Why fish go blind and other evolutionary curiosities

Key Stage 4 Programme

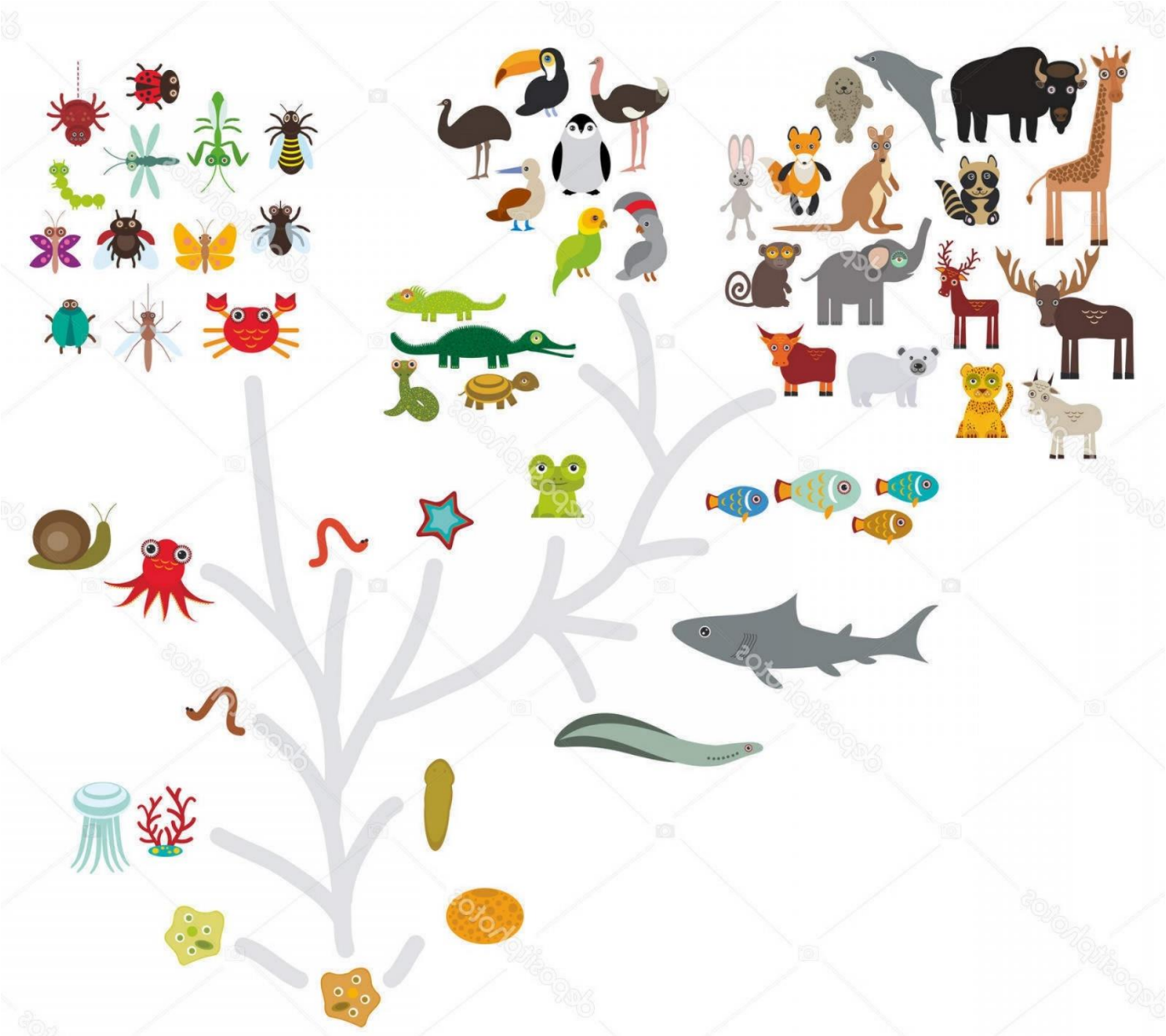
Pupil Name	
Handbook Designed by	**Dr. Paulina Guerrero-Gutiérrez**

Course Rationale

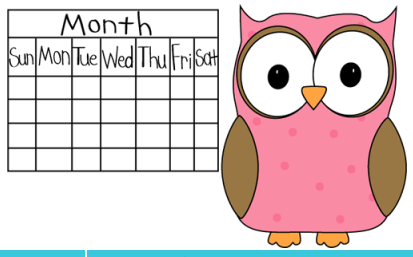
"Nothing in biology makes sense except in the light of evolution" is a very famous phrase said by Theodosius Dobzhansky, one of the most important biologists of the 20th century. He is right. Evolution is biology's theory of everything. It is the big-picture mechanism that has determined everything else about living things. Therefore, it is one of the most important topics to learn in biology.

