, sending him specimens which he thought would be of interest. But although Wallace kept Darwin informed of his ideas, Darwin did not tell Wallace the details of his theory. It was during this period that Wallace suffered the fever and the inspiration for the theory of natural selection came to him.

Wallace, A.R. (1905) *My Life: A record of events and opinions 2 vols* Chapman & Hall
Darwin, C. (1859) *The Origin of Species* Murray, London (1985) *The Origin of Species* Penguin, London

Stephen Gould and Adaptation

For the past 30 years, Stephen Gould has carried out a public quarrel with many of his scientific colleagues. It is useful to know what all the fuss is about.

Stephen Gould alleges that too many of his scientific colleagues dream up adaptive explanations for too many animal behaviours without scientific evidence to back them up.

Gould's views cannot be ignored since he is a scientist of immense stature in the field of evolutionary science. He is not only Professor of Geology and Zoology at Harvard University but also a prolific populist writer on evolution. For two decades his monthly column in Natural History has given professional and amateur biologists a continuing update on the latest ideas and scientific findings about evolution.

Gould has also written endless populist books expounding Darwinism which he defends most vigorously when it is abused, such as when racists claim Darwinism supports their views. He can frequently be found in the law courts as a witness for the defence that the theory should be taught in schools in middle America. Most people have a hazy understanding of evolution, but what views they do have, in America at least, may be due to Gould more than to anyone else.

Why then are so many scientists hostile towards him? The answer is that he attacks his scientific colleagues in the same manner that he attacks critics of Darwinism. He attacks them for all too often fabricating explanations of animal behaviours to fit Darwin's theory.

One example relates to certain sea turtles which migrate all the way across the Atlantic between Africa and South America, spawning on one side, feeding on the other. Adaptionists suggested that this habit started when Africa and South America were first beginning to split apart; at that time, the turtles were just going across the bay to spawn; the distance grew longer over the ages, until their descendants now cross an ocean to spawn.

Gould has criticised this kind of explanation because there was no evidence to support it. Indeed, the story has been discredited since it was found that the breakup between South America and Africa does not match the evolutionary timetable for the turtles. Adaptionists point out that forming hypotheses of this kind, which can be disproved in the light of new knowledge, is the proper scientific method and therefore defend such adaptive explanations even if, sometimes, they may prove to be wrong.

Sometimes Gould does accept an Adaptionist explanation, such as that given to the bizarre behaviour of the cicadas, an insect which is something like a locust and is widespread in the East and Midwest of the United States of America. Its behaviour is unusual because all but one month of its life is spent underground where it feeds on sap from tree roots. After 13 years, all the cicadas emerge from the ground at exactly the same time to moult, feed, mate and die. Another species of cicadas lives in exactly the same way but emerges after 17 years.

The Adaptionist explanation put forward by Lloyd & Dybas (1966) for this odd behaviour continues to be accepted by most scientists as well as by Gould. They maintain that by having a large prime number of years between appearances, the cicadas minimise the likelihood of being discovered and later tracked as a predictable feast by predators who themselves show up every two years, or three years, or five years. If the cicadas had a periodicity of, say, sixteen years, then they would be a rare treat for predators who showed up every year, but a more reliable source of food for predators who showed up every two or four years, and an even-money gamble for predators that got in-phase with them on an eight-year schedule.

The point that Gould is making is that there is no objective way of deciding when an Adaptionist explanation is a valid one, and that once one explanation is discredited, another Adaptionist answer is sought. But there may not be one. Not every physical asset or behaviour has a function that has been selected. For example, the African heron uses its wings primarily to block reflections on the surface of the water while looking for fish. The heron's wings have not evolved to be used as reflectors but to help it fly. Nevertheless, the heron has found a new function for its wings and Gould has argued that to search for adaptive explanations for this behaviour would be futile.

Behaviours and physical features that do not have adaptive histories, Gould has called exaptations. An exaptation describes any organ or behaviour not evolved under natural selection for its current use. Examples of these include the fact that blood is red in colour and that there is a prime number of digits on each hand. A widely disputed claim for an exaptation is language, with Gould, Chomsky and others on one side, and Adaptionists on the other. This subject is discussed further under the section on language in this booklet.

It is hoped that these notes will give you a flavour of the sort of scientific debate that continues on the issue of adaptation. In defence of those opposed to Gould, it is worth pointing out that even if many features and behaviours are not adaptations, this does not minimise the impact of natural selection. Natural selection could still be 'the exclusive mechanism' of evolutionary change even though many features of organisms are not adaptations.

Lloyd, M. & Dybas, H.S. (1966) *The periodical cicada problem* *Evolution*, 20, 132-49

Gould, S.J. & Lewontin, R. (1979) *The Spandrels of San Marco and the Panglossian Paradigm: A critique of the adaptionist programme* *Proceedings of the Royal Society*, Vol B205, 581-98

Gould, S.J. & Vrba, E. (1981) *Exaptation: A missing term in the science of form* *Paleobiology*, Vol 8, 4-15

Mutation

During the film we mentioned DNA and how every living organism shares the same four nitrogen bases, A, C, T and G. These four nitrogen bases are combined in specific ways to form genes. Every species has its own number or 'pool' of genes from which each individual receives its share when it is born. Sometimes the genes get twisted or distorted in some way and the infant inherits a mutant gene.

