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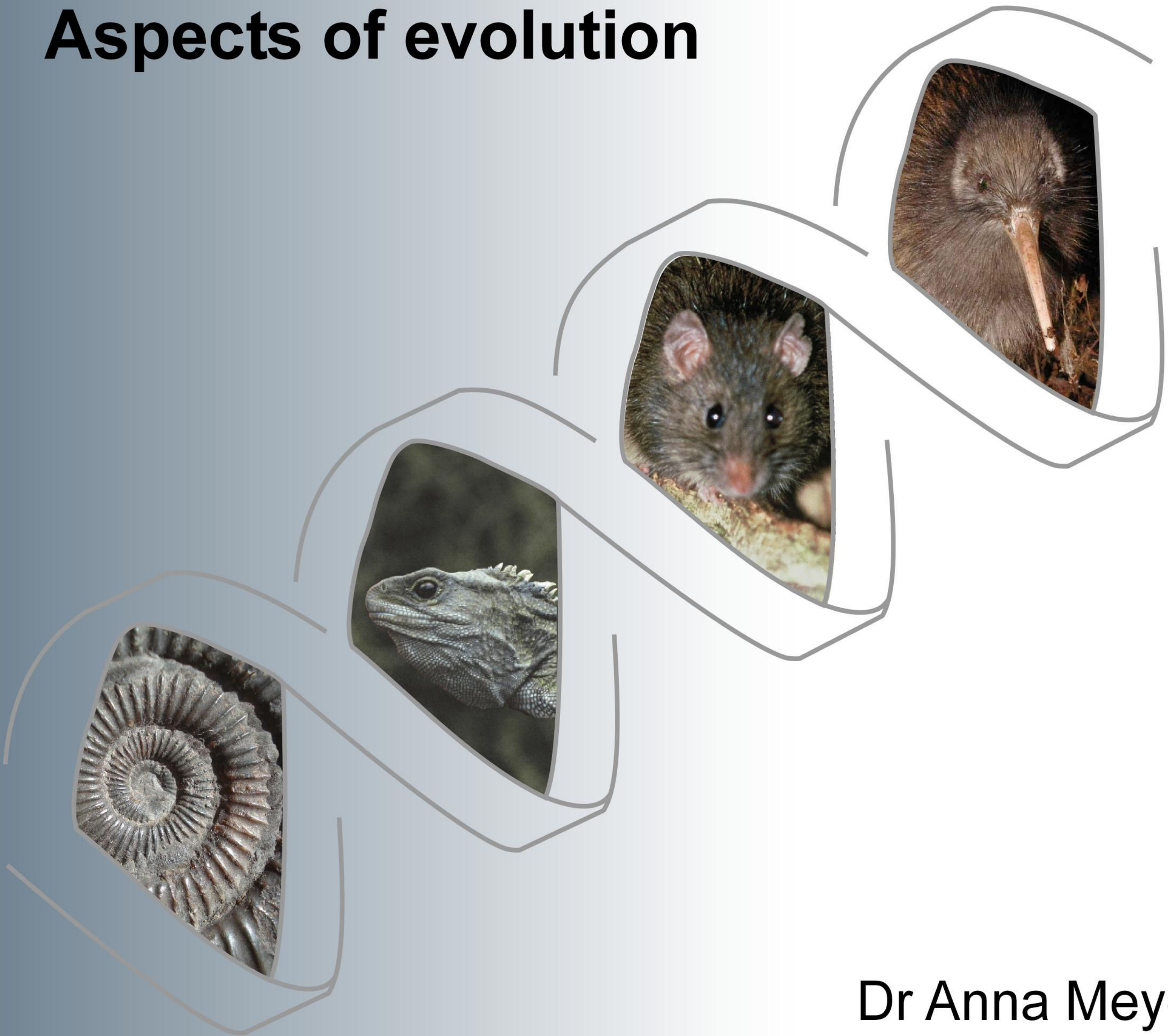
Aspects of evolution



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What is Evolution?

