The History of Animal Evolution

For many people animals are perhaps the most familiar, and most interesting, of living things. This may be because we are animals ourselves. As such, we have a number of features in common with all the organisms placed in the animal kingdom, and these common features indicate that we have a shared evolutionary history.

All animals and plants are classified as **multicellular eukaryotes**: their bodies are made up of large numbers of cells, and microscopic inspection of these cells reveals that they contain a nucleus and a number of other **organelles**. Compared to prokaryotic organisms such as bacteria, plants and animals have a relatively recent evolutionary origin. DNA evidence suggests that the first eukaryotes evolved from prokaryotes, between 2500 and 1000 million years ago. That is, eukaryotes as a **taxon** date from the Proterozoic Era, the final Era of the Precambrian. Fossils of both simple unicellular and more complex multicellular organisms are found in abundance in rocks from this period of time. In fact, the name "Proterozoic" means "early life".

Plants and animals both owe their origins to **endosymbiosis**, a process where one cell ingests another, but for some reason then fails to digest it. The evidence for this lies in the way their cells function. Both plant and animal rely on structures called **mitochondria** to release energy in their cells, using **aerobic respiration** to produce the energy-carrying molecule **ATP**. There is considerable evidence that **mitochondria** evolved from free-living aerobic bacteria: they are the size of bacterial cells; they divide independently of the cell by **binary fission**; they have their own **genome** in the form of a single circular DNA molecule; their **ribosomes** are more similar to those of bacteria than to the ribosomes found in the eukaryote cell’s cytoplasm; and like chloroplasts they are enclosed by a double membrane as would be expected if they derived from bacterial cells engulfed by another cell.

Like the plants, animals evolved in the sea. And that is where they remained for at least 600 million years. This is because, in the absence of a protective ozone layer, the land was bathed in lethal levels of UV radiation. Once photosynthesis had raised atmospheric oxygen levels high enough, the ozone layer formed, meaning that it was then possible for living things to venture onto the land.

The oldest fossil evidence of multicellular animals, or **metazoans**, is burrows that appear to have been made by smooth, wormlike organisms. Such trace fossils have been found in rocks from China, Canada, and India, but they tell us little about the animals that made them apart from their basic shape.

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The Ediacaran animals

Between 620 and 550 million years ago (during the Vendian Period) relatively large, complex, soft-bodied multicellular animals appear in the fossil record for the first time. While found in several localities around the world, this particular group of animals is generally known as the Ediacaran fauna, after the site in Australia where they were first discovered.

The Ediacaran animals are puzzling in that there is little or no evidence of any skeletal hard parts i.e. they were soft-bodied organisms, and while some of them may have belonged to groups that survive today others don't seem to bear any relationship to animals we know. Although many of the Ediacaran organisms have been compared to modern-day jellyfish or worms, they have also been described as resembling a mattress, with tough outer walls around fluid-filled internal cavities - rather like a sponge.

As a group, Ediacaran animals had a flat, quilted appearance and many showed radial symmetry. They ranged in size from 1cm to >1m, and have been classified into three main groups on the basis of their shape: discoidal, frond-like, or ovate-elongate. The large variety of Ediacaran animals is significant, as it suggests there must have been a lengthy period of evolution prior to their first appearance in the fossil record.

The Cambrian "explosion" and the Burgess Shale

The Ediacaran animals disappear from the fossil record at the end of the Vendian (544 million years ago). In their place we find representatives of almost all the modern phyla recognised today: sponges, jellyfish and corals, flatworms, molluscs, annelid worms, insects, echinoderms and chordates, plus many "lesser" phyla such as nemertean worms. These "modern" organisms appear relatively quickly in the geological time scale, and their abrupt appearance is often described as the "Cambrian explosion" however, bear in mind that the fossil record of the "explosion" is spread over about 30 million years. I keep taking things out of brackets because it is interesting relevant and memorable.