No mention is made in the film of *mutation*. This was deliberate because mutation is the stuff of biology and also because Darwin's theory of natural selection can be explained without it. After all, Darwin himself had no knowledge of genes, let alone mutation. **The point about Darwin's theory is that it operates on variation - that is, the differences between individuals within a species. All variation of form is genetically based. Most variation occurs without mutation. Variation occurs because newborns inherit two sets of genes, one set from their father and one set from their mother.**

Siblings who share the same parents do not get the same two sets of genes. Each time a child is born, he or she receives two different sets. This is because the genes are shuffled each time an egg or sperm is created. What mutation does is to introduce novel genes into the gene pool of a species. But its occurrence is very rare.*

It occurs in the first place when an individual is born with an 'altered' gene, which has either been damaged in the shuffling process, or through radiation of some kind. The mutant gene may be detrimental to the body it is born in and is likely to be selected out. That is, the owner of the mutant gene dies before reproducing its own offspring. Sometimes, a mutant gene is beneficial to the body it is born in. In this case, the owner may experience some advantage over others which is passed on to its own offspring and thus, the mutant gene spreads and becomes part of the established gene pool of that species. The mutant gene takes its place on the chromosome where its predecessor lived.

An example of a beneficial mutant gene might be to create teeth in a tiger to be a little sharper than those that would be grown under the influence of a rival gene. A tiger with extra-sharp teeth can kill prey more efficiently than a normal tiger; hence it has more offspring; hence it passes on more copies of the gene that makes sharp teeth. The gene itself benefits by ensuring that it is inherited through subsequent generations. By the same principle, a detrimental mutant gene might occur in the form of a withered bone in an animal's leg, an event which drastically reduces its chances of surviving and producing offspring. Natural selection, in this case, brings about the mutant gene's death.

> * *Rates of mutation vary. In viruses it can be frequent.* ***"The AIDS virus has undergone so much mutation in ten years that its history over that period exhibits more genetic diversity than is to be found in the entire history of primate evolution."*** *(Darwin's Dangerous Idea 1995 p 195).*

Other types of DNA are remarkably stable over billions of years. The H4 gene consists of 306 DNA characters, 304 of them are found in identical form in cows and peas. Calculations suggest the common ancestor of cows and peas lived about 1.5 billion years ago. This means that the H4 gene has copied itself with only two alterations, some 20 billion times. There may have been other errors on the way which did not survive or reproduce themselves and so became edited out by natural selection. (The DNA molecules themselves, as physical entities, do not live for very long, perhaps a few months. What live through millions of generations are perpetual copies of themselves.)

Dennett, D.C. (1995) *Darwin's Dangerous Idea* Penguin London
Dawkins, R. (1990) *The Selfish Gene* Penguin London
Dawkins, R. (1991) *The Blind Watchmaker* Penguin London

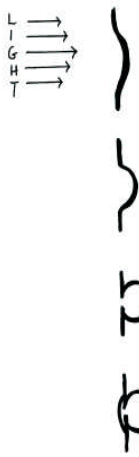
The Problem of the Eye

One of the most commonly quoted examples of why Darwin's theory of natural selection cannot be correct, relates to the human eye. **How could something as complex as the human eye have evolved from nothing? And what advantage would a little bit of an eye benefit an animal? It still wouldn't be able to see.** The explanation anti-Darwinists offer is that the eye must have been created as a whole entity by a designer, and that designer must be God.

It could not have come about from bit-by-bit tiny additions, as Darwin's theory demands. This argument was first voiced by the theologian William Paley in 1802 and has been influential ever since. The reason why it is so difficult to grasp how something as detailed as the eye could evolve is because it is so difficult for us to imagine what hundreds of millions of years must mean. This is the amount of time available for the eye to have gradually appeared, bit by bit, each part building on the whole of the previous form.

As it turns out, computer calculations have been carried out and show that if a mutation causes 1% of change in the size or shape of the eye, the evolution of the eye would take about 250,000 generations, which if each animal lived four years, would be a million years - no time at all in evolutionary time.

Many evolutionary scientists have put their mind to 'the problem of the eye', and shown how it could have happened. Suppose, in the beginning, an ancestor didn't have an eye, but a single sheet of light sensitive cell, such that light and dark could be distinguished. This animal would be advantaged over those who did not have the light sensitive cell.



The next stage of evolution would be light sensitive cell shaped like a shallow cup. This animal would be able to tell the direction that light is coming from because a shadow would appear, and if you can do this, you have a chance of knowing where a predator is located. Over time, as the cup-shape became bigger so that eventually it is an enclosed bowl with just a hole left, this animal would be able to see a fuzzy image as well as locate where other animals and objects are.

When the hole is a pin-hole, the predator would be seen in detail, although out-of-focus. Indeed a mollusc has an eye exactly like this. It is a relative of the octopus, but it lives in a shell and its eye is a simple hole through which sea water can swim in and out. The squid and octopus have more complex eyes because they have a lens.

A lens, in the beginning, would have been a sheet of transparent material which covers the pinhole and protects it. It makes no real improvement on vision until it is thickened, by which time, the animal can identify faces and other fine details of images. Thus it can be seen that half an eye is better than no eye; half an eye is better than 49% of an eye, and 1% of an eye is better than no eye at all.

There are many different kinds of eyes, each of which has evolved independently of each other. Scallops have mirrors instead of lenses, very much like the Jodrell Bank telescope, and form images in the way a reflective telescope does, not as human eyes do. Some insects have hundreds of little eyes which add together to make one image. Spiders and squids have eyes which are completely different and have also each evolved in their own specific ways.

Similar anti-Darwinist arguments have been made against the evolution of the wing. What is the good of half a wing? And so on. The answers follow very much the same steps as those given for the 'problem' of the eye.

Paley, W. (1802) *Natural Theology 5th Ed.* Printed for R Faulder, 1803

Language Evolution

Those of you who have studied the topic of language in psychology will already know that up until 1956, B.F. Skinner's views about language had dominated the psychological landscape for some twenty years. Skinner believed that language was learned through operant conditioning in much the same way that other behaviours are learned. Children imitate their parents and others who, in turn, reinforce children's accurate speech and correct it when it is wrong.

