PRESENTER NOTES: EVOLUTION

INTRODUCTION

SLIDE 1. EVOLUTION
Presenter notes: Evolution is one of the most important concepts in the Science of Biology. In fact Biology simply does not make sense without Evolution. Evolution is the idea that all living things arose from a single common ancestor in the distant past and that life continues to diversify today as new species appear. Evolution explains why we can classify organisms into different groups (because some organisms are more closely related than others). Evolution explains why the cells of all organisms use the same kind of biochemical machinery (because all life shares a common ancestor). This talk deals with the discovery of evolution, how evolution works, and the evidence for evolution.

Background note: A companion talk dealing with the History of Life from its earliest origins to the present day can be downloaded from the Your Planet Earth website: http://www.earth4567.com/talks/life.html. Although these two modules on Evolution and the History of Life can be delivered as stand-alone resources, they are best studied together.

SLIDE 2. THE TREE OF LIFE
Presenter notes: All living things share a single common ancestor in the distant past and all living things are related to one another. In much the same way that we might draw a family tree of our own ancestors, scientists can draw a Tree of Life to show how all living things are related. Evolution is the process by which one species gives rise to another and the Tree of Life grows.

SLIDE 3: EVOLUTION AS THEORY AND FACT
Presenter notes: There is often considerable confusion as to whether the concept of evolution is a theory or a fact. Actually it is both! Evolutionary theory deals with how evolution happens. This is an area of active research and new insights are constantly emerging to explain how one species gives rise to another. However, Evolution is also a fact because there is a great deal of indisputable evidence, as we will see in this talk, in support of its occurrence. What is uncertain is exactly HOW it happens, NOT whether it has happened at all.

Further background reading: Stephen Jay Gould, "Evolution as Fact and Theory," Discover 2 (May 1981): 34-37; available here: http://www.stephenjaygould.org/library/gould_fact-and-theory.html

SLIDE 4: TALK OUTLINE
Presenter notes: This talk has three parts. In the first part we will look at the scientific breakthroughs that led to the discovery of evolution between 1800 and 1940 and consider some of the objections to evolution raised by some fundamentalist religious groups. In the discussion that follows we will debate a controversial issue that is often raised by fundamentalist Christians in the USA - whether Creationism and Evolution should be given “equal time” in science lessons. In the second part, we will think about how Evolution works, and consider how one species can give rise to another. In the Practical we will then consider an example of Evolution in action as we turn our

attention to the case of the Peppered Moth. Finally, and most importantly, we will address the evidence for Evolution and show why Biology simply does not make sense without it.

PART 1: HOW WAS EVOLUTION DISCOVERED?

SLIDE 5: FIXED SPECIES
Presenter notes: So let's start by thinking about the discovery of Evolution. Beginning in Classical times and persisting until long after the Renaissance, scientists thought species were fixed and unchangeable (or 'immutable' to use the language of the era). Their reasoning ran something like this: if God's creation was perfect from the start, why would He bother to tinker with it at a later date?

SLIDE 6: TRANSMUTATION
Presenter notes: However, around 1800, some scientists began to wonder if species could change their form or 'transmute'. One of the early proponents of this idea was French scientist, Jean Baptiste de Lamarck (1744-1829). If species were able to change their form over time, then how did it happen? Lamarck thought that if an animal acquired a characteristic during its lifetime, it could pass it onto its offspring. One of his favorite examples was the giraffe. In his view, the giraffe got its long neck through straining to reach the leaves on high branches, and this characteristic got passed down the generations. Most scientists of his day thought that Lamarck was wrong. At that time, only a few radical thinkers like Charles Darwin's grandfather, Erasmus, agreed that species could change over time.

SLIDE 7: FOSSILS AND STRATA
Presenter notes: About the same time that these radical thinkers were discussing the transmutation (or evolution) of species, geologists like William Smith were beginning to map the rocks and fossils of Britain. Smith and others were able to show that rocks were laid down in a certain order and that the different fossils in different layers lived at different intervals of geological time. Here was clear evidence that different species had existed in the past compared with today. However, Smith did not go on to ask the question, 'Why?' or to consider that this might be evidence for evolution.