However, evolution is a hard theory to understand fully. It requires you to understand many smaller concepts, put them together, and apply them to construct evolutionary explanations. Not only that, the GCSE curriculum allocates only a couple lessons to it, making it even harder to practice.

The idea behind this course is for you to go over what you have already learned about evolution, doing deliberate practice, making sure that you feel confident using the theory. We will be going over all the types of questions that you might encounter in your GCSE. You will also experience a way of revising which is way more useful than just reading and highlighting from your book. Once you feel confident, we'll learn some new things about evolution. You will find out some cool examples of how things evolve and will be able to provide in-depth explanations about it.



Timetable and Assignment Submission



Timetable – Tutorials

Tutorial	Date	Time	Location
1 Baseline Assessment		3:20 - 4:30	Science corridor
2 Darwin and Wallace's Theory of Evolution		3:20 - 4:30	Science corridor
3 Adaptation		3:20 - 4:30	Science corridor
4 Evidence for Evolution		3:20 - 4:30	Science corridor
5 Human Evolution		3:20 - 4:30	Science corridor
6 Assessment		3:20 - 4:30	Science corridor
7 Feedback and reflection		3:20 - 4:30	Science corridor
8 It's not just natural selection		3:20 - 4:30	Science corridor
9 To gene or not to gene		3:20 - 4:30	Science corridor
10 Micro and Macroevolution		3:20 - 4:30	Science corridor
11 Coevolution		3:20 - 4:30	Science corridor
12 Feedback and reflection		3:20 - 4:30	Science corridor

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
After Tutorial 1	None	
After Tutorial 2	Do any unfinished questions from the tutorial	
After Tutorial 3	Do any unfinished questions from the tutorial	
After Tutorial 4	Do any unfinished questions from the tutorial	
After Tutorial 5	Do any unfinished questions from the tutorial	
After Tutorial 6	None	
After Tutorial 7	None	
After Tutorial 8	Practice your evolutionary explanations	
After Tutorial 9	Reviewing genetics	
After Tutorial 10	Coevolution Presentation	
After Tutorial 11	Draft final assignment	
	Final assignment	
After Tutorial 12	Consent forms for trip (only if you submitted your final assignment)	

Contents

Course Rationale **2**
Timetable and Assignment Submission **3**
Timetable – Tutorials 3
Timetable – Homework Assignments 3
Contents **4**
Glossary of Keywords **6**
Tutorial 1-Baseline Assessment **10**
Tutorial 2 – Darwin and Wallace's Theory of Evolution **11**
What is the Purpose of Tutorial 2? 11
Keyword Checklist: Rate yourself red, amber or green 11
Why are we all different? Variations and its causes. 11
Who gets to survive? Natural selection or survival of the fittest 13
How do new species appear? 15
What I learned today and what I need to revise still: 18
Tutorial 3 – Adaptation **19**
What is the Purpose of Tutorial 2? 19
Keyword Checklist: Rate yourself red, amber or green 19
Identifying advantages 19
Explaining Adaptations 20
Generalising evolution: coevolution and selective breeding 23
What I learned today and what I need to revise still: 26
Tutorial 4 – Evidence for Evolution **27**
What is the Purpose of Tutorial 4? 27
Keyword Checklist: Rate yourself red, amber or green 27
We all come from a common ancestor: evidence from anatomy 27
We all come from a common ancestor: evidence from genetics 30
Evidence from the fossil record 32
What I learned today and what I need to revise still: 34
Tutorial 5 – Human Evolution **35**
What is the Purpose of Tutorial 5? 35
Keyword Checklist: Rate yourself red, amber or green 35
Identifying advantages in humans 35
Hominids, hominids, hominids 37
Other evidence for human evolution 39
What I learned today and what I need to revise still: 42
Tutorial 6 – Assessment **43**
Tutorial 7 – Feedback and reflection **44**
What is the Purpose of Tutorial 7? 44
Final assessment feedback 44
Tutorial 8 – It's not just natural selection! **45**
What is the purpose of Tutorial 8? 45
Sexual Selection 45