Chomsky, however, showed that our ability for language is largely innate. We are born with a basic grammar already wired into our brains which is common to all languages. That's why it is so effortless, according to Chomsky, for even 'slow' children to learn to speak. They aren't really learning at all, any more than birds 'learn their feathers' – they just are. He asserts that children's application of inborn rules explains many of their early errors in language. For example, a standard rule for constructing the past tense is to add '-ed' to the end of a verb. So children will be heard to say, "I sitted down," or "I eated" - both forms of speech that are inconsistent with Skinner's emphasis on imitation because most adult speakers don't use speech in this way.

Although Skinner put up a vigorous defence of learning theory and language throughout the 1960s, he was to lose the battle to Chomsky. Now, at the beginning of the 21st century, it looks as though the pattern may well be repeating itself, only this time Chomsky is under attack.

One would think that Chomsky, who accepts that there is 'a mental organ' that is well designed for language acquisition, would view this mental organ as the product of natural selection - that is, as an adaptation. But Chomsky will have none of it.

> *"It is perfectly safe to attribute this development [of innate language structures] to 'natural selection', so long as we realise that there is no substance to this assertion, that it amounts to nothing more than a belief that there is some naturalistic explanation for these phenomena."* (Chomsky, 1972).

'The language organ', Chomsky suggests, is not an adaptation, but a mystery which will be explained one day, not by biology but by physics.

It should now be clear that if a behaviour is an adaptation - that is, it has evolved over time through the process of natural selection - this means it must have evolved for a particular use and function. There are certain circuits in the human brain, which are missing from brains of chimpanzees, that appear to function particularly for language. Stephen Gould, however, does not think so.

> *"I don't doubt for a moment that the brain's enlargement in human evolution had an adaptive basis mediated by selection. But I would be more than mildly surprised if many of the specific things it can now do are the product of direct selection "for" that particular behaviour. Once you build a complex machine, it can perform so many unanticipated tasks. Build a computer for processing monthly checks at the plant, and it can also perform factor analyses on human skeletal measure; play Rogerian analyst, and whip anyone's ass (or at least tie them perpetually) in tic-tac-toe."* (Gould, 1979, p 386)

In December 1989, again at the Michigan Institute, the psycholinguist Steven Pinker and his graduate student Paul Bloom presented a paper, 'Natural Language and Natural Selection', in favour of adaptation. Chomsky and Gould had been scheduled to reply, so the meeting was packed to overflowing. Pinker and Bloom started out by facing the opposition.

> *'Noam Chomsky, the world's greatest linguist, and Stephen Jay Gould, the world's best known evolutionary theorist, have repeatedly suggested that language may not be the product of natural selection.'*

They continued:

> *'The assertion that a natural language grammar functions either as a whole or not at all is surprisingly common. But it has no more merit than similar claims about eyes, wings and webs that frequently pop up in the anti-Darwinian literature. There must have been genetic variation among individuals in their ability to use grammar. There must have been a series of steps that led from no language at all to language as we now find it (just as there have been gradations from no sight at all to the present complex vision we have today). Each stage of grammatical competence must have conferred a reproductive advantage on its speakers, and this advantage must have been large enough for it to have become fixed in our ancestors.'*

So when did language begin and would there have been enough time?

> *'As far as we know, there would be plenty of time for language to have evolved: 3.5 to 5 million years if early Australopithecines were the first talkers, or as an absolute minimum, several hundred thousand years in the unlikely event that early Homosapiens were the first.'*

Pinker and Bloom agree that there is no conclusive evidence to support this issue but, on the other hand, nor is there evidence to dispute it.

> *'Although we have no direct evidence of what early language might have been like, the language of children, tourists, telegrams and headlines provide ample proof that there is a vast continuum of viable communicative systems displaying a continuous gradation of efficiency and expressive power.'*

Chomsky and Gould rejected such views. They believe language is a side effect of other evolutionary forces such as an increase in overall brain size and constraints of as-yet-unknown laws of structure and growth.

Pinker, S. & Bloom, P. (1992) *Natural Language and Natural Selection* In Barkow, J., Cosmides, L. & Tooby, J. (Eds) The Adapted Mind Oxford Oxford University Press
Chomsky, N. (1972) *Language and Mind* New York Harcourt, Brace & Jovanovich
Gould, S.J. (1979) *Panselectionist pitfalls in Paker & Gibson's model of the evolution of intelligence* Behavioural and Brain Sciences, 2, 385-386

How did life on earth begin?

Here are just two of the many explanations that have been put forward:

The Primeval Soup Theory

A precise definition of life is difficult but, in a rough sense, an organism is considered alive if both metabolism and reproduction are active. Metabolism refers to the ability to convert energy from the sun to a usable form, or to convert energy from food. (A virus is only half alive since it can reproduce itself, but cannot convert energy).

Before life began, the atmosphere on earth consisted of water vapour, methane and ammonia, with very little oxygen. Experiments in the laboratory have shown that if these four elements are placed in a test tube and subjected to electric sparks, simulating lightning or energy from the sun, all major building blocks of life will appear. In particular, nucleic acids have been found, the molecules from which DNA is formed.

Such an occurrence may well have been happening some three to four thousand million years ago. Rain would have carried these molecules into lakes and oceans to form an ever-thickening 'primeval soup'. Since all the elements for life were sloshing about in this 'soup', some sticking together to make more complex molecules, it is not too far fetched to assume that some of these would eventually 'glue' together in the shape of the first self-replicating molecule RNA. Soon, the Darwinian principle of natural selection began to play an important role, favouring those replicating molecules that could find energy most readily, and DNA was born. These primitive systems eventually evolved into cells and life on earth began.