SLIDE 8: DARWIN'S VOYAGE
Presenter notes: In the early nineteenth century, Charles Darwin (1809-1882) rekindled ideas about evolution. In a sense, Evolution was in Darwin's blood because, as we've already noted, his grandfather was an early supporter of the concept. From 1831-1836, Darwin toured the world on HMS Beagle as a young naturalist. He was dazzled by the amazing diversity of life, including some amazing fossils such as rodents the size of ***hippopotamuses*** and started to wonder how it might have originated.

SLIDE 9: SURVIVAL OF THE FITTEST
Presenter notes: On his return from the Beagle the jigsaw pieces started to fit together in his mind. Around 1842 Darwin read an essay about human population growth by Malthus. Malthus had argued that human population would grow more quickly than food supply. Consequently competition for food would become intense and only the fittest and most able would survive. Darwin applied these ideas to all of life and came up with his now famous concept of Natural Selection. Darwin reasoned that if an

organism possessed a character that improved its chances of survival, then it would be more likely to pass on that character to the next generation. Therefore organisms would become progressively adapted to their environment, leading to the evolution of new species. Darwin published this idea in his “Origin of Species by means of Natural Selection” in 1859.

SLIDE 10: HUXLEY V. WILBERFORCE
Presenter notes: However, Darwin’s concept of Evolution by Natural Selection was met with considerable controversy and debate. Although some Christians were willing to accept Evolution, if God was allowed to guide the process, most were opposed to the idea of Evolution being driven by random competition and natural laws. However, some leading scientists did embrace Evolution. One of these was Thomas Henry Huxley (1825-1895), who became known as “Darwin’s bulldog” for his ferocious support of Darwin. On 30 June 1860, Huxley debated Evolution with Bishop Wilberforce at a British Association meeting in Oxford. In the debate, Wilberforce infamously inquired of Huxley whether it was through his grandfather or grandmother that he claimed descent from a monkey! Huxley then rose to the defence of Evolution, finishing his speech with the now legendary ‘put-down’ that he was not ashamed to have a monkey for his ancestor, but he would be ashamed to be connected with a man who used great gifts to obscure the truth! This debate saw many people come to accept Evolution. However, there was little support or enthusiasm for Darwin’s mechanism of Natural Selection.

SLIDE 11: GENETICS
Presenter notes: While all this was going on, and unbeknown to the scientific elite in Britain, an Austrian monk called Gregor Mendel (1822-1884) was carrying out important experiments that would eventually prove that Darwin’s Natural Selection was in fact correct. For seven years, Mendel cross-bred different strains of pea plants to investigate how characteristics like the colour of the flowers got passed down the generations. In a quite amazing feat, he cultivated almost thirty thousand pea plants and in doing so figured out the basic principles of, what would later become known as, Genetics. He showed that offspring received characteristics from both parents, but only the dominant characteristic was expressed. This was contrary to the prevailing view at the time that the characteristics of both parents were somehow “blended” together. Unfortunately, Mendel’s work was overlooked by scientists in the West, only coming to light long after his death.

SLIDE 12: MAKING SENSE
Presenter notes: When Mendel’s work on Genetics was finally “re-discovered” in 1900, it started to make sense of evolution in a new way and stimulated renewed interest in Darwin’s work of fifty years earlier. Building on Mendel’s work, studies showed how genetic traits in a population of animals or plants could be selected by environmental pressures and how a population could become progressively adapted to its environment. This Modern Synthesis, as Julian Huxley called it, brought Darwin’s concept of Natural Selection right back to the centre of evolutionary theory, as we will see in the next part of the talk.

SLIDE 13: OPPOSITION
Presenter notes: However, despite becoming universally accepted by the scientific community in the early 20th century, Evolution by Natural Selection continued to

meet strong opposition by certain religious groups. This was especially true of Christian fundamentalists, who saw the concept as an erosion of God's sovereignty. In 1925, the State of Tennessee, USA outlawed the teaching of Evolution completely. When one teacher, John Scopes, continued to teach evolution he was tried and found guilty in what is now infamously known as the "Scopes Monkey Trial"!

SLIDE 14: DISCUSSION – CREATIONISM
Presenter notes: This religious opposition to Evolution has continued to the present day. However, today opposition to Evolution is often more subtle. For example several US states have recently argued that Evolution and Creationism should be given "equal time" in the Science classroom. Creationism maintains than a literal reading of the Book of Genesis in the Bible is the only adequate explanation for how Life came into being and that the concept of Evolution is incorrect. On the surface, this demand seems OK. After all, isn't it fair to present both sides of the debate? Over the next few minutes, we'll look at this issue at little more closely as we discuss this important question: should Creationism and Evolution should be given "equal time" in the Science classroom?