Atrophy and pseudogenes: why do fish go blind? 47
Today I learned… 50
Homework assignment: Practice your evolutionary explanations 50
Tutorial 9 – To gene or not to gene? 51
What is the purpose of Tutorial 9? 51
Evolution can be like a bag of marbles 51
Genetic Drift 51
Epigenetics 53
Today I learned… 54
Homework assignment: Reviewing genetics 54
Tutorial 10 – Micro and Macroevolution 55
What is the purpose of Tutorial 10? 55
General processes of microevolution 55
General processes of macroevolution 57
EVO-DEVO: Connecting micro and macro evolution 58
Today I learned… 59
Homework Assignment: Coevolution Presentation 59
Tutorial 11 – Coevolution 60
What is the purpose of Tutorial 11? 60
How can you be sure? 61
Today I learned… 63
Homework Assignment: Draft final assignment 63
Final Assignment 64
Draft Assignment Feedback 67
Tutorial 12 – Feedback and reflection 68
What is the Purpose of Tutorial 12? 68
Final assessment feedback 68
Uni Pathways – Pupil Feedback Report 69
Appendix 1 How to Write an Essay? 70
Appendix 2 – Some Tips on Essay Writing 71
Appendix 3 – Essays Dos and Don'ts 72
Appendix 4 – The Good, the Bad, and the Ugly Introductions 73
Appendix 5 – Using Reliable Sources 74
Appendix 6 – Referencing Correctly 75
What is a reference? 75
How do I reference Using Numbers? 75
How do I reference using APA style? 77
Notes 79

Glossary of Keywords

These definitions are modified from The Oxford Dictionaries of Biochemistry and Molecular Biology[1] (2 ed.), of Biology[2] (6 ed.), and of Genetics[3], unless specified otherwise.

Word	Definition	In a sentence
Advantage	A variation that puts an organism or population in a better position than others in the competition for limited resources.	Being fast gives the deer the advantage of escaping predators.
Adaptation	Any change in an organism's structure or function that allows it better to deal with its environmental conditions. It is the result of natural selection.	Being able to store water in its humps is an adaptation camels have to live in the desert.
Archaea	One of three domains of living things, together with Eukarya and Bacteria. They are unicellular organisms whose DNA has regions that do not code for proteins.	Archaea usually live in extreme environments.
Artificial Selection	The modification of a species by selective breeding. Animals or plants with desirable characteristics are selected and cross bred over many generations with the aim of modifying their genetic material and producing a new strain of the organism for a specific purpose. For example, sheep are bred by means of artificial selection in order to improve wool quality.	Thanks to artificial selection we have dozens of different dog breeds today.
Ardipithecus ramidus	Hominids that existed around 4.4 million years ago. They had a height around 1.2 m tall and 50 kg. Their leg bones show that they may have been able to walk upright. They had long arms, long big toes, and an unclear ability to climb trees given the shape of the feet and pelvis.	Ardi was the first *Ardipithecus ramidus* ever fond.
Australopithecus afarensis	Hominids that existed 3.9-3 million years ago. They had a height around 1.07 m and walked upright. Their toe bones are arranged similarly to modern humans but more curved. They were probably able to walk upright and climb; and had apelike face proportions and small skull.	Lucy is the most complete skeleton we have of *Australopithecus afarensis.*
Bacteria	Any of a vast group microorganisms that exist as single cells or in clusters of single cells. The majority of bacteria possess a rigid cell wall. Bacteria, Archaea, and Eukarya constitute the three primary domains of living things.	It is important to use antibiotics responsibly to prevent bacteria from developing resistance.
Chromosome	A threadlike structure of DNA that carries genes in a linear sequence. The number of chromosomes in each cell is constant throughout all the cells of a species. In animals, plants, fungi, and protists, the chromosomes occur in pairs. Bacterial cells contain only a single circular chromosome.	Human beings have 46 chromosomes: 23 inherited from their fathers and 23 from their mothers.
Coevolution	Evolution of complementary adaptations in two species caused by the selection pressures that each exerts on the other. For example, many insect-pollinated plants have evolved flowers whose shapes, colours, etc., make them attractive to particular insects; at the same time the pollinating insects have evolved sense organs and mouthparts specialized for quickly locating, and extracting nectar from, particular species of plants.	Several orchids have coevolved with a single type of insect. If the insect goes extinct, the orchid would have no other pollinator and would die.
Common ancestor	The most recent ancestral form or species from which two different forms or species have evolved	Humans and apes come from a common ancestor.
Environmental Variation	See variation	