One of the most famous assemblages of Cambrian fossils comes from the Burgess Shale of British Colombia. The rocks of the Burgess Shale were laid down in the middle Cambrian, when the "explosion" had already been underway for several million years. They contain familiar animals such as trilobites, molluscs and echinoderms, but also the first appearance of brachiopods, and some odd animals, e.g. Opabinia, that may have belonged to extinct phyla. Even an early chordate, Pikaia, has been found in this fossil assemblage.

The Burgess Shale fossils are important, not only for their evidence of early variety among animal forms, but also because both soft parts of animals and their hard bodies (i.e. the whole animal) is preserved, and animals that were entirely soft-bodied. Preservation of soft-bodied organisms is rare, and in this case seems to have occurred when the animals were rapidly buried in a mudslide down into deep, anaerobic waters, where there was little bacterial decay. Prior to the discovery of this fossil assemblage, early in the 20th century, there was no evidence of soft-bodied animals from the Cambrian (remember that this is before the Ediacaran fauna were found).

These fossils also provide good evidence of predatory animals (e.g. Anomalocaris), and therefore of complex predator-prey relationships. They also give insights into how evolution might have progressed relatively early in the history of multicellular animals, and in fact some authors view the Cambrian as a period of extreme "experimentation" and diversity.
The cause of the proliferation of animal forms in the Cambrian is a matter of considerable debate among scientists. Some point to the increase in atmospheric oxygen levels that began around 2000 million years ago, supporting a higher metabolic rate and allowing the evolution of larger organisms and more complex body structures. Changed ocean chemistry would have played a part here, allowing for the first time the development of hard body parts such as teeth and supporting skeletons based on calcium carbonate (CaCO₃), and also supporting higher levels of primary production as a result of increased concentrations of phosphates and nitrates. The mass extinction that marked the end of the Vendian period would have opened up ecological niches that the new animals exploited, as would habitat changes wrought by continental drift.

Genetic factors were also crucial. Recent research suggests that the period prior to the Cambrian explosion saw the gradual evolution of a "genetic tool kit" of genes (the homeobox or "hox" genes ) that govern developmental processes. Once assembled, this genetic tool kit enabled an unprecedented period of evolutionary experimentation -- and competition. Many forms seen in the fossil record of the Cambrian disappeared without trace. Future evolutionary change was then limited to acting on the body plans that remained in existence.

Recently many scientists have begun to question whether the Cambrian explosion was a real event, or a reflection of the patchiness of this ancient fossil record. Genetic data suggest that multicellular animals evolved around 1000 million years ago; this is supported by fossil embryos from rocks in China that date back 600 million years. These embryos are more complex than those of simple organisms such as sponges and jellyfish, which suggests that multicellular animals must have evolved much further back in time. In addition, trilobites were a very diverse group even early in the Cambrian, and some scientists suggest that this indicates that the arthropod group must have had a much earlier evolutionary origin.

A foot on the land

Whatever their origins, animals may have ventured onto land early in the Cambrian. Previously scientists believed that animals did not begin to colonise the land until the Silurian (440 - 410 million years ago). However, the 2002 discovery of the footprints of animals that scuttled about on sand dunes about 530 million years ago has changed this view. These animals were arthropods, and resembled centipedes about the size of crayfish. They probably didn't live on land, instead coming ashore to mate or evade predators. At this time the only land plants appear to have resembled mosses.

The earliest vertebrates

Animals continued to diversify in the Ordovician seas (505 - 440 million years ago). They were mostly invertebrates, including graptolites, which were stick-like branching colonies of tiny animals, together with brachiopods, trilobites, cephalopods, corals, crinoids and conodonts. We now place the conodonts with the chordates, but for a long time they were known only by their tiny, but very common, teeth.

In terms of number of species invertebrates were by far the most common Ordovician animals - as they still are today. However, members of another taxon were also evolving in the Ordovician seas. These were the fish.