PART 2: HOW DOES EVOLUTION WORK?

SLIDE 15: ALL IN THE GENES
Presenter notes: In this second part of the talk, we will think about the mechanism of evolution, or to put it more simply, how evolution works. Earlier, we've mentioned the importance of genetics in the discovery of Evolution, and we'll think much more about that over the next few slides. But first of all, let's introduce ourselves to a few technical terms. The genetic make-up of an organism is known as its genotype. The genotype of an organism and the environment in which it lives (nature and nurture together) determine the characteristic traits of the organism, or its phenotype.

SLIDE 16: DNA
Presenter notes: The genotype of an organism is stored in DNA molecules, which are a sort of information bank found within the nucleus of every cell. Every time an organism grows a new cell a new copy of the DNA is created. It is important that every copy of the DNA is identical, since any errors copying the genotype may prevent the cell from functioning properly. In 1953, Watson and Crick figured out that DNA had a helical structure and showed how it copies itself with such amazing accuracy. When DNA replicates, the helix unwinds and each strand produces an exact mirror image copy of itself. This ensures that each copy is identical to the original.

SLIDE 17: MUTATION
Presenter notes: However, very occasionally, tiny copying errors can and do occur when DNA is replicated. These copying errors are called mutations. Mutations may be caused by a number of factors including radiation, viruses, or carcinogens (cancer-causing materials). As the genotype provides the blueprint for how each cell should grow and function, even a tiny mutation might mean that the cells fail to work properly. Take for example the common fruitfly: a single mutation in the fruitfly can change the colour of the eye from red (its normal colour) to white. White-eyed fruitfly are less successful at mating. Because of the potential for mutation, most organisms have a group of special enzymes whose job it is to go round and repair any faulty DNA.

SLIDE 18: VARIATION
Presenter notes: Mutations give rise to variants, or alleles, of the same gene. One person may have one set of alleles, and another person, a different set. For example, take hair colour in humans. One of the genes that codes for hair colour occurs as two alleles, brown and blonde. If you throw you mind back to earlier in this talk you'll remember how Mendel showed that one allele is usually dominant and the other recessive. In the case of hair colour, brown is dominant and blonde is recessive. So if a person gets a brown allele from one parent and a blonde allele from the other parent, they will have brown hair. A person will only have blonde hair where they receive blonde alleles from both parents.

SLIDE 19: NATURAL SELECTION
Presenter notes: If a person, or any other organism that reproduces sexually for that matter, develops a new allele (a mutation), they can spread this around the population by sexual reproduction. However, if the allele exerts a harmful effect on the individual then this will reduce the likelihood of it reproducing and the allele will be removed from the population. Only those mutant alleles that have beneficial effects that increase the likelihood of reproduction will be passed on to offspring. In this way, harmful alleles are removed from a population while favourable alleles accumulate. This is Darwin's concept of Natural Selection and shows how a population adapts to its environment over time.

SLIDE 20: PEPPERED MOTH
Presenter notes: The case of the Peppered Moth is an excellent example of Darwin's Natural Selection in action put forward by the biologist J.B.S. Haldane in 1924. The gene that controls the colour of the Peppered Moth occurs as two alleles, a mottled allele (pale colour) and a melanic allele (black colour). Early in the 18^{th} century, pale moths were dominant in the countryside around Manchester. However, during the Industrial Revolution the trees on which the moths rested became covered in black soot. Pale mottled moths were poorly camouflaged on the black tree trunks and were preferentially eaten by birds. In contrast, the black melanic moths were better at avoiding predation. Natural Selection acted against the pale moths and in only a few generations, the melanic moths were dominant. However, there was one final twist. As the skies of Manchester became cleaner in the 20^{th} century, the mottled moths made a comeback and displaced the melanic moths again.