The Inorganic Mineral Theory

This theory was first proposed in the 1960s by the Glasgow chemist Graham Cairns-Smith and elaborated in Seven Clues to the Origin of Life. Cairns-Smith argues that DNA was itself an evolution from some simpler element that could replicate itself. This original replicator would have been crystals such as those found in clay and mud.

Clays and muds and rocks are made of tiny crystals. These crystals replicate themselves, something which can be shown by carrying out a simple experiment:

Dissolve a large quantity of photographer's 'hypo' fixer in very hot water. Then let the solution cool down, being very careful not to let any dust drop in. The solution is now 'supersaturated'. Now, drop into the solution a tiny flat crystal and a tiny chunky crystal. The two crystals grow visibly; they break up from time to time and the pieces grow. Flat crystals give rise to a population of flat crystals. Chunky crystals give rise to a population of chunky crystals, all sticking together.

If you were to look at these crystals under a microscope, you would see that they are not all identical. Some are slightly different, or flawed in some way. The important point here is that the flawed crystals are copied again and again, just as the original ones were.

But there is still the missing ingredient of 'life'. The suggestion is that the inorganic crystals that we have talked about here will have at some time been integrated with organic, or carbon-type elements, which are crucial to the existence of living organisms.

At this point the theory converges with primeval soup theories. The molecules that formed early versions of DNA, called RNA, may not necessarily have been self-replicating. Cairns-Smith suggests that RNA would coat the outsides of clay particles and in so doing would pick up the self-replicating qualities of the crystals. Once replication of RNA got going, it was more efficient than the crystals they took over. RNA has survived to this day, but very soon splintered into the DNA molecule, the replicator from which all living things on earth have grown.

Dawkins, R. (1991) *The Blind Watchmaker* Penguin Harmondsworth
Dennett, D.C. (1995) *Darwin's Dangerous Idea* Penguin Harmondsworth

Altruism and Selfishness Re-visited

A great deal of the film has dealt with the paradox of altruism. Why are animals and humans able to display a caring and sharing nature when natural selection favours genetic self-advancement at the expense of others? An example of extreme uncaring behaviour is shown by the female digger wasp. She will sting a caterpillar so as to paralyse it but not to kill it. She then lays her egg in the caterpillar so that the larva can feed on the fresh meat. It is not known whether the paralysis acts as a general anaesthetic, or if it freezes the victim's ability to move. If the latter, the caterpillar will be aware of being eaten alive from inside but unable to move a muscle to do anything about it.

Because humans have a moral outlook, the wasp's behaviour appears cruel to the extreme. The wasp, however, is not concerned about the rights or wrongs of the matter. It is completely indifferent. It has no morality.

But according to Frans de Waal, in his book 'Good Natured', many species of animals do demonstrate a moral sense and concern for others, and these acts very often appear to be outside the realms of kin selection or reciprocal altruism. For example, he describes alpha male chimpanzees breaking up fights between other chimps without choosing sides.

He also describes a chimp 'Madam Bee', who was too old and sick to climb a tree where some of the only available fruit hung. From the ground, she watched her two daughters gathering food. Then one daughter climbed down, carrying fruit in her mouth and also in her hand. Little Bee approached, also grunting and placed the fruit from her hand on the ground beside her mother. She then sat nearby and the two ate together.

He recounts an incident in 1976 in which a group of 30 false killer whales stayed together for three days in shallow water near an island off Florida, surrounding their largest member who was sick. Each time an oceanographer swam out to investigate he was lifted out of the water and carried back to the beach by one of the whales. Although the whales could have returned to deep water any time they remained with the sick whale until he died, and then swam out to sea.

Though we would not expect fish to mourn or even notice that one of their number has succumbed to a fishing-hook, according to de Waal whales, dolphins, elephants and apes demonstrate a human-like caring attitude towards their fellows. de Waal, who has studied apes for 20 years, identifies the paradox of how 'evil' (selfish genes) leads to the capacity for 'good' (caring and sharing).

His argument is not that animals have a concept of right and wrong in the way that humans do, but rather that certain aspects of the behaviour of certain animals demonstrate when the evolutionary starting point for morality in humans began.

> *'The fact'* de Waal writes, *'that the human moral sense goes so far back in evolutionary history that other species show signs of it, plants morality firmly near the centre of our much–maligned nature.'*

This approach is in direct contrast to the views of Richard Dawkins and other evolutionary scientists who see nature as selfish. Caring is shown under the guise of kin selection or reciprocal altruism. Morality, which is thought to exist only in humans, is a human invention which is outside the biological realm.

In contrast, de Waal is mainly concerned with the caring behaviour shown by animals. He believes that morality, which includes sharing and sympathy for others, is also an adaptation. Our ability to care for others has been inherited from animals just as our aggressive and darker side has been. He suggests that, instead of human nature being either fundamentally brutish or fundamentally noble, it is both.

There are problems with this argument. Most of de Waal's evidence is anecdotal and this is weak evidence because it relies on de Waal's own interpretation of what is going on. Secondly, de Waal does not state exactly how both selfish nature and a caring one could have evolved side by side through natural selection. Thirdly, de Waal's argument seems to suggest that animals often act on behalf of their group rather than in their own self-interest. Group selection was not mentioned in the film because the issue has been overwhelmed by the impact of gene selection. It seems that de Waal is hinting at the matter once again.

More information can be found in Wynne Edwards (1986) and discussions about group selection in various textbooks. Altruism and selfishness are topics that will not be going away. It is important to keep ahead of these debates to see in which direction they next turn.

