

PRESENTER NOTES: THE HISTORY OF LIFE

SLIDE 1: THE HISTORY OF LIFE

Presenter notes: Life is what makes our planet different. As far as we know, Earth is the only planet in the Solar System ever to have harboured life, although it is not impossible that it may have once existed on Mars in the distant past. Life is hugely important for the way our planet works and has altered almost every aspect of its atmosphere, ocean and land. This talk discusses the History of Life from the earliest times to the present day. Being a historical account of how life evolved, it does not deal with the process by which that change happened. This is examined in depth in a companion talk on Evolution.

Background note: The companion talk on Evolution can be downloaded from the Your Earth website: <http://www.earth4567.com/talks/evolution.html>

SLIDE 2: DIVERSITY – SIMPLE ORGANISMS

Presenter notes: The richness of life on Earth is simply incredible. Around 1.8 million species have been discovered and named so far. However, conservative estimates suggest that an additional 8 million are left to describe - so less than a quarter of all living species are known to Science! Despite all this diversity, all organisms fall into just one of two categories. One group of organisms has simple cells with DNA strands floating within a capsule. These prokaryotes, as they are called, are all single celled bacteria. We still know very little about the diversity of bacteria.

SLIDE 3 – COMPLEX ORGANISMS

Presenter notes: The second group of organisms, which we call eukaryotes, have complex cells that have compartments with special jobs and DNA located in a nucleus. This group includes the familiar kingdoms of organisms like animals, plants and fungi. Most of the organisms in these kingdoms are multicellular, made up of many cells working together. However, other eukaryotes include the single-celled kingdoms of the protozoa and the 'golden brown algae' or chromists.

SLIDE 4: THE FOSSIL RECORD

Presenter notes: When organisms die they may leave behind a record in the form of their skeleton or shell or stem. These fossil remains can survive for millions and sometimes billions of years. Palaeontologists extract fossil remains from the rock and use them to piece together the History of Life. Organisms are only preserved in special conditions so only a tiny proportion of all living things ever become fossils. Consequently the fossil record is incomplete and many questions remain unanswered about the History of Life. Nevertheless in general terms the fossil record gives a surprising clear insight into the historical sequence of events that gave rise to the life we see around us today.

SLIDE 5: GEOLOGICAL TIME

Presenter notes: The history of the Earth stretches back over 4550 million years (or 4.55 billion years). Geologists have divided up this vast abyss of geological time into an orderly series of eons, eras, and periods. By determining the age of the strata in which the fossils are found, their order of occurrence can be worked out, and the History of Life established. At the bottom of every slide in this talk, you will see a geological time scale like the ones shown here. This will pictorially show the age of the fossils discussed in that slide. Also note that a common abbreviation used throughout this talk is mya, which stands for ‘million years ago’ (e.g. 500 mya is shorthand for 500 million years ago)

Note: There is another Your Planet Earth talk that specifically deals with Geological Time. You can download it here: www.earth4567.com/talks/time.html

SLIDE 6: TALK OUTLINE

Presenter notes: This talk has three parts. In the first part, we will discuss the early history of life and see how life began in the Sea about 3800 million years ago. In the first activity we will then examine the ecology of one of the most famous fossil sites anywhere in the world: the Burgess Shale of British Columbia, Canada. In the second part, we will learn about the invasion of land, which began about 500 million year ago, and in the following activity we will compare two early land ecosystems and think about the progressive development of food webs. Finally, in the third part, we will see how life continued to diversify to the present day, but was occasionally subject to waves of extinction. Five mass extinctions have occurred over the past 500 millions and have profoundly shaped Life on Earth. We will conclude by asking whether human activity is now triggering a sixth mass extinction.

PART 1: LIFE BEGINS IN THE SEA

SLIDE 7: BOMBARDMENT

Presenter notes: So let’s begin our story of the History of Life and travel back in time to the origin of the Earth. For much of its earliest history, the Earth was probably not a very hospitable place for life to evolve. For 700 million years after its origin, the Earth was bombarded by massive meteorites, chunks of rock left over from the formation of the Solar System. Plate tectonics, together with weathering, has all but erased the numerous impact craters that must have been formed on Earth at this time. However, on the moon, where weathering and plate tectonics do not occur, the heavily cratered surface has survived. Life probably began sometime after the phase of heavy bombardment ended about 3800 million years ago. No one has yet figured out how life began, and there are even question marks over whether life started on Earth. Some scientists hypothesize that life could have begun on Mars, or somewhere else in Space, only later ‘seeding’ the Earth. In support of this idea is the fact that certain meteorites contain the basic building blocks of life, and the fact that some dormant bacteria can potentially survive in the vacuum of space for millions of years. Nevertheless most scientists think that life began on Earth.