Evolution simply means that living things change over time. This means that the variety and type of living things that we see now on Earth are not the same as they were in the past. If we could travel far back in time, say 100 million years, life on Earth would look very different to what it does today.

For some long-lived species, such as kauri trees, evolution is a slow process, so it can take a long time to see any changes happening. We can't watch evolution directly in these species, we simply don't live long enough. This makes it seem like evolution only happened in the past. However, evolution is a continuous process - it has been happening since life began, and is happening today. In fact evolution can be so fast, as with viruses like HIV and influenza, that we can see changes over just a few months.

Evolution doesn't just mean that one species changes to form another, although this is part of what happens. As species evolve, they can also split into two or more different species, which can split again, and so on. This process is how all species on Earth today evolved. If we go back far enough in time – at least 3.5 billion years - all living things can be traced back to a single common ancestor from which all life originated.

Charles Darwin and natural selection

Charles Darwin was an English scientist who lived from 1809 to1882, and visited New Zealand in 1835 on a British navy survey ship, the *Beagle*. He developed a famous theory to explain the process of evolution, summarised as 'natural selection'. First published in 1859, this is still what scientists use today to explain how evolution works.

Darwin's theory of natural selection is simple and each part is testable.
The population/ecology part simply says that

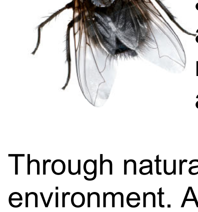
- many offspring can be born in each generation
- resources are limited, and so there is competition for resources (both within and between populations).

> In biology, a population is a group of organisms of the same species, living together in an area separate from other groups of the same species.

The genetics component of his hypothesis was that

- each member of a population is very slightly different
- part of this variability is inherited
- some of this genetic variability affects the probability of survival and reproduction.

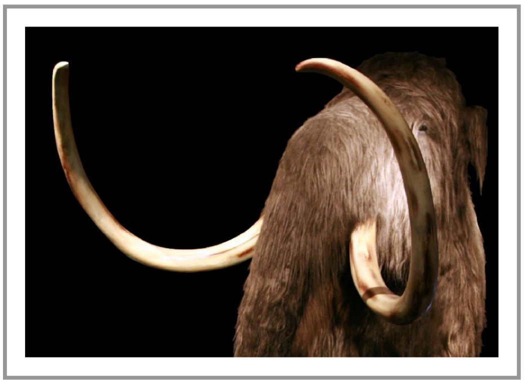
Limited resources and competition mean that only some individuals in a population are able to survive to produce their own offspring. Although there is a lot of variation, on average the 'fittest' in each generation (those that can survive and reproduce the best in the environment they are in) are able to pass on their genes to the next generation.



For example, say one fly can lay 100 eggs, and does so every month. If all the offspring survived to reproduce, and all of their offspring survived and so on, there would be billions of flies within months. Luckily this does not happen, as limited food and space means that only some flies (on average, the fittest) survive and reproduce.

Through natural selection, over many generations, populations evolve to suit their environment. As the environment continues to change, natural selection continues to occur.

Why and how do scientists study evolution?
Evolution is a fascinating topic to study. Scientists who study it want to know what changes have happened in the past; how species have evolved; how the species we see today are related to each other and how they are related to ones in the past. Just a few specific topics studied are:



- When did life start to evolve?
- How did humans evolve?
- In what way are elephants and extinct mammoths related?
- How do bacteria become resistant to antibiotics?
- How fast did mammals and birds evolve after dinosaurs became extinct?

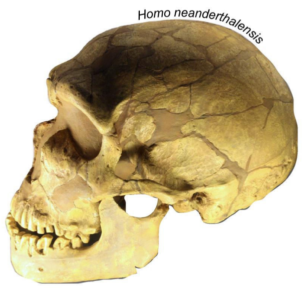
There are many different ways to study evolution, including fossils, DNA, ecology, maths and computers. Scientists can even watch evolution happening in some species that evolve very fast, such as bacteria and certain viruses, such as HIV and influenza. Researchers from different areas of science often work together to study evolution, which can help solve difficult problems.

