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WHAT IS EVOLUTION?

Imagine a volcano growing on the ocean floor and erupting through the water's surface. The lava cools, forming a new island. A flock of birds have been blown off course in their migration, and they stop to rest on the new island. The only food available is the shrimp that wash up on the shore. Only a few of the birds have a taste for these shrimp. The rest of the flock either dies or flies to look for food somewhere else.

The birds that are left lay eggs. Some of these chicks will have a taste for the shrimps and so they can feed. Others are like the rest of the original flock – they cannot eat them, so they die. Only those that can eat the shrimps grow up and have chicks of their own.

After many years, only the shrimp-eating birds have survived. The descendants of the rest of the original flock come back to the island, having been blown off course again. They find that their distant relatives who stayed have become so different that they have become a different species. This is evolution.

Changing and adapting

Evolution can happen anywhere and at any time, not just on a new island. Any change in habitat or climate can spark evolution. An animal does not decide to evolve. It is a process that takes small changes over many generations.

Mutations

When animals have babies, most of their offspring are very similar to their parents and can live in the same environment. Occasionally there will be a random change in the genes that control a baby animal's traits. This kind of change is called a mutation. Most mutations make the animal less likely to survive. If it dies, or does not have babies of its own, the mutation cannot be passed on.

However, once in a while, the mutation will actually give the animal an advantage. The animal will survive and will likely have lots of healthy offspring of its own, passing on its useful mutation. We call this process natural selection, and it is how evolution works. Mutations produce changes, and natural selection leads to more animals with the successful mutations.

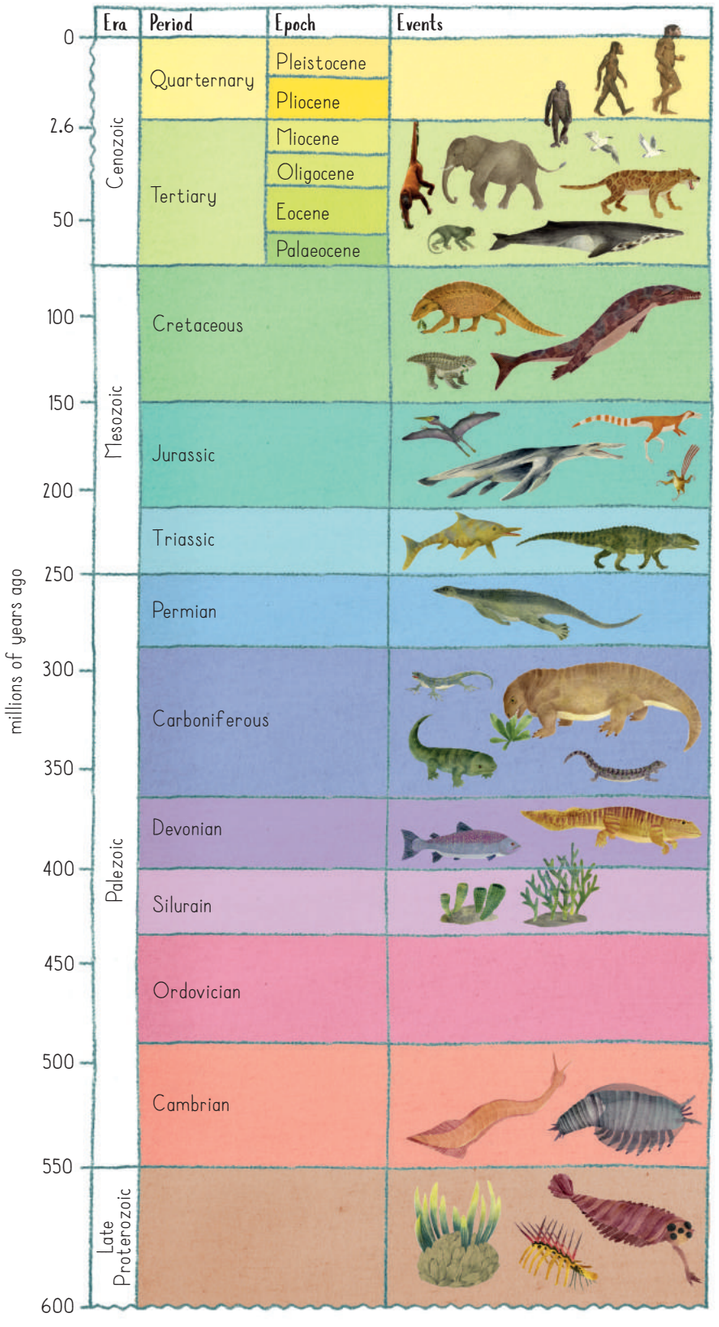
The journey begins...