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Evolution Research in the 21st Century

Exciting things are happening in biomolecular labs throughout the world and many new proteins are being found to develop new, more powerful and effective drugs.

We will start by looking at the debates surrounding the theory of evolution where the debates and discussions about many aspects of the theory are still going strong.

The Theoretical Debate

It might be expected that the debate on Evolution by Natural Selection would have quietened down by now but far from it. Enter the phrase 'Evolutionary Theory' into a search engine you get about 38 million hits!

Theologians and scientists are still producing volumes of heated arguments about the evidence for evolution by natural selection.

The view that life on earth has evolved and that species share common ancestors is, however, widely accepted and questions now being asked include:

- How does evolution happen?
- How are novel features and behaviours produced?
- Are genes selfish or altruistic?
- Why are some clades (groups of organisms such as species) very diverse and others unusually sparse?
- Does evolution proceed steadily or in quick jumps?

A debate currently at the leading edge of evolutionary theory is that of the Geneticists versus the Paleontologists which considers this last question.

The geneticists argue that evolution proceeds slowly but surely, driven by competition among organisms to transmit their genes from generation to generation.

The Paleontologists argue that fossil records show that in fact evolution proceeds only sporadically with long periods of no change, which shows that evolution is driven far more by environmental forces than by genetic.

It seems surprising that there are still such very different current views. However, in the 1970s two world-renown researchers, Niles Eldredge and Steven Jay Gould, strengthened this side of the argument with a new theory and also fuelled a long lasting debate on the true nature of evolution. Their theory is called the **punctuated equilibria theory**, that is, long periods of no change (equilibria) are punctuated by episodes of rapid evolutionary activity.

Stephen Jay Gould died aged 60 in May 2002. The following is an extract from The Washington Times on May 25th 2002:

> *Paleontologist, Steven Jay Gould, a principled independent who passed away this week at age 60. Mr Gould was an evolutionary thinker who punctuated his prolific scientific writings with an insight and wit that both the scientific establishment and the general public found simply irresistible. While he was an expert on Cerion land snails and helped inspire the comparatively new field of evolution and development, perhaps his greatest contribution was in developing (with Niles Eldredge) and popularizing the theory of punctuated equilibrium, which proposes that evolutionary change happens in explosions over short time periods, rather than at a steady state.*
>
> *Steady state, however, might describe Mr Gould himself, who scribbled 20 best-sellers and a series of 300 consecutive science essays for Natural History magazine between 1974 and 2001. He brought the scientific essay genre back from the brink of extinction, often linking completely different lines of thought - from dinosaur bones to baseball.*

In 2002 Gould produced a final massive work which traces the history of evolutionary theory, discusses modern day theories and gives a last response to his protaganists from the Darwinian fundamentalist camp - Richard Dawkins and Daniel Dennett.

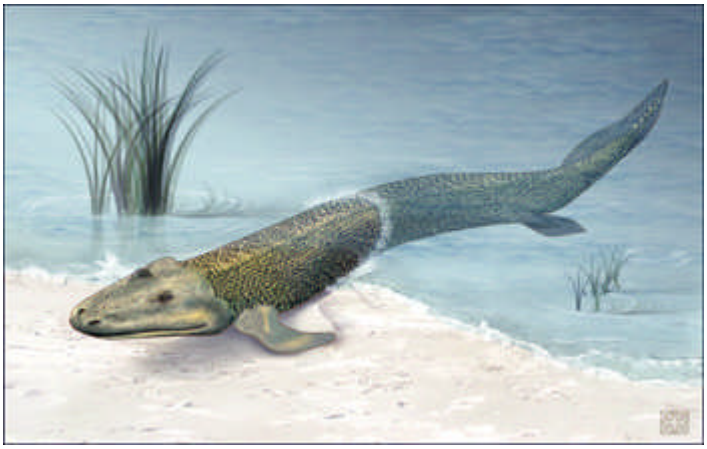
Gould, Steven Jay *The Structure of Evolutionary Theory* Cambridge, Massachusetts: Harvard University Press, 2002

Gould, Steven Jay & Eldredge, Niles *Punctuated equilibrium comes of age* *Nature* 366 (6452, 1993): 223-227

Eldredge, Niles (1995) *Reinventing Darwin: The Great Debate at the High Table of Evolutionary Theory* Wiley Revisits the great debate and offers the case for the paleontologists' view very convincingly. He reviews the major findings and current interpretations of evolutionary theory.

New discoveries are still being made which help to complete the evolution jigsaw.

Recently (April 2006) the US National Science Foundation reported the finding of a huge fossil in Arctic Canada. (See press release at http://www.nsf.gov/news/ and enter Tiktaalik in their Search box).



The 375 million year old fossil has the head of a crocodile and the scales and gills of a fish and is a previously unknown extinct species. This half tetrapod and half fish, which has been named Tiktaalik, bridges the evolutionary gap between fish and land animals. It provides clues about a key transition in the history of life and helps us to understand the order in which certain traits evolved and what their function was. As a transitional form between fish and four-legged vertebrates, Tiktaalik, will be one of a series of fossils representing different points in this transition. Put 'Tiktaalik' into a search engine and see more information and images.

Evolutionary psychologists are also contributing to many areas of research including the evolution of language, emotions and morals.

Holcomb (2000), however, argues that evolutionary psychology is not a mature science. The reasons he gives are:

- it makes premature claims to explanatory success
- its explanatory results are variations on evolutionary truisms or unconvincing if truly novel
- it too often employs weak scientific methods in testing explanatory hypotheses
- its main explanatory goals are conceptually confused and unrealizable using present methods

On a positive note he says that *"evolutionary psychologists can use this criticism constructively to tackle the hard problems they have swept under the rug, thereby advancing the science. Unless they do so, I worry that evolutionary psychology will never become a mature science."*

Much of the current research is actually being done by biomolecular scientists and molecular psychiatrists (yes, they really exist!).