DNA
Living things, including ourselves, are made up of collections of cells, all working together. Inside virtually every cell is a nucleus, which contains a set of chromosomes. Each chromosome contains a long strand of the chemical known as DNA. A large number of units, called genes, are found on each DNA strand. Genes influence many aspects of how we look, function, and behave. Each gene can be involved in a single characteristic (such as eye colour, height, or hair colour) or can affect many.

Using DNA to Study Evolution
DNA is extremely useful for studying evolution. The reason is that DNA is inherited, and has been passed down through generation after generation, pretty much since life began. Each parent passes on their DNA to their children, who then pass it on to their children, and so on. The DNA that we find in today's species is not exactly the same as it was in the past, because DNA 'mutates' or changes over time – in other words, it evolves. Scientists can use this fact to study a lot of things about evolution.

DNA is now the main method for studying the family trees of groups of present-day species. For example, comparing the DNA of kiwis with DNA from emus, ostriches, and cassowaries from Australia, and rheas from South America tells us that this group of flightless birds are all closely related, and shared a common ancestor many million years ago.

DNA can also tell us when today's species might have first evolved. For example, comparing the DNA from humans around the world now tells us that modern humans first evolved about 200,000 years ago, in Africa.



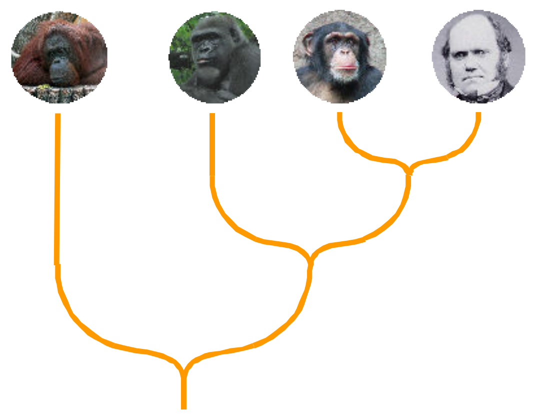
Scientists can also extract DNA from the bones or teeth of relatively recently extinct living things (that died up to a few tens of thousands of years ago), and compare it to DNA from present day species, to see how they are related. For example, a comparison of human DNA with DNA from Neanderthals, who lived in Europe until about 30,000 years ago, showed that Neanderthals are not the direct ancestors of humans.

At the other end of the scale DNA can also be used to look at the origin of life and its early evolution. DNA can also be used to study the evolutionary process itself, such as the speed and mechanism by which evolution occurs. To work out rates of evolution, the dates of specific fossils (which can be measured very accurately) are used in combination with DNA.

Profile: David Penny

Professor David Penny is a Principal Investigator of the Allan Wilson Centre for Molecular Ecology and Evolution, centred at Massey University. David uses DNA to study evolution, and looks at many different interesting questions.

For example, David and his colleagues have compared the DNA of chimpanzees and humans, and have found that our DNA is extremely similar, which means that we are very closely related – and there is nothing in the human genome that is not typical of mutations between populations and closely related species.



DNA studies show that chimpanzees are more closely related to humans than to other apes

David is also interested in events that happened around the extinction of the dinosaurs, 65 million years ago. His research group's work on the DNA of birds and mammals shows that modern birds and mammals had begun to diversify before the dinosaurs became extinct. Before this, it was thought that modern birds and mammals didn't evolve until after the dinosaurs had disappeared.

David also uses DNA to look at more recent events in evolution (such as the numbers of Polynesian women from the Pacific that settled Aotearoa/New Zealand), as well as very ancient events, such as how and when the first life forms evolved.