SLIDE 8: FIRST LIVING THINGS

Presenter notes: Whatever the origin of life, there is fossil evidence of the simplest prokaryotic life-forms that had evolved by 3500-3800 million years ago. Structures found in rocks of this age include small layered domes called stromatolites. Similar structures are found today in places like Shark Bay on the western coast of Australia and form by the growth of sticky bacterial films. The sticky bacteria trap mud, which results in the build up of the small layered domes. The existence of stromatolite domes in the fossil record therefore implies that bacteria had evolved in the sea by this time. One fossil site in Australia called the Apex Chert contains organic filaments that may represent actual bacteria. However some scientists dispute whether these features are really fossil bacteria and say that they could have a non-biological origin.

SLIDE 9: OXYGEN

Presenter notes: Although the fossil record of the early Earth is difficult to interpret, other evidence supports the idea that simple bacteria evolved in the sea very early the planet's history. One important bit of evidence is the thick deposits of iron oxide that occur in rocks of this age. Geologists believe that the early Earth lacked oxygen. If that was the case then where did all the oxygen come from which combined with the iron to form the iron oxide deposits? One idea is that the first bacteria grew by capturing energy from the sun by photosynthesis like do plants today. Oxygen is the waste product of photosynthesis, so as the bacteria grew they would have released oxygen into the seas. This would have reacted with any iron in the seawater causing it to 'rust' and form a layer of iron oxide on the seabed. The iron oxide deposits are therefore indirect evidence for the existence of bacteria at that time.

SLIDE 10: COMPLEX CELLS

Presenter notes: Simple prokaryotic bacteria were the only life forms on our planet for the first half of its history! However, nearly two billion years after the evolution of the first bacteria cells, there was amazing leap forward in the way that living things were constructed. About 1900 million years ago, fossils called acritarchs appear in the fossil record. These comprise a single eukaryotic cell with compartments with special jobs like mitochondria to make energy and a nucleus to store the DNA. No one knows exactly how eukaryotic cells evolved. One idea is that a prokaryotic bacterium enveloped another prokaryotic cell, but rather than digesting it as might normally happen, it incorporated as a special compartment in the cell. What is known is that eukaryotes are oxygen-hungry cells so their evolution was probably delayed until enough oxygen had built up in the seas. The evolution of the eukaryote cell paved the way for the diversity of complex life forms seen today.

SLIDE 11: MULTICELLULAR LIFE

Presenter notes: It's amazing to reflect on the fact that for the first two-thirds of our planet's history, the only life-forms were single-celled. However, all that changed around 1400 million years ago, when the fossil record shows that many-celled organisms evolved. One fossil from this time period is called Grypania. This is a coiled tube about 2 mm wide and up to 5 cm long that is found in rocks from North America, China and India. No one knows what kind of organism Grypania was, but its large size strongly suggests that it must have been made up of many cells working together.

SLIDE 12: BIOLOGY'S BIG BANG

Presenter notes: Another major event in the History of Life that happened about this time was the origin of sex! In Canadian rocks more than 1200 million years old, a fossil called Bangiomorpha has been found. This is a kind of red algae, the group that includes most seaweeds today. Not only was Bangiomorpha another early example of a many-celled organism, it also occurs in two forms, male and female, that demonstrate that sexual reproduction had evolved. Sex allowed life-forms to juggle their genes and increase the speed at which evolution could take place. This important event has been called 'Biology's Big Bang' by some smutty palaeontologists!

SLIDE 13: EDIACARA EVIDENCE

Presenter notes: By about 630 million years ago, and probably earlier, fossils show that the three familiar kingdoms of animals, plants, and fungi had probably evolved. However, not all fossils from this time interval are easy to interpret. In rocks aged 630-542 million years old, strange fossils are present known as the Ediacara Fauna. No one is quite sure what these fossils represent, but it is likely that some are early marine animals - though quite different from any animals today. These weird but important fossils were first brought to the world's attention by a English schoolboy in the 1950s who found specimens at Charnwood Forest in Leicestershire. This just goes to show that sharp-eyed amateurs can make fossil discoveries of huge importance.