Holcomb, H.R. (2000) *Will Evolution Psychology Grow Up?* Free Enquiry Vol 21(1) p51 Winter 2000

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Evolutionary Diversification

Dr Jonathan Losos and his colleagues have recently looked at the changes which have taken place in lizards isolated on islands.

This research focuses on evolutionary diversification – how and why species adapt; in particular lizards of the genus Anolis. There are over 300 species of anoles and 50% of these are found in the Caribbean with the majority on the islands of Jamaica, Puerto Rico, Hispaniola and Cuba.

Ever since Darwin noted the change in finch populations in the Galapagos Islands, many examples of comparatively rapid change in populations (such as the peppered moth) have been shown. **However, for the first time, Losos and his team have been able to provide experimental evidence of these changes in response to an altered environment.**

Anolis lizards (*Anolis sagrei*) were taken from the Bahamian Island of Staniel Cay and introduced onto 14 smaller nearby islands between 1977 and 1981. These little islands had sparser, shorter vegetation than the original habitat. The researcher's hypothesis was that, as Anolis sagrei spend a lot of time sitting on branches, the shorter vegetation would lead to correspondingly shorter hind limbs over time. This is exactly what was found when the lizards were checked just 10 years later in 1991.

More recently, Losos and his colleagues (2005) have used molecular phylogenetic methods (see later explanation) to investigate the contribution of overwater dispersal to diversification of a lizard (*Anolis carolinensis*) in the northern Caribbean. New DNA sequences from five species of lizard were analysed with sequences sampled from five related species on Cuba. This confirmed that all five non-Cuban species represent distinct, independently evolving, lineages that warrant continued species recognition.

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The Human Genome Project

Modeling Natural Evolution
DNA breeding in the Biochemistry Lab

Life has evolved into more than a million diverse forms over billions of years. The uniqueness of each is found in the array of proteins in its cells. Yet, in the midst of this diversity there are surprising similarities between living things. For example, humans and the fruit fly have many proteins which are similar in sequence and task showing our common ancestry! Amazingly when scientists have put human disease genes into flies, they often cause the same symptoms in the insects as they do in people!

The differences now seen between the humans and fruit flies are the result of millions of years of mutations. These are called polymorphisms, and they form the basis for a vast number of combinations each with a potentially different set of properties. Having a low mutation rate is important for complex organisms such as humans, so the main source of genetic diversity is based on using recombinations of sister chromosomes which already exist thus creating new combinations. Each generation is thus creating novel combinations of mostly old mutations. Indeed recombination followed by natural selection is the foremost mechanism of organic evolution (Stemmer, 2003). These constant rearrangements of existing mutations are usually beneficial but also harmful as in genetic diseases.

Now, biomolecular engineers are attempting to custom-build proteins in laboratories using the strategy of natural evolution. Two methods are being used – computer modeling and directed evolution.

Computer modeling tries to predict which amino acid sequence will produce a protein with the desired properties for a specific application. This is an incredibly difficult task as there are an enormous number of interdependent variables that influence proteins. Computer modeling is also limited by the massive computation power required.

Directed evolution does not rely so heavily on computer power, capacity and speeds not yet attainable. Stemmer and his team have had some success with this alternative method. In simple terms, they harness natural selection at a molecular level and direct the evolution of proteins towards a specific need set by, say, medicine or industry. The most powerful form of directed evolution, called DNA breeding, follows the same pattern as traditional breeding of plants or animals.

Select promising parents, breed them to create a diverse pool of genetic variants and then select the offspring with the best combination of desired traits.

DNA breeding takes place in test tubes rather than kennels, using established biochemical techniques to apply strong selective pressure to molecules rather than whole animals. This method can create an enormous number of new sequences in just a few hours and the biggest task is searching through them all to find the ones that can perform the desired function.

A major advance on this is what is known as multi-gene shuffling or DNA family breeding. Rather than starting from single genes, it uses recombination of multiple equivalent genes from related species – ones with old proven mutations. So, there is plenty of novelty due to cross-species interchange while most harmful and unwanted mutations have long since been removed by natural selection.

This method can be broadened by using whole genomes rather than single genes which is known as widespread shuffling. An example of its success can be seen with the production of the antibiotic, Tyrosin.

Previous work, using the classic approach of random point mutation and screening, took 20 years of mutation and selection in the lab plus screening of more than a million mutations, to produce a six fold increase in the bacteria which is a natural source of tyrosin (Streptomyces). Stemmer's team performed a similar search using genome shuffling, and found the same increase but it took only one year and screening of only 24,000 mutations.

Today virtually any human protein, such as growth factor, antibody or enzyme, can be cloned and made ready to be administered therapeutically. The completion of the Human Genome Project has enabled scientists to identify hundreds of new proteins with the potential to treat disease. Where DNA screening comes in is to optimise the proteins to meet specific therapeutic needs by enhancing desirable factors such as stability and reducing undesirable side effects such as toxicity.

Stemmer (2003) has used this method to improve the anti-cancer drug, Interferon. In tests on live mice, animals that were given the new interferons were fully protected against viral infection. The work continues.

He is also working on a vaccine for dengue fever, a viral disease spread by mosquitos, which was originally a tropical disease but is now rapidly spreading throughout the world including the USA. Using shuffling techniques a protein has been found and its potential successfully tested on mice. Candidate vaccines are now progressing to trials on primates.