[1] (2006). Cammack, R., Atwood, T., Campbell, P., Parish, H., Smith, A., Vella, F., & Stirling, J. (Eds.), Oxford Dictionary of Biochemistry and Molecular Biology. : Oxford University Press. Retrieved 7 Feb. 2014, from http://www.oxfordreference.com/view/10.1093/acref/9780198529170.001.0001/acref-9780198529170.

[2] Martin, E., & Hine, R. (2008). A Dictionary of Biology. : Oxford University Press. Retrieved 7 Feb. 2014, from http://www.oxfordreference.com/view/10.1093/acref/9780199204625.001.0001/acref-9780199204625.

[3] King, R., Stansfield, W., & Mulligan, P. (2007). A Dictionary of Genetics. : Oxford University Press. Retrieved 7 Feb. 2014, from http://www.oxfordreference.com/view/10.1093/acref/9780195307610.001.0001/acref-9780195307610.

Eukarya	One of the three major domains of cellular organisms, the others being Archaea and Bacteria. The Eukarya are characterized by the presence of a nucleus bounded by a nuclear membrane and containing true chromosomes.	Animals, plants, protists and fungi are all examples of Eukarya.
EVO-DEVO	Short for evolution of development – a field of study concerned with the relationship between developmental genetics and evolution. It has revealed how diversity in form and function can arise from mutations that alter the course or timing of embryonic development. All complex animals share a set of genes (homeotic genes) whose signals control development. Development normally must proceed in an orderly sequence of stages, disruption of which often leads to death of the embryo, but can also affect the organization of body plans, such as repeated limbs or body segments. Duplication of these parts may lead to its further adaptation into a novel structure. In this way relatively few mutations affecting development can have profound effects on the morphology of the mature organism.	Thanks to Evo-devo we know that there can be changes in some genes that can affect the size of whole structures!
Evolution	The gradual change process by which the present diversity of plant and animal life arose from the earliest organisms. The current most accepted theory of the process of evolution makes use of modern knowledge of genes and chromosomes to explain the source of the genetic variation upon which Darwin's natural selection works.	Nothing in biology makes sense except in the light of evolution.
Evolutionary tree	A diagram depicting the evolutionary relationships between species or groups of organisms as branching lines to form a treelike pattern. In some trees, changes in the relative abundance of a lineage are indicated by the width of the branch. A phylogram is a special type of evolutionary tree constructed so that the branch lengths reflect the evolutionary distance separating ancestors and descendants.	You can tell from that evolutionary tree that we all share a common ancestor.
Extinction	The irreversible condition of a species or other group of organisms of having no living representatives in the wild, which follows the death of the last surviving individual of that species or group. Extinction may occur on a local or global level. Species at the top of a food chain (e.g. large birds of prey) will be more prone to extinction since they exist in relatively small numbers and will be affected by a change at any of the levels in the food chain	It is very likely for millions of species to go extinct in the next 50 years if we don't control global warming.
Fossil	The remains or traces of any organism that lived in the geological past. In general only the hard parts of organisms become fossilised (e.g. bones, teeth, shells, and wood) but under certain circumstances the entire organism is preserved. For example, virtually unaltered fossils of extinct mammals, such as the woolly mammoth and woolly rhinoceros, have been found preserved in ice in the Arctic. Small organisms or parts of organisms (e.g. insects, leaves, and flowers) have been preserved in amber.	I love seeing all the dinosaur fossils in the Natural History Museum.
Gene	A sequence of DNA, forming part of a chromosome, which contains the information for either a protein determining a particular characteristic or an RNA molecule. It can exist in different forms called alleles, which determine which aspect of the characteristic is shown (e.g. for the characteristic "blood type", there are 3 alleles of the gene: A, B, and o).	I wish I could roll up my tongue like you, but it's just not in my genes.
Genetic analysis	The sequencing and comparison of sections of the DNA of a series or group of organisms. The organisms which are more closely related or have a more recent common ancestor will have more similarities in their DNA or genome than those with a more distant common ancestor.	Genetic analysis has allowed us to clarify whether red pandas are bears or racoons.
Genetic drift	Any random change with time in gene frequency in a population. It may be either directed (steady drift) or undirected (random drift).	Not all characteristics come from natural selection. Genetic drift is an important process as well.
Genetic variation	See variation	
Hominid	Any member of the primate family Hominidae, which includes humans and their fossil ancestors (fossil hominids) in the genus *Homo* as well as the great apes (chimpanzees, gorillas, orang-utan) and extinct groups, such as *Australopithecus*.	Ardi and Lucy are both hominids.