Appearance of the fish

Like the conodonts, fish are members of the chordate phylum because they display certain defining characteristics: a dorsal stiffening rod called the notochord, a dorsal nerve cord, pharyngeal gill slits and a tail that extends beyond the anus. However, fish are placed in the subphylum Vertebrata, because they also show the development of skeletal features such as a backbone, skull, and limb bones.

Not all the modern groups of fish were represented in the Ordovician oceans. At this time only the jawless fish had evolved from a chordate ancestor. The sharks and their relatives and two extinct groups, the placoderms (which had bony plates covering their heads) and the acanthodians (the first known jawed vertebrates, with a skeleton of cartilage) made their appearance in the Silurian. However, neither the sharks nor the agnathans became common until the Devonian. The other two living lineages, the ray-finned (e.g. carp and kahawai) and the lobe-finned fish (e.g. lungfish and the coelacanth), evolved during the Devonian period.
The jawless fish

Agnathans, or jawless fish, were the earliest fish: an excellent fossil of *Haikouichthys ercaicunensis* dates back about 530 million years, to the Cambrian. Previously the earliest-known agnathans were dated to around 480 million years ago. Agnathans have traditionally been placed with the **vertebrates** due to the presence of a skull, although the modern forms such as hagfish lack a vertebral column. The earliest agnathans were **Ostracoderms**. They were bottom-feeders and were almost entirely covered in armour plates. When the sharks and bony fish began to evolve, around 450 million years ago, most ostracoderms became extinct. Only the lineage that produced the modern hagfish and lampreys survived.

Colonisation of the land

Fish continued to evolve during the Silurian period (440 - 410 million years ago). At the same time some groups of plants and animals took a major step as they colonised the land for the first time. We are not sure why this advance occurred, but it was probably the result of competition in the marine ecosystems, plus the opportunity to escape predators and the availability of new terrestrial niches.

Arthropods, which had ventured temporarily onto land 100 million years earlier, were the first animals to become more permanent colonists. Fossil footprints made in the sandy flats surrounding temporary lakes dating back about 420 million years have been found in Western Australia.

The arthropods were **pre-adapted** to life on land. By the time they moved ashore, they had already evolved lighter bodies and slim, strong legs that could support them against the pull of gravity. Their hard outer **exoskeletons** provided protection and would help to retain water, although the development of a waxy, waterproof cuticle was necessary for efficient water conservation.

Spiders, centipedes and mites were among the earliest land animals. Some of them were giants: the largest was **Slimonia**, the size of a man and a relative of the scorpions. This animal was still too big and too heavy and the walking legs too small to venture onto land for any length of time and so they lived in marginal marine (deltaic) environments.

Problems encountered in the move to land

These early land animals had to solve the same problems that plants faced when they moved to the land: water conservation, gas exchange, reproduction and dispersal, and the fact that water no longer buoyed them up against the pull of gravity. Like plants, animals evolved waterproof external layers, internal gas exchange systems, ways of reproducing that did not involve water, and strong support systems (**endoskeletons** and **exoskeletons**) that allowed them to move about on land. Remember that not all animal taxa were equally successful in solving these problems.

The evolution of amphibians

By the Devonian period two major animal groups dominated the land: the **tetrapods** (4-legged terrestrial vertebrates) and the arthropods, including arachnids and wingless insects. The first tetrapods were **amphibians**, such as *Ichthyostega*, and were closely related to a group of fish known as lobe-finned fish e.g. *Eusthenopteron*. Once thought to be extinct, the **coelacanth** is a living representative of this group.

*Eusthenopteron* had a number of **exaptations** that pre-adapted it to life on land: it had **limbs (with digits)** that allowed it to move around on the bottom of pools, lungs - which meant it could gulp air at the surface, and the beginnings of a neck. This last is important as a terrestrial predator cannot rely on water current to bring food into its mouth, but must move its head to catch prey. And the bones in *Eusthenopteron*'s fins are almost identical to those in the limbs of the earliest amphibians, an example of **homology**.
Ichthyostega’s skull was almost identical to that of the lobe-finned fish Eusthenopteron, a definite neck separated its body from its head, and it retained a deep tail with fins. While Ichthyostega had four strong limbs, the form of its hind legs suggests that it did not spend all its time on land.