This book will take you on a tour of the history of life on Earth, following all of its twists and turns. The thirteen case studies will each describe the evolution of a different group of animals, from the earliest fish to modern humans. As you uncover the history of each group, see if you can spot the patterns in the ways that different animals have evolved.

A TIMELINE OF LIFE ON EARTH

There has been life on Earth ever since the planet was cool enough and stable enough to support it – about three and a half billion years. The timescales are so vast that they are hard to comprehend. To make it easier, scientists divide earth's history into manageable chunks, or periods. These periods are based on the types of living things that existed during that time.

Geologic time scale, 600 million years ago to the present



As long as there has been life, there has been evolution. For most of Earth's history, the only life forms that existed were simple organisms made up of a single cell. More complex living things appeared about 600 million years ago.

The chart on the left shows the geological time scale of life on Earth from this point onwards. The time scale is always laid out like this, with the oldest at the bottom and the youngest at the top. This reflects the sequence in which the earth's rocks were laid down.



Where do fossils come from?

Fossils are the remains of living things that have been preserved in rock. Most fossils are found in sea sediments. In fact until about 400 million years ago all life was in the water. After this, fossils of land plants and animals begin to appear, but these fossils are very rare compared with those of sea-dwellers.

EARTH TODAY



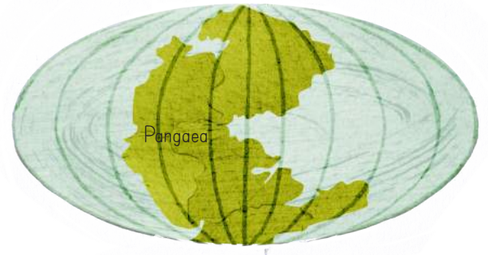
CRETACEOUS PERIOD
66 MILLION YEARS AGO



JURASSIC PERIOD
145 MILLION YEARS AGO



PERMIAN PERIOD
250 MILLION YEARS AGO



SILURIAN PERIOD
419 MILLION YEARS AGO



Changing Earth

It is not only life that has been changing – the surface of the planet has been changing too. Millions of years ago, there were several large continents scattered across the globe. They were moving all the time, "floating" on the softer rock deep inside the earth. About 335 million years ago, all the continents came together and fused into a single "supercontinent" that we call Pangaea.

Pangaea existed for about 60 million years, and then, in the middle of the Jurassic period, it began to split up. The pieces slowly drifted apart, giving us the continents that we know today. Have you ever wondered why the eastern coast of South America seems to be a perfect fit with the western coast of Africa? They were joined together, long ago. The continents are still moving, but very slowly – an inch or less per year.



All change

Today, each corner of the world is home to very different animals. Millions of years ago, different kinds of animals lived on different continents, but they mixed with other species as continents came together. They then became separated when the continents split up again. Continents' climates changed as they moved between the hot tropics and cold polar regions. These changing conditions, combined with natural selection, produced the huge variety of life we see today.

WORKING OUT THE EVOLUTIONARY TREE

The idea of evolution – one group of animals changing into another – has been around for a long time. However, it was British scientist Charles Darwin (1808-82) who really brought it to people's attention with his book On The Origin of Species, published in 1859.