Homo erectus	Hominids that existed between 1.8 and 0.5 millions of years ago. They were tall (1.79 m) and strongly built. They were the earliest humans with modern human-like body proportions: long legs and shorter arms. They were adapted to life on the ground, probably able to run long distances.	*Homo erectus* was first discovered in Asia.
Homo habilis	Hominids that existed between 2.4-1.4 millions of years ago. They were one of the earliest members of the genus Homo. They were quite short with long arms, but walked upright. The *habilis* in its name is because it is one of the earliest hominids to use tools.	Louis and Mary Leakey discovered *Homo habilis* in Tanzania.
Leakey, Louis and Mary	See *Homo habilis*.	
Macroevolution	Evolution on a relatively large scale, involving, for example, the emergence of entire groups of organisms, such as the flowering plants or the mammals.	The seed was the most notable adaptation that appeared during the macroevolution of plants.
Microevolution	Evolution on a relatively small scale, such as changes within a single population.	Antibiotic resistance was caused by the microevolution of certain bacteria.
Mutation	A sudden random change in the genetic material of a cell that potentially can cause it and all cells derived from it to either die or differ in appearance or behaviour from the normal type. Most are point mutations, which consist of invisible changes in only one "letter" of the DNA of the chromosomes, but some (the chromosome mutations) affect the appearance or the number of the chromosomes. An example of a chromosome mutation is that giving rise to Down's syndrome. The majority of point mutations in DNA are neither useful nor harmful and can spread throughout a population. Mutations that alter characteristics are generally harmful, but a very small proportion may increase an organism's fitness; these spread through the population over successive generations by natural selection. Mutation is therefore essential for evolution, being the ultimate source of genetic variation.	Instead of giving you superpowers, mutations can actually give you white hairs and cancer.
Natural Selection	The process that, according to Darwinism, brings about the evolution of new species of animals and plants. Darwin noted that the size of any population tends to remain constant despite the fact that more offspring are produced than are needed to maintain it. He also saw that variations existed between individuals of the population and concluded that disease, competition, and other forces acting on the population eliminated those individuals less well adapted to their environment. The survivors would pass on any heritable advantageous characteristics (i.e. characteristics with survival value) to their offspring and in time the composition of the population would change in adaptation to a changing environment. Over a long period of time this process could give rise to organisms so different from the original population that new species are formed	The giraffes with the shortest necks were not able to feed themselves and died. Those with the long necks survived and had offspring. Giraffes today have so long necks because of natural selection.
Offspring	New individual organisms that result from the process of sexual or asexual reproduction.	Only the fittest survive and have offspring.
Pentadactyl limb	A limb with five digits, characteristic of amphibians, reptiles, birds, and mammals. It evolved from the paired fins of primitive fish as an adaptation to locomotion on land and is not found in modern fish. The limb has three parts: the upper arm or thigh containing one long bone, the forearm or shank containing two long bones, and the hand or foot, which contains a number of small bones. This basic design is modified in many species, according to the function of the limb, particularly by the loss or fusion of the terminal bones.	The fact that species as diverse as the whale and the bat have the same basic structure for the pentadactyl limb suggest they all come from a common ancestor.
Proteins	Biomolecules found in all living organisms, composed of carbon, hydrogen, oxygen, nitrogen, and often sulphur, which form three-dimensional structures and perform one of many possible functions inside the cells, such as catalysing chemical reactions (enzymes), forming structures like muscles (myosin) and hair (keratin and collagen), immune responses (antibodies), etc.	It is very important that you get enough proteins in your diet or you won't have anything to build up your muscles!