SLIDE 14: DIVERSITY EXPLODES

Presenter notes: Once the animal kingdom had evolved, it quickly exploded into a wide diversity of different species. This explosion happened so quickly that it is difficult to explain in term of normal evolutionary processes. Evolution usually happens slowly but between 542 and 515 million years ago, animal life took an incredible leap forward. In less than 30 million years, almost every major group of animals evolved from jellyfish to snails to vertebrates. In addition, some weird animals also appeared that subsequently went extinct. These evolutionary experiments included a 2 metre long sea monster called Anomalocaris (see slide). One of the best places in the world to study marine life just after this explosion in animal life is the 515 million year ago Burgess Shale of British Columbia, Canada. This fossil site preserves the remains of animals in beautiful detail and even the soft tissue has survived.

SLIDE 15: ACTIVITY – THE BURGESS SHALE

Presenter notes: In the first activity we will learn more about the fossils of the Burgess Shale of Canada and investigate what they tell us about the ecology of early communities of marine animals.

PART 2: LIFE INVADES THE LAND

SLIDE 16: MAKING TRACKS

Presenter notes: About the time that the Burgess Shale animals were alive, the History of Life was experiencing another major development. Up to this point in time, life had been largely restricted to the sea, but 500 million years ago, the invasion the land commenced. The earliest evidence we have for the invasion of land comes from tracks left in coastal dune sands in North America. The tracks were probably made by giant lobster-like creatures called eurypterids, or their relatives. Eurypterids mostly lived in the sea but made temporary excursions onto land to feed and mate in much the same way that horseshoe crabs do today.

SLIDE 17: PERMANENT RESIDENTS

Presenter notes: Eurypterids were only temporary visitors to land and permanent residents did not establish themselves for quite some time later. However, about 460 million years ago, fossil soils in the USA contain complex burrow systems. The diagram on the left reconstructs what these burrows looked like in three dimensions. They were probably made by worms mining through the soil and show that land animals had arrived. At exactly the same time, remains of primitive plants start to appear in the fossil record. These include fragment of liverworts, the most primitive of the living plants today. Liverworts probably formed a spreading mat over the surfaces of wet soils and created a habitat which other animals could begin to colonize.

SLIDE 18: A TASTE FOR PLANTS

Presenter notes: The first animals to come onto land were either carnivores, eating other animals, or detritivores, living off dead and decaying organic matter in the soils. However, about 420 million years old, the fossil record tells us that animals started to get a taste for plants. The evidence is in the form of fossilized faecal pellets, or poo (!), excreted by millipedes and related animals and found in the famous Ludlow Bone Bed of Shropshire. The poo contains the remains of plants, showing that the first herbivores, or plant-eating animals, had evolved.

SLIDE 19: TIME CAPSULE

Presenter notes: We have already stressed the fact that only a tiny proportion of living organisms are ever preserved in the fossil record and as result it is often incomplete. However, this is not always the case, as illustrated by an amazing 400 million year old fossil site at Rhynie in Aberdeenshire, Scotland. The Rhynie Chert preserves an entire land-based ecosystem in amazing detail. This unique 'time capsule' was formed when a nearby volcanic geyser, or hot spring, erupted and overwhelmed the adjacent ecosystem in boiling water. The boiling water carried lots of silica in solution that mineralized every cell of every organism, preserving them in extraordinary detail. The Rhynie Chert is a rare 'snap shot' of what life was like on land 400 million years ago. It demonstrates that the tallest plants were no more than 10 cm high and scurrying through this vegetation was a diverse group of invertebrates including mites, springtails, and spiders.

SLIDE 20: FIRST FORESTS

Presenter notes: This world of ankle-high plants didn't stay like that for long because huge evolutionary change was transforming the plant kingdom. Fossils show that by 380 million years ago, some plants had acquired huge tree trunks that formed leafy forest canopies more than 30 metres high. At the same time plants were changing the way they reproduced. The earliest plants had reproduced using spores, as ferns do today, but now they developed seeds. Seeds help germinating plants to better survive drought. Once the seed had evolved, plants had the capacity to colonize dry land away from the coastal wetlands.