Fossils

Fossils are the preserved remains of prehistoric organisms. Usually only the hard parts, such as bones, teeth, shells, wood and pollen become fossils. Organisms with hard parts become fossils more easily – soft, squishy animals such as worms are less likely to. Fossils also include footprints, such as dinosaur or bird footprints.

A fossil begins to form when an animal or plant dies and over time is buried by thick layers of sediment. Pressure on the forming fossil increases, and water is forced out. Chemical changes occur, and eventually the sediment becomes rock, with the remains of the plant or animal trapped inside.

Once formed, fossils can last up to many millions, or even billions of years. The oldest fossils are stromatolites, collections of microscopic organisms which are an incredible 3.5 billion years old. Other fossils aren't as old as this, but can still be ancient – the oldest insect fossil found is about 400 million years old, and the oldest fish fossil is about 580 million years old.

Using Fossils to Study Evolution

Fossils are a great way to study evolution because they show us what living things looked like in the past, and how they have changed. By comparing fossils from a range of ages with modern-day living things, scientists can see how a species or group of species have evolved. They can see how and when new species formed, and estimate when things became extinct.

Fossils were one of the first pieces of evidence used to study evolution, and are still important. There are some problems though. Firstly, not all things that lived form fossils. Also, even if a fossil is formed it might later get destroyed before it can be discovered. Some fossils are buried so deep, or in such remote places, that they may never be discovered. All this means that there are gaps in the fossil record – it doesn't always show the complete history of how a species or group of species has evolved. This means that important stages could be missed or misinterpreted. Fortunately, fossils are not the only method used to study evolution.

Profile: Ewan Fordyce

Associate Professor Ewan Fordyce works in the Department of Geology at the University of Otago. Ewan uses fossils to study the evolution of whales, dolphins and penguins.

One of the most interesting fossils that Ewan and his colleagues have discovered is the skull of an ancient dolphin, which lived about 23-34 million years ago. They named the species *Waipatia maerewhenua*, and it is an ancestor on the dolphin family tree.

As well as being an unexpected new species, the discovery is also fascinating because it cleared up a mystery: for more than a century, researchers around the world had discovered a lot of small dolphin teeth. Because they didn't have any other part of the animal, they could not know for sure which species they belonged to. Ewan's discovery of the skull cleared up the mystery – the teeth all belong to the same type of dolphin.

Ecology

Ecology involves studying living things and how they interact with each other and their environment. Ecologists look at the numbers and distribution of species of living things in particular regions. They also look at the fit of living things with their environment, which is called adaptation. They examine how individuals in a group of animals relate to each other and investigate how two species interact with each other. They also look at how changes in the environment affect a species or ecosystem, such as how global warming is affecting coral reefs. Such research is very important in efforts to save endangered species, as knowing how a species relates to other species and its environment can help in designing ways to help it survive.

Ecologists can study living things at a variety of levels, from proteins and DNA to individual organisms, populations, ecosystems and communities. Ecologists use a variety of methods to carry out their work, including laboratory research such as DNA analysis, and field work such as investigating species in the wild.

Ecology is very useful for studying evolution. The patterns of species and their interaction with each other and their environment that we see today can tell us a lot about how they have evolved. For example, in New Zealand, the flightlessness of kiwi and other native birds tells us that they have lived for a long time with no predators, and have therefore lost the ability to fly.

Profile: Charles Daugherty

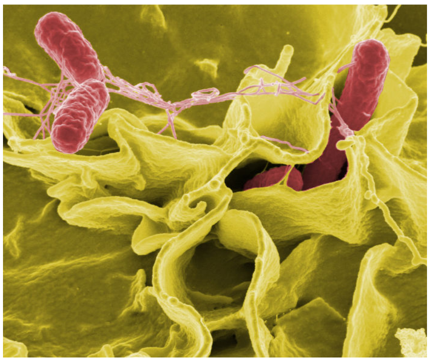
Professor Charles Daugherty is the Assistant Vice Chancellor (Research) at Victoria University of Wellington, as well as being a part of the Allan Wilson Centre for Molecular Ecology and Evolution. Charles and his colleagues study native New Zealand animals, such as the tuatara, kiwi and lizards, to learn about their ecology and how they have evolved.