SLIDE 21: MICROEVOLUTION
Presenter notes: The case of the Peppered Moth shows how natural selection can change the frequency (or relative proportion) of alleles in a population. A more straightforward example of the same phenomenon is the breeding of dogs. Humans have been breeding dogs for thousands of years and trying to develop certain characteristics. This "artificial selection" is exactly the same process as natural selection but controlled by human intention rather than natural forces. Although humans have been successful in changing the frequency of alleles in different dog breeds, they haven't created new species. The definition of a species is a population that can interbreed and produce fertile offspring. Most dogs can successively interbreed with other dogs, and also with wolves, so in actual fact all dog breeds are just subspecies of the wolf, *Canis lupus*! Dog breeding is therefore an example of

what biologists called Microevolution; the frequency of alleles in the population have changed, but not greatly enough to give rise to a new species.

SLIDE 22: MACROEVOLUTION
Presenter notes: To give rise to a new species, Microevolution needs to go on for more much longer than humans have been breeding dogs. For example, if a species was to become divided into two isolated populations for tens of thousands of years, then natural selection would eventually change the frequency of alleles to such an extent that members of the two populations could no longer interbreed. This process would result in the birth of new species or speciation. Where speciation occurs, biologists refer to the process as Macroevolution. An excellent example of Macroevolution is that observed by Charles Darwin during his world tour on HMS Beagle. When visiting the Galapagos Islands in the Pacific Ocean he noticed that each island had its own distinctive species of finch. Darwin argued that the islands had originally been colonized by just one species of finch, but then in isolation, each island population had evolved in response to different environmental conditions.

SLIDE 23: SPECIATION TODAY?
Presenter notes: An obvious question as we conclude our look at how evolution works is: are there any examples of evolution by natural selection going on today. Obviously, the answer is yes, as all species are undergoing evolution. However, as the rate of change is very slow, examples are very difficult to detect and even harder to prove. One possible example is the case of the 'London Underground Mosquito'. This mosquito found its way into the Tube system around 1900 when the railway lines were being constructed. It became infamous during the Second World War as it would constantly bite people sheltering from the Blitz. The London Underground Mosquito has been isolated from the surface for over a hundred years and studies indicate that there are already genetic differences between it and its above-ground relatives. The differences are so great that the two populations have difficulty interbreeding. Perhaps here is an example of ongoing speciation today?

SLIDE 24: PRACTICAL – PEPPERED MOTH
Presenter notes: We've already discussed the case of the Peppered Moth as an example of Natural Selection in action. In this next activity we'll look more closely at the Peppered Moth and discover how natural selection works in detail.

PART 3: WHAT IS THE EVIDENCE FOR EVOLUTION?

SLIDE 25: BIOCHEMISTRY
Presenter notes: In this third and final part of the talk, we'll consider the evidence for evolution and reflect on the fact that Biology simply doesn't make sense if we take Evolution out of the equation. One of the most striking pieces of evidence for evolution is the basic similarity of all living things. First of all, as we'll already stressed, all living things pass on genetic information from generation to generation using the DNA molecule. However another basic shared characteristic is the use of the ATP molecule to carry energy around the cell. These two fundamental similarities suggest that all living things evolved from a single common ancestor.

SLIDE 26: SIMILAR GENES

Presenter notes: If life was generated through evolution then we might also predict that closely related organisms will be more similar to one another than more distantly related organisms. This is borne out by comparison of the human genetic code with that of other organisms. These studies show that chimpanzees, our closest relations, are nearly genetically identical (their genes differ by only 1.2%) whereas the more distantly related mouse differs by some 15%.

SLIDE 27: COMPARATIVE ANATOMY
Presenter notes: Very similar comparisons can be made based on anatomical evidence. For example the skeleton of humans is very similar to that of the gorilla, our close relative, but both are very different from the exoskeleton of the woodlouse. Yet even primates and woodlice share some basic anatomical characteristics such as bilateral symmetry suggesting that they are all related in the Tree of Life, albeit distantly. Here again is clear evidence for the inter-relatedness of all living things.

SLIDE 28: HOMOLOGY
Presenter notes: Another piece of evidence that supports evolution is the concept that biologists have called homology. Homology refers to an anatomical feature possessed by an ancestor that has subsequently been modified by its descendents for a specific function. Take, for example, the pentadactyl (or five fingered) limb. This is found in all vertebrates from fish to amphibians to reptiles to mammals to birds. This structure is easily recognizable in all these diverse groups of organisms but has been adapted to suit particular purposes in each. So we find it adapted as wings for flight in birds, as fins for swimming in fish, as scrapers for digging amongst moles and so on. As all these diverse organisms have the same anatomical blueprint, this strongly suggests they are inter-related.