SLIDE 21: AMPHIBIANS

Presenter notes: At the same that plants were undergoing this radical transformation, similarly dramatic changes were occurring amongst back-boned animals, or vertebrates. Fossil skeletons show that the first amphibians, the ancestors of frogs, evolved about 380 million years ago. Several early amphibian fossils have been found but one of the most famous is Ichthyostega from Greenland. Amphibians like Ichthyostega may have evolved from lungfish, or similar fish. Lungfish are freshwater fish that have the ability to breathe air for limited periods. As they live in ponds that occasionally dry up, the fish will burrow into the mud, slow down their heart beat and breathe air until the next rains fill the pond again. Whatever were the ancestors of amphibians, they had to undergo many evolutionary adaptations to life on land. Changes included the development of limbs instead of fins, the acquisition of lungs instead of gills, and changes to sensory organs like eyes and ears.

SLIDE 22: REPTILES

Presenter notes: As anyone who's ever seen frog spawn in ponds knows, one of the characteristics of amphibians is that they need to return to water to breed and reproduce. About 315 million years ago, fossil skeletons found in Nova Scotia, Canada show that the first reptiles had evolved from amphibian ancestors. The fossil were found by a famous North American geologist called William Dawson at a place known as the South Joggins. In a slightly unorthodox approach to fossil collecting, Dawson used dynamite to blast fossils out of the cliff. Fortunately some of the fragile reptile fossils survived this ordeal! One of the features that makes reptiles distinct from amphibians is that they lays eggs on land. Somewhat similar to the evolution of the seed in the plant kingdom, the reptile egg allowed these animals to colonize drier areas away from rivers and ponds

SLIDE 23: FIRST RAINFORESTS

Presenter notes: By 300 million years ago life on land was really thriving. Across Europe and North America at this time, thick layers of coal were formed. These coal layers are the remains of the first tropical rainforests to develop on our planet. Next time you have a coal fire, see if you can find any fossil leaves compacted in the coal. Fossils show that these rainforests were inhabited by a rich diversity of animals including giant-sized dragonflies and millipedes!

SLIDE 24: ACTIVITY – LAND FOOD WEBS

Presenter notes: In the second activity we will compare land ecosystems of the Devonian Period, 375 million years ago, when the first trees were evolving, with those of the Carboniferous Period, 300 million years ago, when the first rainforests appeared. We will think about developing food webs and what this tells us about the invasion of land over geological time.

PART 3: LIFE BOOMS... THEN BUST?

SLIDE 25: THE GREAT DYING

Presenter notes: Around 251 million years a devastating event threatened to wipe out life on Earth entirely. No one knows what happened exactly but more than 95% of all species in the sea disappeared and life on land was also brought to brink of collapse. Such events are known as mass extinctions. There have been five “big” mass extinctions since the invasion of land, 500 million years ago, but this extinction was by far the biggest of all time. The perplexing thing is that no one really knows what caused it. Some scientists argue that there was a massive volcanic eruption at that time that went on for thousands of years but others disagree that this was the cause.

SLIDE 26: DINOSAURS

Presenter notes: Following this “mother of all extinctions”, 251 million years ago, life slowly recovered. Subsequently, it went from strength to strength, getting ever more diverse over time. One of the great success stories of this boom time in the History of Life were the dinosaurs. They evolved 220 million years ago and dominated the land for the next 150 million years. As everyone knows “dinosaur” means “terrible lizard” but these giant reptiles included both plant-eating giants such as Diplodocus as well as ferocious meat-eating dinosaurs like T. rex. Scientists used to think that dinosaurs were sluggish cold-blooded animals like modern reptiles, but now evidence has emerged to show that at least some dinosaurs were warm-blooded. One piece of evidence comes from dinosaur footprints that show that some could run as fast as Olympic sprinters (up to 27 miles per hour). Cold-blood animals could not achieve such speeds.

Note: You can learn much more about dinosaurs in another Your Earth talk that can be downloaded here: <http://www.earth4567.com/talks/dinosaurs.html>

SLIDE 27: BIRDS

Presenter notes: One of the most exciting recent revelations in the History of Life is that birds evolved directly from two-legged dinosaurs like T. rex about 155 million years ago. In fact some palaeontologists now refer to birds as ‘avian dinosaurs’. The similarity between birds and dinosaurs has been recognized since the 1840s but only recently has fossil evidence proved this relationship beyond reasonable doubt. Some dinosaurs have even been found with feathers!

Much controversy remains as to how birds evolved the ability to fly. Some scientists think the first birds hunted from the tree tops and developed wings to control descent when pouncing on prey from above. Others think they developed wings to help them run along the ground.