For example, Charles found that brown kiwis from different parts of the South Island show interesting differences in their DNA from brown kiwis from the north island. This is probably because the different populations of brown kiwis have been separated from each other for quite long periods of time in the past, and have evolved slightly differently. Because they all still look very similar, they have previously been grouped together as one species. Now, they are classified as three separate species.

As well as being interesting for learning about how species have evolved, information like this is useful for conservation biology, which involves using ecology and evolution studies to help preserve native species and their habitat. For example, because the brown kiwi species are slightly different, each might need to have different conservation plans applied to it.

Viruses and bacteria

When we get sick with a 'bug' such as a cold, flu, or ear infection, this is because we have been invaded by tiny life forms called viruses and bacteria. Microscopic bacteria are very widespread, and most of them do not make us ill. They live in soil, on our bodies, pretty much everywhere. There are millions of different species of bacteria, each specialised for its own environment.



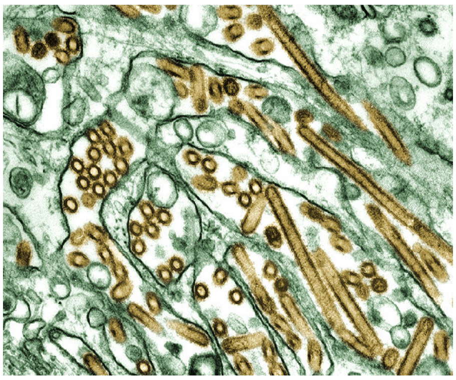
Coloured electron micrograph of Salmonella typhimurium (red) invading cultured human cells.

Viruses are even smaller still, and there are many different species of those too. Viruses can only reproduce inside the cells of other living things. They use the hosts they invade to make copies of themselves and to spread.

With most species, including humans, evolution happens over a long period of time. This is partly because we reproduce very slowly – the average generation time for a human is about 25 years. This means that we can't usually watch evolution happening directly, because no one lives long enough to see enough generations pass by for any significant changes to occur. Viruses and bacteria are very exciting for evolution, because we can actually watch them evolve over very short periods of time, because they reproduce and mutate extremely fast. Bacteria, for example, can reproduce in as little as 20-30 minutes.

The fast evolution of bacteria and viruses can be very frustrating for medical researchers who want to cure diseases caused by them. Viruses can evolve quickly enough to escape the effects of our immune system and vaccinations, and bacteria can change enough to become resistant to drugs such as antibiotics which once killed them.

Two good examples of viruses that evolve fast are HIV and the flu virus. The HIV virus causes Aids, and evolves so fast that it changes within a single person over the time that they are infected. This is partly why HIV is so hard to treat – it evolves so rapidly that it becomes resistant to medications. The flu virus also evolves very quickly, which is why we need to have a new flu injection every year.

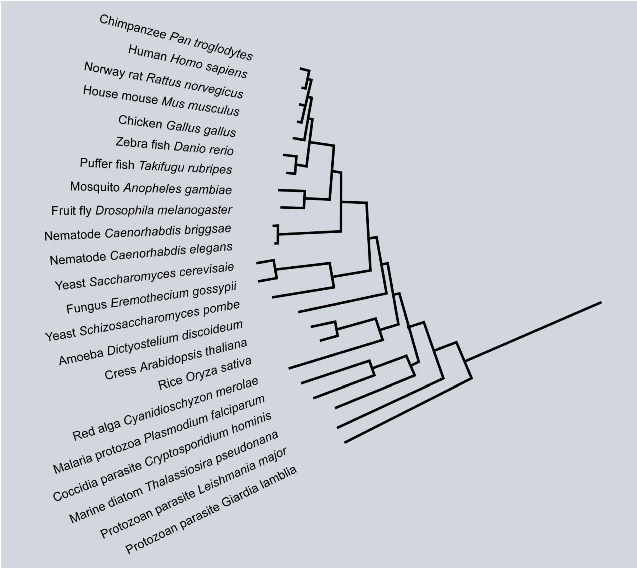


Coloured electron microscope image of avian influenza viruses (gold) inside living cells (green)

Viruses and bacteria are also used as a 'model system' to study evolution. Because evolution happens so fast in these organisms, it can give information about how evolution as a process might occur in other more slowly evolving species.