Stemmer, Willem & Holland, Brett (2003) *Survival of the Fittest molecule: Biochemists harness a novel form of evolution to sculpt new compounds for the fight against Dengue Fever, Cancer and other modern plagues* American Scientist Vol 91 (6) p 526 Dec 2003

Willem 'Pim' Stemmer invented DNA breeding and co-founded Avidia Research Institute where the work is taking place.

Brett Holland is an assistant professor of Biology at California State University where he teaches evolution and genetics.

Further Reading

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Current Applications

Crime

DNA fingerprinting allows forensic scientists to determine whether DNA found at the scene of a crime comes from a particular person. This works because although humans are virtually genetically identical, the human genome has 3 billion base pairs. In fact no two people on earth have exactly the same genetic sequence as far as we know, except identical twins.

Samples of DNA can be collected from almost any part of a human egg hair, blood, saliva etc. The repetitive stretches of DNA can then be studied and compared. Many wrongly convicted people have been released as a result of the development of the advances in DNA research and it has become an accepted form of evidence in criminal courts as well as paternity suits.

Agriculture

Evolution underlies many improvements in agriculture, such as the artificial selection of crop strains and livestock breeds which improve the production and supply of food. With the coming of fertilisers, pesticides and biotechnology our ability to produce enough food to feed the world should be limitless. However, in mass-producing genetically-similar foods we have left them vulnerable to diseases and pests due to lack of genetic variation. New insects and diseases continue to evolve as new technologies are introduced so it has become a vicious circle.

The use of antibiotics unnecessarily for agriculture and livestock purposes may lead to the evolution of resistant strains and could also introduce antibiotics into humans via their food.

Medicine

Like all biological systems, the organisms that cause disease and their victims both evolve.

Antibiotic resistance

Only a few decades ago antibiotics were the wonder drugs but now, precisely because they have worked well and are therefore used extensively, they are now becoming less effective. Evolutionary theory predicts that this would happen. Given time, heredity and variation, any living organisms including bacteria will evolve when a selective pressure is introduced. One example is the bacteria which causes gonorrhea (Neisseria gonorrhoeae) which is gradually becoming resistant to most antibiotics eg in SE Asia 98% of the gonorrhea bacteria is resistant to penicillin.

Doctors can only at the moment try to prolong the useful lifespan of antibiotics by trying various strategies such as not prescribing them for viral infections, giving high dose, short-term treatment to kill the bacteria and trying different antibiotics rather than a continuing dose of the same one.

The same processes of evolution that can be seen in fossils and creatures apply to influenza viruses. However instead of decades or centuries, some take as little as 15 minutes to pass through a generation. As the influenza viruses move through populations around the world and switch hosts, they change so much that vaccines are rendered ineffective every year. It seems that we are locked into a constant battle to keep pace with pathogens which are evolving as fast as we develop new defences against them.

Huntington's Disease is a currently incurable genetic disease caused by an abnormal dominant allele that disrupts the function of the nerves, slowly eroding their control over bodies and minds and ultimately leading to death. Research has found the cause to be a stretch of DNA which repeats itself over and over again CAG CAG CAG CAG CAG etc. Those with a gene carrying more than about 35 repeats develop the disease, so by DNA screening we are able to predict Huntington's Disease. Most people inherit the faulty gene from their parents but those with no family may have new mutations which cause Huntington's.

It is a relatively rare disease which we would expect would have died out due to natural selection. The reason that Huntington's is not naturally selected is that it occurs usually after people have reproduced and there is a 50:50 chance of any offspring inheriting it.
Today, genetic testing which works in the same way as DNA fingerprinting, can identify people with a Huntington's allele long before the onset of the disease and therefore they can make reproductive choices.

The Human Immunodeficiency Virus (HIV) is one of the fastest evolving entities known and our understanding of evolution will help us fight it. A single virus can spawn billions of copies in just one day and while doing so accumulates a large number of mutations. Looking at the evolutionary history of the virus, it has been found that wild cats and primates carry strains of closely-related viruses which do not seem to harm them. Over time new strains of this virus began to affect humans.

Why are some people resistant to it?

Scientists have discovered that up to 20% of the European population carry at least one copy of a mutant to a gene called CCR5 left over from a plague seven centuries ago. Very few Africans or Asians have the allele as they were not exposed to the same epidemic. It is now known that mutant CCR5 has a side effect – it offers resistance to HIV. It is hoped that studying this by-product of past selection will help them develop new treatments for the HIV epidemic.

A losing battle?

HIV is evolving faster than we can produce new drugs. A patient takes an HIV drug and this stops some of the viruses reproducing but those that have some resistance will survive and resistant virus strains will evolve within the patient, sometimes in just a few weeks. The only way in the past to slow this down was to give the patients several different HIV drugs together.

A therapy that has produced some hope also comes from evolutionary theory which predicts that if you place resistant and non-resistant organisms in head-to-head competition in the absence of a drug, the drug resistant organisms will usually win. This has been put into practice in patients - a drug to which the viruses have become resistant is stopped for a while and the non-resistant forms of the virus take over after which the patient takes very strong doses. This therapy is showing promise, not of a cure but of a way of slowing down replication and reducing the patient's viral load considerably.

However, those who criticise the reductionist approach of biomolecular science are not optimistic about its success.