SLIDE 29: VESTIGIAL STRUCTURES
Presenter notes: Whilst ancestral anatomical features can be adapted to new purposes (as we've just seen), they can also find themselves redundant altogether. Features that get sidelined by evolution in this way are called Vestigial Structures. One example is the human coccyx or tail bone which is a much reduced version of a bony tail possessed by our ancestors. Formerly adapted to aid balance and climbing, a tail has little function in human behaviour so has been selected against. It probably has been retained in a vestigial form because it has some use as a point for muscle attachment in the bottom. Another example of a vestigial human organ is the appendix.

SLIDE 30: FOSSIL RECORD
Presenter notes: All the pieces of evidence that we have discussed so far point to the inter-relatedness of all living things and their evolution from a single common ancestor. However, perhaps the most compelling piece of evidence in support of evolution is the fossil record itself. The fossil record shows a sequence from simple bacteria in the oldest rocks through to more complicated organisms like dinosaurs and humans in much younger rocks. It shows that different species arose at different times and, as we see in the next slide, in many cases there are clear transitions from one species, or group, to another.

Background note: A companion talk on the History of Life can be downloaded from the Your Planet Earth website: http://www.earth4567.com/talks/life.html

SLIDE 31: TRANSITIONAL FOSSILS
Presenter notes: One of the most famous examples of a species that is transitional between two major groups, is the 150 million year old Archaeopteryx. Archaeopteryx has several characteristic features seen in certain dinosaurs including teeth and a bony tail. However, it has more features that are characteristic of modern birds such as a wishbone, wings with flight feathers, and a partially reversed first toe. Although geologists classify Archaeopteryx as an early fossil bird they recognize that it is more closely related to the dinosaurs than any birds living today. Archaeopteryx therefore provides good evidence of the evolutionary transition from dinosaurs to birds.

SLIDE 32: GEOGRAPHY
Presenter notes: A rather different source of evidence in support of evolution comes from the geographic distribution of species today. If we take for example the case of marsupials, we see that this primitive group of mammals is found in the Americas and Australasia. Marsupials are not renowned as strong swimmers so this raises the questions as to how two populations came to be separated by the Pacific Ocean if they evolved from a common ancestor. However, this problem is resolved if we remember that the Earth's continents have not remained stationary over time but have drifted around the surface of the Earth. During the Jurassic Period, 160 million years ago, all the Southern Hemisphere landmasses were joined together and you could have walked from Australia to South America across what is present day Antarctica. Fossil evidence shows that marsupials evolved in the Jurassic but after the continents started to break-up, the marsupials must have got separated into two populations, one in the Americas and the other in Australasia. In fact fossil marsupials have even been found in Antarctica and South Africa as well, providing evidence that that these continents acted as a land bridge connecting the two populations for a time.

SLIDE 33: ANTIBIOTIC RESISTANCE
Presenter notes: A final and perhaps especially convincing piece of evidence for evolution is the familiar way that bacteria may become resistant to antibiotics. Bacteria have a fast life cycle and can produce a new generation every 4 hours. As natural selection acts on each generation this means bacteria can rapidly respond to environmental pressures. In effect the antibiotics act to weed out those bacteria with low resistance in each generation. Only bacteria with high resistance survive and pass their alleles to the next generation. Consequently, in just a short time, natural selection increases the resistance level of the bacteria population. This is an example of evolution in action amongst the simplest organisms on our planet – and then having an impact on the most complex organisms!

CONCLUSION

SLIDE 34: EVOLUTION
Presenter notes: In this talk we have discussed how Evolution was first discovered, how Evolution works, and last of all, the evidence for Evolution. In particular, we've reflected on the fact that Biology simply does not make sense when Evolution is taken out of the equation. In addition, we've noted that while aspects of Evolution remain theoretical, that Evolution is happening is an established fact, through great quantities of excellent evidence. Yet, outside the scientific community, surveys show that in the USA, 40% of people do not believe in Evolution by Natural Selection, and even in the UK, some 21% are said to be doubtful. As we close, discuss why non-scientists are

reluctant to accept Evolution. Do you think that Evolution is a threat to religions like Christianity? Have scientists been inadequate in the way they have communicated Evolution? Is our science education system at fault? How could understanding of Evolution be improved amongst the public at large?