Pseudogene	A sequence in DNA that is very similar to a functional gene but cannot be transcribed and turned into a protein. This may be due to the accumulation of mutations that make its expression impossible.	Pseudogenes are like the corpses of past genes.
Random Variation	See mutation.	
Resistance	The degree to which a given organism can withstand the negative effects of a toxic substance or pathogenic organism. It depends on the selection and spread within a population of genes that confer the ability to destroy or minimize the effects of a toxic substance or pathogenic organism.	Throughout time, bacteria have become resistant to antibiotics because people are not careful with their medication.
Selective breeding	Selective breeding of both plants and animals is used in agriculture to produce offspring that possess the beneficial characters of both parents. To do so, the breeder selects individual plants or animals that possess the characteristic of interest, and make controlled crosses between those individuals until they obtain a new breed.	Thanks to selective breeding, we have dozens of breeds of dogs.
Sexual selection	The means by which it is assumed that certain secondary sexual characteristics, particularly of male animals, have evolved. Females presumably choose to mate with the male that gives the best courtship display and therefore has the brightest coloration, etc.: these features would be inherited by its male offspring and would thus tend to become exaggerated down the generations.	Given that big tails don't give peacocks any evolutionary advantage, the only way such tails could have evolved is by sexual selection.
Species	The category of organism that ranks below genus and consisting of a group of closely related individuals that can interbreed freely to produce fertile offspring.	There are millions of species of insects in the Amazon alone.
Survival of the fittest	See natural selection	
Variation	The differences between individuals of a plant or animal species. Variation may be the result of environmental conditions; for example, water supply and light intensity affect the height and leaf size of a plant. Differences of this kind, acquired during the lifetime of an individual, are not transmitted to offspring. Genetic variation, where variation is due to differences in genetic constitution, is inherited. Wide genetic variation improves the ability of a species to survive in a changing environment, since the chances that some individuals will tolerate a particular change are increased. Such individuals will survive and transmit the advantageous genes to their offspring.	Those individuals with beneficial variations are more likely to survive and have offspring than those without the variations.

Tutorial 1-Baseline Assessment

Use this space to glue your baseline assessment.

Tutorial 2 – Darwin and Wallace's Theory of Evolution

What is the Purpose of Tutorial 2?

- To be able to explain what causes organisms to be different.
- To understand why some organisms survive while others do not.
- To know how and why new species appear.

Keyword Checklist: Rate yourself red, amber or green

Keyword	Now	End of tutorial
Variation		
Mutation		
Genetic		
Environmental		
Natural selection		
Survival of the fittest		
Offspring		
Species		

Why are we all different? Variations and its causes.

Key concepts to remember

We use the term **variation** to refer to all of the differences between organisms.

There are two main types of variation:

- **Genetic variations**: are due to differences in our genes. Therefore, they can be inherited to offspring. They are caused by:
  - **Mutation**: Any **RANDOM** change in our DNA. Most mutations are neutral: they neither do harm nor benefit. However, depending on the environment, they might provide advantages or disadvantages that might affect survival. They are one of the most important factors for evolution.
  - Sexual reproduction: The production of gametes (or sex cells) using meiosis involves some changes in the genes. These gametes then combine with the gametes of another organism to produce offspring that are different from each other and the parents.
- **Environmental variations:** are due to factors other than genes. This includes diet, damage to body parts, etc.

Most of our characteristics are determined by a mixture of genetics and environment. For example, your genes determine your likelihood to gain weight but it is your diet that will determine whether it actually happens. Since only genetic variation is inherited, it is what evolution operates on.