Darwin is usually credited as being the first person to realize that the process of evolution requires a combination of mutation and natural selection. But great minds think alike – another scientist, Alfred Russell Wallace, was working in a different part of the world, and he came up with the same idea at the same time.

The tree of life

Darwin didn't picture evolution working as a single line, with one animal changing into another and then into another. Instead, he saw it as more like a tree or a bush. There were various lines branching off in different directions. Most of them died out, but some carried on and survived. Each surviving branch was capable of branching into even more branches.

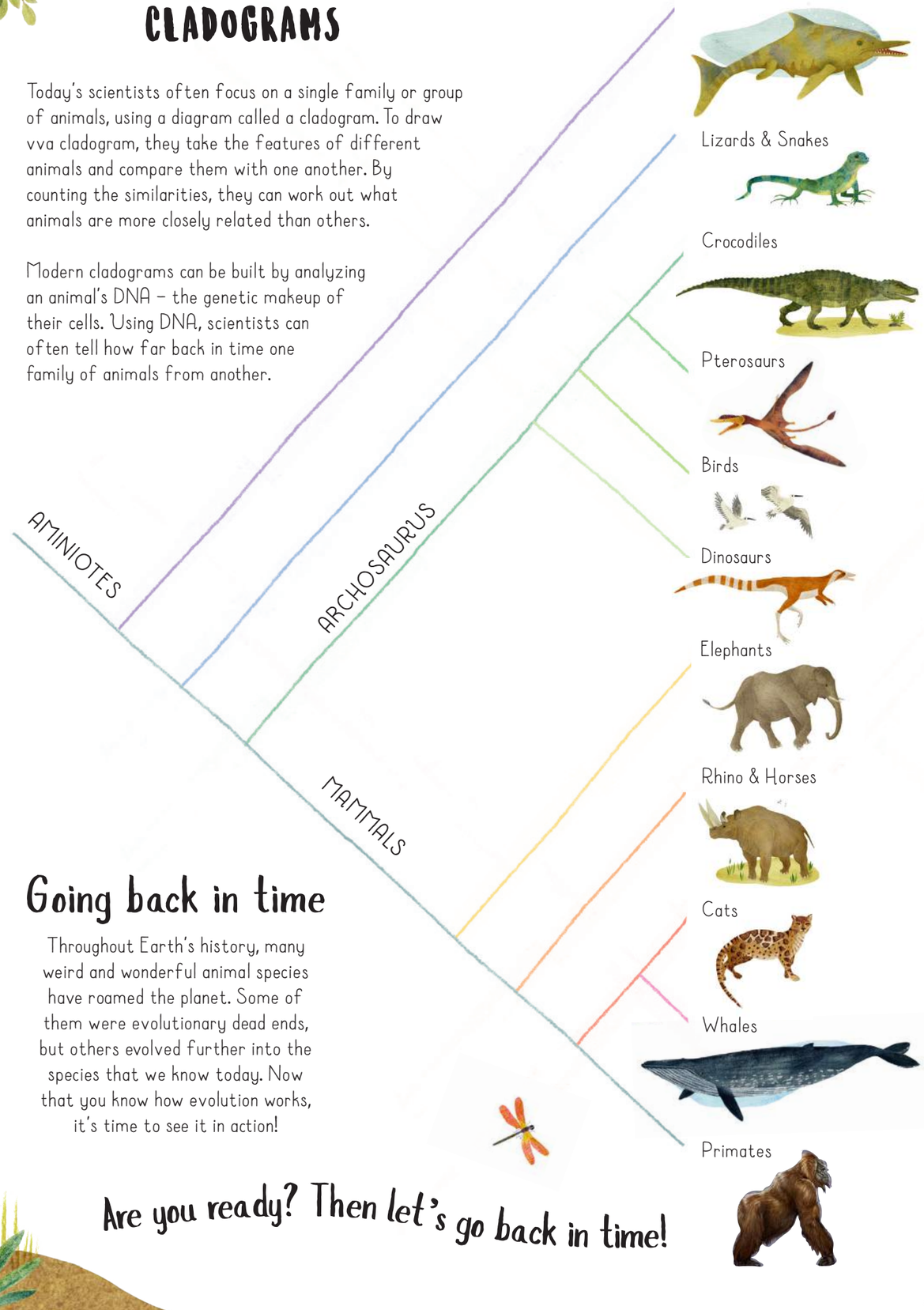
Darwin's idea of a "tree of life" soon became the standard way of illustrating evolutionary history, and it lasted for about a hundred years. The various branches on the tree were based on fossil evidence and could be fitted neatly into the geological timescale. Fossil hunters around the world searched for new discoveries that would serve as the "missing link" to show how one animal evolved into another.