All modern tetrapods have a maximum of 5 digits on each limb, and are thus said to have a pentadactyl limb. For a long time scientists believed that pentadactyly was the ancestral state for tetrapods. However, careful examination of the fossils of early amphibians such as Ichthyostega and Acanthostega has revealed the presence of up to 8 toes on each foot!

In addition, these early amphibians were large-bodied animals with strong bodies and prominent ribs - quite different in appearance from modern representatives such as frogs and axolotls.

What drove amphibian evolution?

It was originally believed that the tetrapods evolved during periods of drought, when the ability to move between pools would be an advantage. The animals would also have been able to take advantage of terrestrial prey, such as arthropods. Juvenile animals could avoid predation by the land-based adults by living in shallow water.

However, fossil and geological evidence tells us that the early tetrapods lived in lagoons in tropical regions, so that drought was not an issue. They were unlikely to be feeding on land: arthropods are small and fast-moving, unlikely prey for large, sluggish amphibians. But amphibians that laid their eggs on land, rather than in water, would be at a selective advantage, avoiding predation by aquatic vertebrates (such as other amphibians and fish) on gametes, eggs and hatchlings.

Even today some amphibians e.g. the Eleutherodactyliid frogs of Australia and Indonesia lay their eggs in soil on the land. However, they must still be in a moist environment, and the size of the egg is restricted to less than 1.5cm in diameter. This is because the egg is dependent on diffusion alone for gas exchange, and means that the embryo must develop rapidly into a food-seeking larval form rather than undergo prolonged development within the egg.

In the Devonian seas, brachiopods had become a dominant invertebrate group, while the fish continued to evolve, with sharks becoming the dominant marine vertebrates. The placoderms and acanthodian fish were quite diverse during the Devonian, but their numbers then dwindled rapidly and both groups became extinct by the end of the Carboniferous period. Lobe-finned fish also peaked in numbers during the Devonian.

Early reptiles and the amniotic egg

One of the greatest evolutionary innovations of the Carboniferous period (360 - 268 million years ago) was the amniotic egg, which allowed early reptiles to move away from waterside habitats and colonise dry regions. The amniotic egg allowed the ancestors of birds, mammals, and reptiles to reproduce on land by preventing the embryo inside from drying out, so eggs could be laid away from the water. It also meant that in contrast to the amphibians the reptiles could produce fewer eggs at any one time, because there was less risk of predation on the eggs. Reptiles don’t go through a larval food-seeking stage, but undergo direct development into a miniature adult form while in the egg, and fertilisation is internal.

The earliest date for development of the amniotic egg is about 320 million years ago. However, reptiles didn't undergo any major adaptive radiation for another 20 million years. Current thinking is that these early amniotes were still spending time in the water and came ashore mainly to lay their eggs, rather than to feed. It wasn’t until the evolution of herbivory that new reptile groups appeared, able to take advantage of the abundant plant life of the Carboniferous.

Early reptiles belonged to a group called the cotylosaurs. Hylonomus and Paleothyris were two members of this group. They were small, lizard-sized animals with amphibian-like skulls, shoulders, pelvis and limbs, and intermediate teeth and vertebrae. The rest of the skeleton was reptilian. Many of these new "reptilian" features are also seen in little, modern, amphibians (which may also have direct-developing eggs laid on land e.g. New Zealand’s leioelmid frogs, so perhaps these features were simply associated with the small body size of the first reptiles.
The early mammals

A major transition in the evolution of life occurred when mammals evolved from one lineage of reptiles. This transition began during the Permian (286 - 248 million years ago), when the reptile group that included Dimetrodon gave rise to the "beast-faced" therapsids. (The other major branching, the "lizard-faced" sauropsids, gave rise to birds and modern reptiles). These mammal-like reptiles in turn gave rise to the cynodonts e.g. Thrinaxodon during the Triassic period.