> *"Despite the achievements of genomic medicine, evidence of its limitations is accumulating. Already the hope for what one writer (Conrad et al, 1999) has called "O-GOD" - there would be one-gene-one-disease - has been dashed. For example, the identified genes for breast cancer account for only 10% of cases. Except when a disease is the expression of a single gene, genetic understanding of disease may prove to be extremely complex. And there is no certainty that genetic knowledge will give rise to genetic therapies that are effective, practical, and affordable. Perhaps the most negative effect of the human genome project might come in its diversion of resources, scientists, and physicians from other promising paradigms. To understand how genomic medicine might be a diversion, it is useful to place its development in the broader history of medicine."* Coulter (2001)

(For more details on the Reductionism in Medicine debate see the Reductionism programme in this Series and accompanying User's Guide: Psychological Perspectives: Reductionism)

Conservation

Biological systems change and evolve all the time and we fight to conserve species that are dying out in favour of better adapted relatives. We all want to preserve rare species but evolutionary theory suggests that this is not often possible. For example, there are just 65 northern hairy-nosed wombats left in the wild. The hope would be that they would reproduce and build up numbers again with some help from conservationists. However, evolutionary theory says that very small populations face two main dangers – inbreeding depression and low genetic variation which are likely to prevent them recovering.

Thanks to biologists there is more hope for the kakapo, a large flightless bird from New Zealand islands, which is a critically endangered species with just 51 remaining in 1995. However it was announced in 2006 that the kakapo's problems may largely come down to sex and that a simple diet could help save them.

It seems that the kakapo population has become male based. The birds lay more male than female eggs. The problem restricts population growth because however many males fertilise one female, she can only produce a few eggs.

Evolutionary theory helped to reverse this. We would expect organisms to evolve adaptations that would produce more children and future generations. One of these is sex allocation whereby an organism may maximise its fitness by producing all-girl offspring or in other situations, all-male offspring. Males grow larger and faster to give them the optimal chance of winning fights for a mate and they therefore need more resources from their mother. This means that in times of low resources a mother is better to produce a girl and, even if small, will be likely to produce a grandchild. A male in times of low resources would probably be weak and small and would find it difficult to attract a mate and produce grandchildren.

In 2001 Robertson et al arranged for underweight females to be given extra food and this has remedied the sexual imbalance.

> *"This is a world first, using evolutionary theory to inform conservation practices and the first time anyone has used sex allocation theory to manipulate sex ratios with a critically endangered species. Our work has not only remedied the immediate problem of an overproduction of sons, but also highlights the value of incorporating evolutionary theory into modern conservation practice." Robertson (2006)* http://www.comsdev.canterbury.ac.nz/news/2006/060116a.shtml

Robertson, B.C., Elliott, G.P., Eason, D.K., Clout, M.N. and Gemmell, N.J. (2006) *Sex allocation theory aids species conservation* Biology Letters FirstCite Early Online Publishing March 15, 2006

Sutherland, W.J. (2002) *Conservation biology: Science, sex and the kakapo* *Nature* 419: 265-266.

Tella, J.T. (2001) *Sex-ratio theory in conservation biology* Trends in Ecology & Evolution 16 (2): 76-77.

Websites

www.uniview.co.uk
a large collection of psychology videos, DVDs, posters, brain jellies, X-psyting extras, etc
worth checking regularly for latest news

www.theatp.org
the home of the Association for the Teaching of Psychology
invaluable access to information and advice for teachers of psychology in UK and Europe

www.bps.org.uk
the home of The British Psychological Society
free downloads of recent articles from The Psychologist magazine

www.apa.org
the home of the American Psychological Association
nothing free on this site!

www.psychology.heacademy.ac.uk
details of psychology events, resources and research
lists all UK university psychology departments; BPS list of accredited undergraduate courses

www.s-cool.co.uk
revision site for students on a limited number of topics; club-like feeling with an s-magazine giving advice on bank accounts, interview skills and even how to shave! Teachers World with generic information; linked to AQA (A) & (B) Evolution

http://www.mrmind.com/mrmind3
turning the Turing Test upside down, MRMIND challenges you to take the Blurring Test and prove to him(?) that you are human - make your case to a robot of your choice
take the Human Quotient test - great fun and time-waster!

www.youramazingbrain.org.uk
just go and enjoy – the brain in great detail, packed with information, activities

www.holah.karoo.net
information, fun activities, links – excellent for staff and students alike

http://psyonline.edgehill.ac.uk
A Level resource from Edgehill College for AQA. Good and reliable resource for students and teachers. Includes a countdown to Mod 4 exams to the nearest second!

http://psyberfun.users.btopenworld.com/
too new to comment on but looks promisingly weird, wacky and addictive!

http://en.wikipedia.org/wiki/Psychology
extraordinary free encyclopedia which anyone can edit anytime even without being online! Over 1 million entries with definitions and further information

http://www.brainconnection.com/
an award-winning site (USA) with lots of relevant material and some excellent animated mini-demonstrations

The Internet has an enormous number of useful sites relating to Evolution, accessible by searching for 'evolution' or 'evolutionary theory' and then narrowing down the search to your area of special interest, eg altruism, kin selection

http://www.pbs.org/wgbh/evolution/
a large collection of evolution resources can be found on the web pages of the Public Broadcasting Service (PBS) television network in USA. With a huge evolution multimedia library, a teacher and student section and excellent graphics and interactive features. The website content stands on its own and goes well beyond simply supporting the TV series

http://www.psych.ucsb.edu/research/cep/
the centre for Evolutionary Psychology in California – large amount of up-to-date academic research and conference details

Human Genome Project Information
the enormous Human Genome project site with everything you need to know about what is happening in genetic research currently; teachers section

http://www.stephenjaygould.org/
the unofficial Steven Jay Gould Archive - includes an evolution library, book reviews, a biography, interviews and much more

http://psych.hanover.edu
the psychology department of Hanover College, USA; full of notes, demonstrations, animations, links etc including learning resources

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The ATP has highly experienced teachers and examiners ready to give advice and assistance, especially for new teachers of this topic. They can recommend textbooks and resources that will get you started.

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home: dorothycoombs@24whinchat.freeserve.co.uk 01287 636502

New teachers of this topic are well advised to get in touch with the ATP:

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