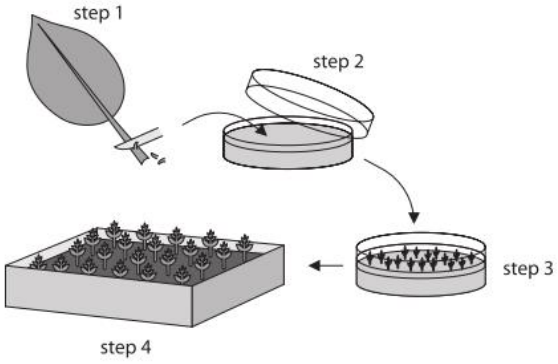
Genetic diversity helps species survive. For example, if a whole population was genetically identical and a disease hit, the whole population would die. This partly explains why so many species reproduce sexually, even though it would be quicker and it would use up fewer resources to just reproduce asexually.

TOP TIPS

Remember!
Genetic variations happen by chance.
There is no purpose to them and cannot be chosen by the organisms

Let's Practice:

1. Figure 1 shows a method of producing plants using tissue culture.



Step 1. Cells taken from parent plant.
Step 2. Cells placed on agar growth medium. Step 3. Cells develop into tiny plantlets.
Step 4. Plantlets grown in compost.

a) Describe two advantages and one disadvantage of producing plants by the method shown in Figure 1. (3) _____

_____

_____

_____

_____

b) One of the plantlets had different coloured leaves. Give one reason why this plantlet had different coloured leaves. (1)_____

2. The photograph shows a potato with powdery scab disease. This disease causes damage to the potato skin. In an investigation, equal numbers of two varieties of potato were planted in a field. The potato plants were harvested and checked for the disease. The results are shown in the table.

Potato Variety	Number of potatoes harvested	Number of potatoes affected by powdery scab disease	Percentage affected by powdery scab disease
Charlotte	200	2	1
Pentland	350	140	40

Suggest one reason for the difference in the number of potatoes affected by powdery scab disease. (1)_____

_____

3. Explain the meaning of the term mutation. (2) _____

_____

_____

4. Mutation is one cause of variation. State one other cause of variation. (1) _____

_____

5. Explain how variations in a species occur [3 marks] _____

_____

_____

_____

_____

_____

6. Describe the role of mutations in evolution [4 marks] _____

_____

_____

_____

_____

_____

_____

Mini Assessment 1:

To the right is a species of cricket which was described in 1609 in the Lake District. According to the field notes, at that time, all the crickets of the species were a very pale brown. A team of researchers returned to the area in 2019 and found pale brown, dark brown, light green, and dark green varieties of the cricket. What is the main reason for the new colours to have first appeared in the population?

a. So that the crickets could camouflage with their surroundings and avoid predators.
b. Because crickets of different colours bred with each other and had offspring which represented new varieties.
c. Because of random variations that occurred in the population through mutations.
d. As the result of changes in the diet of the existing cricket population.

For my revision list:

Who gets to survive? Natural selection or survival of the fittest

Key concepts to remember

Genetic variations are RANDOM.
Sometimes, one of those variations benefits certain individuals over others in that population who do not have the variation.

The organisms with the variations that give them the most advantages are more likely to survive, reproduce, and pass those characteristics to their offspring. That is what we call **"survival of the fittest"** or **"natural selection"**. Those without beneficial characteristics are less likely to survive.

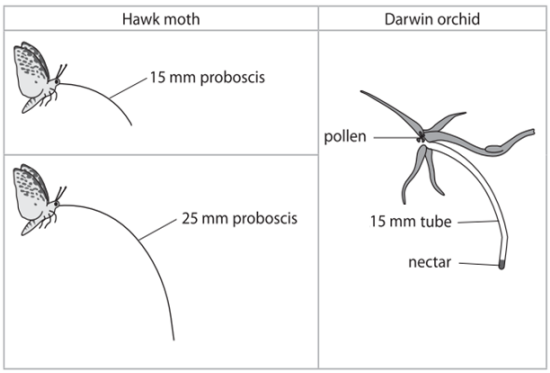
As long as the conditions (or "**selection pressures**") remain the same, there will be more and more individuals with the beneficial characteristics. However, in the absence of selection pressures, enough random mutations might accumulate, such that some characteristics disappear (that's why there's blind fish in caves!)

Note to keep in mind: some behaviours have a genetic basis. Those behaviours are subject to natural selection too. For example, hibernation could lead to a higher survival rate during winter in very cold places.