This lineage provides an excellent series of transitional fossils. The development of a key mammalian trait, the presence of only a single bone in the lower jaw (compared to several in reptiles) can be traced in the fossil history of this group. It includes the excellent transitional fossils, Diarthrognathus and Morganucodon, whose lower jaws have both reptilian and mammalian articulations with the upper. Other novel features found in this lineage include the development of different kinds of teeth (a feature known as heterodonty), the beginnings of a secondary palate, and enlargement of the dentary bone in the lower jaw. Legs are held directly underneath the body, an evolutionary advance that occurred independently in the ancestors of the dinosaurs.

The end of the Permian was marked by perhaps the greatest mass extinction ever to occur. Some estimates suggest that up to 90% of the species then living became extinct. (Recent research has suggested that this event, like the better-known end-Cretaceous event, was caused by the impact of an asteroid.) During the subsequent Triassic period (248 - 213 million years ago), the survivors of that event radiated into the large number of now-vacant ecological niches.

However, at the end of the Permian it was the dinosaurs, not the mammal-like reptiles, which took advantage of the newly available terrestrial niches to diversify into the dominant land vertebrates. In the sea, the ray-finned fish began the major adaptive radiation that would see them become the most species-rich of all vertebrate classes.
One major change, in the group of reptiles that gave rise to the dinosaurs, was in the animals' posture. This changed from the usual "sprawling" mode, where the limbs jut sideways, to an erect posture, with the limbs held directly under the body. This had major implications for locomotion, as it allowed much more energy-efficient movement.

The dinosaurs, or "terrible lizards", fall into two major groups on the basis of their hip structure: the saurischians (or "lizard-footed" dinosaurs) and the ornithischians (misleadingly known as the "bird-footed" dinosaurs). Ornithischians include Triceratops, Iguanodon, Hadrosaurus, and Stegosaurus. Saurischians are further subdivided into theropods (such as Coelophysis and Tyrannosaurus rex) and sauropods (e.g. Apatosaurus). Most scientists agree that birds evolved from theropod dinosaurs.

Although the dinosaurs and their immediate ancestors dominated the world’s terrestrial ecosystems during the Triassic, mammals continued to evolve during this time.

**Further developments in the early mammals**

Mammals are advanced synapsids. Synapsida is one of two great branches of the amniote family tree. Amniotes are the group of animals that produce an amniotic egg i.e. the reptiles, birds, and mammals. The other major amniote group, the Diapsida, includes the birds and all living and extinct reptiles other than the turtles and tortoises. Turtles and tortoises belong in a third group of amniotes, the Anapsida. Members of these groups are classified on the basis of the number of openings in the temporal region of the skull.

**Synapsids** are characterised by having a pair of extra openings in the skull behind the eyes. This opening gave the synapsids (and similarly the diapsids, which have two pairs of openings) stronger jaw muscles and better biting ability than earlier animals. (The jaw muscles of a synapsid are anchored to the edges of the skull opening). Pelycosaurs (like Dimetrodon and Edaphosaurus) were early synapsids; they were mammal-like reptiles. Later synapsids include the therapsids and the cynodonts, which lived during the Triassic.

Cynodonts possessed many mammalian features, including the reduction or complete absence of lumbar ribs implying the presence of a diaphragm; well-developed canine teeth, the development of a bony secondary palate so that air and food had separate passages to the back of the throat; increased size of the dentary - the main bone in the lower jaw; and holes for nerves and blood vessels in the lower jaw, suggesting the presence of whiskers.

By 125 million years ago the mammals had already become a diverse group of organisms. Some of them would have resembled today's monotremes (e.g. platypus and echidna), but early marsupials (a group that includes modern kangaroos and possums) were also present. Until recently it was thought that placental mammals (the group to which most living mammals belong) had a much later evolutionary origin. However, recent fossil finds and DNA evidence suggest that the placental mammals are much older, perhaps evolving more than 105 million years ago. Note that the marsupial and placental mammals provide some excellent examples of convergent evolution, where organisms that are not particularly closely related have evolved similar body forms in response to similar environmental pressures.