Computers and evolution

Computers are important for studying evolution as they allow complicated calculations to be carried out quickly and easily. For example, comparing DNA from different species and drawing their 'evolutionary trees', which show the relationships between the species, would be extremely complex and time consuming and less accurate if done by hand. There are many different ways to draw evolutionary trees, and computers can find the



Relationships between organisms that have had their genomes mapped – from a computer-drawn image, part of an on-line 'Tree of Life' project http://www.tolweb.org/tree/

most suitable one for each particular study. Computers also allow scientists to search databases of many thousands of DNA samples that would be impossible to search by hand.

Computers are also useful in conducting 'virtual' experiments that are difficult or impossible to do in real life. Computer simulations are also used to create 'artificial life' and to watch it evolve. Just like real living things, the artificial life forms are made to reproduce, mutate and to undergo natural selection. By changing variables and watching what happens, researchers learn about how evolution works in real life.

Finally, computers are very useful for displaying and analysing geographical information, such as rainfall in a particular area. Information like this is very important for understanding how New Zealand plants and animals evolved, because our country has been affected by climate change a great deal in the past, which has had a large effect on the evolution of our native species.

The calculations that are carried out in evolutionary studies are complex, and use a lot of computing power. Because of this, the Allan Wilson Centre and Massey University have built a supercomputer called the Helix. This is a collection of 130 computers linked together which allows difficult computing tasks to be split up among the different computers. This is excellent for tasks like drawing complicated evolutionary trees.

Working together: The Allan Wilson Centre

The Allan Wilson Centre for Molecular Ecology and Evolution is a group of researchers from different areas of science who work together to look at a wide variety of interesting evolutionary puzzles. The centre is hosted by Massey University, but participating researchers are found at the University of Auckland, Victoria University of Wellington, Canterbury University and Otago University. The Allan Wilson Centre has scientists from a wide range of areas of science, including ecologists, evolutionary biologists, and mathematicians.

Allan Wilson Centre researchers are all interested in evolution, and work together on a variety of interesting questions. For example, how fast does evolution occur? Is it different for different species and different periods of time? How fast do kiwi and tuatara evolve? How fast do plants evolve? What plant extinctions have happened in the past? How do tuatara choose their mates? How and when was New Zealand settled? And what are the best mathematical methods for studying evolution?

Find out more about the Allan Wilson Centre at www.allanwilsoncentre.ac.nz

Profile: Lisa Matisoo-Smith

Dr Lisa Matisoo-Smith is Professor of Biological Anthropology at the University of Auckland and is part of the Allan Wilson Centre. Lisa studies the recent evolution of the animals that accompanied Polynesian settlers to New Zealand. This includes domestic animals such as dogs and pigs, as well as 'stowaway' animals such as the kiore, or Pacific rat.

Lisa uses rat samples from different parts of the Pacific. This includes both present day rats, and long-dead ones. Using their DNA, Lisa can re-trace the steps the rats went through when they migrated through the Pacific with the first settlers. This can help us learn about how the people themselves migrated.

Acknowledgements

Written by Dr Anna Meyer.
Reviewed by Professor David Penny, Massey University.
Edited and designed by Neville Gardner.

Thanks to the researchers profiled: Associate Professor Ewan Fordyce (University of Otago), Professor David Penny (Massey University), Professor Charles Daugherty (Victoria University of Wellington) and Dr Lisa Matisoo-Smith (University of Auckland).

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