SLIDE 28: MAMMALS

Presenter notes: About the time that dinosaurs were starting out, another important group was also evolving: the mammals. The mammals lived in the shadows of the dinosaurs for 150 million years. Based on their skeletons, scientists think that many early mammals were small insectivores. They were also probably nocturnal, being active in the night to avoid being eaten by dinosaurs. This may explain why mammals independently evolved as warm-blooded animals. Not all mammals lived in this way, however. Some fossils from China show that certain dog-sized mammals actually preyed on and ate baby dinosaurs!

SLIDE 29: DEEP IMPACT

Presenter notes: We have already noted that there have been five mass extinction events on our planet since the invasion of land, 500 million years ago. Earlier we discussed the greatest of all extinctions that happened 251 million years ago. However, arguably a much more famous mass extinction occurred 65 million years – the extinction that wiped out the dinosaurs and many other organisms. For years, there was great controversy as to what killed the dinosaurs but now scientists mostly agree that the likely cause was the impact of a 10 km diameter meteorite with the Earth. The evidence for a meteorite impact is compelling. One piece of evidence is the occurrence of quartz grains in rocks that date from the extinction of the dinosaurs that show fracture patterns characteristic of a massive explosion. More recently a 200 km diameter impact crater has been found in the Gulf of Mexico which shows exactly where the meteorite struck! This Crater of Doom is a lasting reminder of how vulnerable life is to extraterrestrial impacts. The meteorite would have caused global tsunamis and wildfires in the first few hours after impact but over the longer term the planet would have been plunged into a nuclear winter-like scenario with dust blocking out the light of the sun.

SLIDE 30: GRASS AND GRAZERS

Presenter notes: Long after the extinction of the dinosaurs, climate became cooler and drier. Grasses that had evolved right at the end of the age of the dinosaurs spread over much of the world. The mammals that for so long had lived in the shadow of the dinosaurs became the dominant large animals on land. In particular, a variety of grazing mammals evolved, feeding off the grasslands of this increasingly modern-looking world. Grass contains a hard compound, silica and as mammals started to eat grass they had to evolve a battery of teeth that continued to grow throughout their lives. This was because the silica in the grass constantly ground down their teeth as they grazed.

SLIDE 31: HUMANS

Presenter notes: As recently as 2 million years ago, our human ancestors evolved from primates, the group of mammals that include the apes. We belong to the genus, *Homo*. Today there is only one human species, *Homo sapiens*, which means “wise human”. However, earlier in our evolutionary history several human species lived side by side including *Homo erectus* (Upright Man) and *Homo neanderthalensis* (The

so-called Neanderthal Man). Some major milestones in the evolution of humans included the ability to walk upright, the ability to use fire and tools to control the world around them, and perhaps most importantly of all, the development of society and culture. The walls of the famous Lascaux Cave in France are covered by paintings of animals and human hunters dating back more than 10,000 years and show that art had been born by this time.

SLIDE 32: SIXTH EXTINCTION

Presenter notes: Shortly after the evolution of Homo sapiens in Africa, about 130,000 years ago, modern humans spread worldwide. Around 15,000 years ago many large mammals like the woolly mammoth started to go extinct and it is possible (though difficult to prove) that human hunting was responsible. As human society continued to develop, forests were cleared for agriculture, and the industrial revolution began, so the rate of extinction related to human activity increased. It is difficult to estimate the rate at which species are going extinct today but famous ecologist E.O. Wilson believes that half of all species will go extinct before 2100. We have already noted that there have been five mass extinction events over the past 500 million years. Given the facts, it seems unavoidable to believe that we are now in the midst of a sixth mass extinction.

SLIDE 33: THE HISTORY OF LIFE

Presenter notes: In this talk we have looked at what the fossil record can tell us about the amazing History of Life on Earth. We've examined the evidence for an early origin for life in the sea, 3800 million years ago, and investigated how life invaded the land about 500 million years ago. In our last section we discussed the subsequent boom in life that massively increased biodiversity but also noted how the History of Life is frequently punctuated by mass extinctions. Today we stand on the threshold of a new mass extinction event. The biodiversity that we take for granted and that sustains human life is threatened to a degree only rarely seen in 4500 million years of Earth History.

As we conclude discuss amongst yourselves the following questions: Are we really on the brink of a mass extinction? What would be the consequences for society of losing half of all species by 2100? Are there actions that we can take – as individuals and as society - to help protect life on Earth?