However, despite the fact that the mammals had what many people regard as "advanced" features, they were still only minor players on the world stage. As the world entered the Jurassic period (213 - 145 million years ago), the dominant animals on land, in the sea, and in the air, were the reptiles. Dinosaurs, more numerous and more extraordinary than those of the Triassic, were the chief land animals; crocodiles, ichthyosaurs, and plesiosaurs ruled the sea, while the air was inhabited by the pterosaurs.

**Taking wing: Archaeopteryx and the origins of the birds**

In 1861 an intriguing fossil was found in the Jurassic Solnhofen Limestone of southern Germany, a source of rare but exceptionally well-preserved fossils. Given the name *Archeopteryx lithographica* the fossil appeared to combine features of both birds and reptiles: a reptilian skeleton, accompanied by the clear impression of feathers. This made the find highly significant as it had the potential to support the Darwinians in the debate that was raging following the 1859 publication of "On
the origin of species".

While it was originally described as simply a feathered reptile, Archaeopteryx has long been regarded as a transitional form between birds and reptiles, making it one of the most important fossils ever discovered. Until relatively recently it was also the earliest known bird. Lately, scientists have realised that Archaeopteryx bears even more resemblance to the Maniraptora, a group of dinosaurs that includes the infamous velociraptors of "Jurassic Park", than to modern birds. Thus the Archaeopteryx provides a strong phylogenetic link between the two groups. Fossil birds have been discovered in China that are even older than Archaeopteryx, and other discoveries of feathered dinosaurs support the theory that theropods evolved feathers for insulation and thermo-regulation before birds used them for flight. This is an example of an exaptation.

Closer examination of the early history of birds provides a good example of the concept that evolution is neither linear nor progressive. The bird lineage is messy, with a variety of "experimental" forms appearing. Not all achieved powered flight, and some looked quite unlike modern birds e.g. Microraptor gui, which appears to have been a gliding animal and had asymmetric flight feathers on all four limbs, while its skeleton is essentially that of a small dromaeosaur. Archaeopteryx itself did not belong to the lineage from which modern birds (Neornithes) have evolved, but was a member of the now-extinct Enantiornithes. A reconstruction of the avian family tree would show a many-branched bush, not a single straight trunk.

The end of the dinosaur age

Dinosaurs spread throughout the world - including New Zealand, which had its own dinosaur fauna - during the Jurassic, but during the subsequent Cretaceous period (145 - 65 million years ago) they were declining in species diversity. In fact, many of the typically Mesozoic organisms - such as ammonites, belemnites, gymnosperms, ichthyosaurs, plesiosaurs, and pterosaurs - were in decline at this time, despite the fact that they were still giving rise to new species.

The origin of flowering plants (the angiosperms) during the early Cretaceous triggered a major adaptive radiation among the insects: new groups, such as butterflies, moths, ants and bees arose and flourished. These insects drank the nectar from the flowers and acted as pollinating agents in the process.

The mass extinction at the end of the Cretaceous period, 65 million years ago, wiped out the dinosaurs along with every other land animal that weighed much more than 25 kg. This cleared the way for the expansion of the mammals on land. In the sea at this time, the fish again became the dominant vertebrate taxon.

The appearance of modern mammal groups

At the beginning of the Palaeocene epoch (65 - 55.5 million years ago) the world was without larger-sized terrestrial animals. This unique situation was the starting point for the great evolutionary diversification of the mammals, which up until then had been nocturnal animals the size of small rodents. By the end of the epoch, mammals occupied many of the vacant ecological niches. While mammal fossils from this period of time are scarce, and often consist largely of their characteristic teeth, we know that small, rodent-like insectivorous mammals roamed the forests, the first large herbivorous mammals were browsing on the abundant vegetation, and carnivorous mammals were stalking their prey.