CLADOGRAMS

Today's scientists often focus on a single family or group of animals, using a diagram called a cladogram. To draw vva cladogram, they take the features of different animals and compare them with one another. By counting the similarities, they can work out what animals are more closely related than others.

Modern cladograms can be built by analyzing an animal's DNA – the genetic makeup of their cells. Using DNA, scientists can often tell how far back in time one family of animals from another.



Going back in time

Throughout Earth's history, many weird and wonderful animal species have roamed the planet. Some of them were evolutionary dead ends, but others evolved further into the species that we know today. Now that you know how evolution works, it's time to see it in action!

Are you ready? Then let's go back in time!

A BIG EXPERIMENT

Something strange happened about 540 million years ago. Hard shells suddenly evolved. This might not sound all that impressive, but it had a big impact. Before this, animal life consisted of soft squidgy things, built like little duvets, with flexible outer coverings and squashy organs inside. Hardly anything was able to be fossilized. Now, with hard shells, things could be preserved as fossils, and from this point onwards we have a clear idea of how life evolved.

Trial and error

The hard shell or skeleton was so successful, that it allowed all sorts of new things to evolve, based on this new plan. Nature seemed to be trying out all sorts of shapes and lifestyles to see what worked. Most did not, but some went on to evolve into the many animals that we see about us today.

Strange fossils

The evolution of hard shells marks the beginning of what we call the Cambrian period. On the side of a mountain in British Columbia, Canada, there is a sequence of Cambrian rocks called the Burgess Shales. These contain the fossils of the many strange creatures that evolved in the oceans at this time. Here are just a few!

HALLUCIGENIA

Pronounced: Hal-oo-si-jen-eye-a
Size: 3.5cm long

Tentacles along one side, stilt-like struts along the other, a trunk at one end. Scientists are still trying to work out how *Hallucigenia* lived – or even which way up it stood. It only lived in Cambrian times.

WIWAXIA

Pronounced: Wi-wax-eea
Size: 5cm across

Like a slug with chain mail and spikes, *Wiwaxia* was very widespread at the time – fossils have been found in both Canada and China. However, it did not survive very long.

CANADASPIS

Pronounced: Can-ah-das-pis
Size: 7.5cm long

Here is one that seemed to work. *Canadaspis* had a segmented body, a heavy shield at the front, paired limbs and feeding organs at the head. It probably belonged to the line that survived and developed into the modern marine arthropods – the group of animals that contains crabs and lobsters.

OPABINIA

Pronounced: Oh-pa-bin-eea
Size: 7cm long

This had a segmented body, a pair of jaws on a long trunk at the front, possibly gills on the tail – and five eyes. Count them! This one did not survive either.

PIKAIA

Pronounced: Pie-kaiah
Size: 4cm long

Another success! *Pikaia* had paired muscles along an internal support, and swam by moving its whole body from side to side. It seems to have been an early form of chordate – the group that contains all the vertebrates from the fish, through the reptiles and the mammals to ourselves.