The oldest confirmed primate fossils date to about 60 million years ago, in the mid-Palaeocene. The early primates evolved from archaic nocturnal insectivores, something like shrews, and resembled lemurs or tarsiers (the prosimians). They were probably arboreal, living in tropical or subtropical forests. Many of their characteristic features are well suited for this habitat: hands specialised for grasping, rotating shoulder joints, and stereoscopic vision. They also have a relatively large brain size and nails on their digits, instead of claws.

The earliest known fossils of most of the modern orders of mammals appear in a brief period during the early Eocene (55.5 - 33.7 million years ago). Both groups of modern hoofed animals, the Artiodactyla ("even-toed" taxa such as cows and pigs) and Perissodactyla ("odd-toed" taxa, including the horses), became widespread throughout North America and Europe. The evolutionary history of the horses is particularly well understood: Stephen Jay Gould (1983) provides an excellent discussion of it in his book "Hens' teeth and horses' toes".
At the same time as the mammals were diversifying on land, they were also returning to the sea. The evolutionary transitions that led to the whales have been closely studied in recent years, with extensive fossil finds from India, Pakistan, and the Middle East. These fossils chronicle the change from the land-dwelling mesonychids, which are the likely ancestors of whales, through animals such as *Ambulocetus*, which was still a tetrapod but which also has such whale-like features as an ear capsule isolated from the rest of its skull, to the primitive *whales called the Archaeocetes*.

The trend towards a cooler global climate that occurred during the Oligocene epoch (33.7 - 23.8 million years ago) saw the appearance of the grasses, which were to extend into vast grasslands during the subsequent Miocene (23.8 - 5.3 million years ago). This change in vegetation drove the evolution of browsing animals, such as more modern horses, with teeth that could deal with the high silica content of the grasses. The cooling climate trend also affected the oceans, with a decline in the number of marine plankton and invertebrates.

While DNA evidence suggests that the great apes evolved during the Oligocene, abundant fossils do not appear until the Miocene. Hominids, on the evolutionary line leading to humans, first appear in the fossil record in the Pliocene (5.3 - 1.8 million years ago). The story of human evolution is covered here - Human Evolution material.

New Zealand, by virtue of its isolation and its relatively recent geological development, was not the centre of any novel evolutionary development. However, many of the species that date back to Gondwanaland, or that arrived more recently as migrants, have undergone significant adaptive radiation in their new homeland. Some of the best examples of this can be related to the major ecological changes that accompanied the Pleistocene Ice Ages.

Throughout the Pleistocene there were about twenty cycles of cold glacial ("Ice Age") and warm interglacial periods at intervals of about 100,000 years. During the Ice Ages glaciers dominated the landscape, snow and ice extended into the lowlands, transporting huge quantities of rock with them. During these periods the South Island was extensively glaciated, and there were small glaciers on the Tararua Ranges and Central Plateau. Because a lot of water was locked up in ice, the sea levels dropped during the glacial periods (up to 135m lower than at present). Extensive land bridges joined the main and many offshore islands, allowing the migration of plants and animals. During the warmer periods large areas became submerged again under water. These repeated episodes of environmental fragmentation drove rapid adaptive radiation in many NZ species, especially (but not exclusively) the alpine plants.

For example, speciation patterns in the native *Placostylus* flax snails of Northland can be related to changes in sea level. Originally 2-3 species were widespread at a time of low sea levels. Rising seas at the end of the glacial period isolated these as populations on offshore islands, where differential natural selection pressures led to the evolution of a greater number of separate species.

The distribution of land snails such as *Powelliphanta* in Marlborough and the southern North Island also offers evidence for the presence of land bridges and the possibility of future speciation. The same varieties are found both north and south of Cook Strait, implying a continuous land bridge in the past as the animals die in salt water. The fact that no further speciation has occurred in this case suggests that the land bridge was recently submerged by rising seas, perhaps only 10,000 years ago.

New Zealand Example

For more information on NZ examples of evolution, click here.

Reference Books


Gould, Stephen Jay (1983) *Hen's teeth and Horses' toes*