TOP TIPS

Remember!
Who is "the fittest" depends on the environment. People often get confused and think it means getting stronger or bigger. However, in different environments, it might be more advantageous to be small, fast, slow, most nurturing, etc.

Let's Practice:



1. The Darwin orchid, *Angraecum sesquipedale*, is a flower found in Madagascar. It is pollinated by a species of hawk moth. Hawk moths feed from orchids using a long tube called a proboscis. Pollen sticks to the head of the hawk moth when it attempts to feed. The diagram shows a cross section of the orchid and two different species of hawk moth.

   Explain which variety of hawk moth is less likely to survive [2] _____

2. What does natural selection mean? [2] _____

3. Chimpanzees can use gestures to communicate with each other. The picture shows a parent using the sole of its foot to communicate to the baby chimp, 'climb onto my back'. This gesture helps the chimpanzee to care for its young. Explain how parental care contributes to evolution. [2]. _____

4. It is frequent for patients with bacterial infections to stop taking their penicillin as soon as they start feeling better, rather than finishing the whole prescribed course of treatment. Knowing that some individual bacteria are slightly more resistant to penicillin, doctors recommend that people finish their courses of penicillin when they are ill. Explain why they give this advice [4]. _____

5. The photograph shows the common rat *Rattus norvegicus*. A population of this rat has adapted and can eat the rat poison Warfarin and survive. Suggest what would happen to the rats' genes for warfarin resistance if farmers stopped using warfarin altogether for thousands of years [4 marks]. _____

Mini Assessment 2:
Use the line to the left of each statement to write T if the statement is true and F if the statement is false. If the statement is false, cross out the incorrect information and replace it so that the resulting statement is true.

___ Natural selection makes species better.
___ In the struggle for existence, only the strongest survive.
___ Bacteria became resistant to antibiotics because of a random mutation.
___ All behaviours are subject to natural selection.

For my revision list:

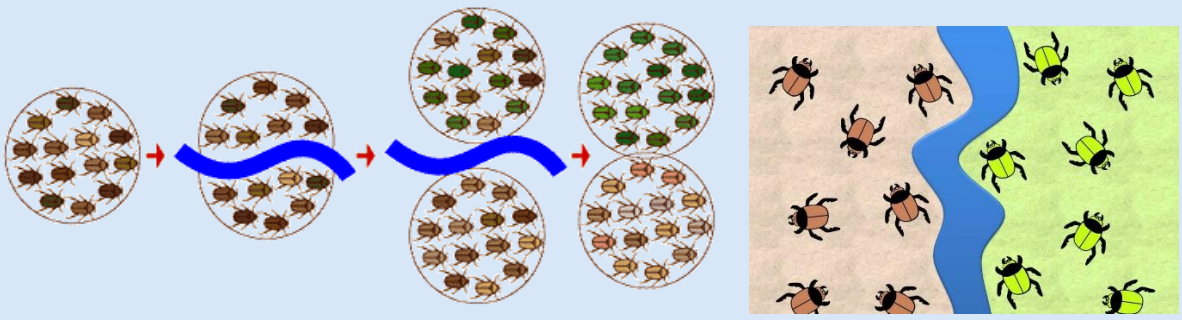
How do new species appear?

Key concepts to remember

As we have established, genetic variations are random. Some of them are beneficial and might help organisms to survive. If enough variations appear and accumulate, the resulting organisms can be so different from their ancestors that they can be considered new **species**.

Why are there so many different species?

- When a population of a species is spread in a wide area, it can get separated by the appearance of new **geographical barriers** (for example, a river), resulting in two or more separate populations. Members of the species could also migrate to new areas.
- Since mutations are random, the ones happening in the new (now separate) populations will be different. Additionally, since the environments of both populations are different, there will be different characteristics making organisms fitter for that specific environment.
- Therefore, after thousands or millions of years, the populations will have turned into separate species.
- In the example below, the beetles were separated by a river. Since one side of the river was fuller of vegetation, the colour green was beneficial, while on the other, dryer side, the colour brown was beneficial. Therefore, two separate species of beetle evolved through natural selection.



Note to keep in mind: Sometimes, two species can breed and form **hybrids**. However, hybrids are not considered different species unless they can interbreed, that is, mate with other hybrids and have fertile babies.

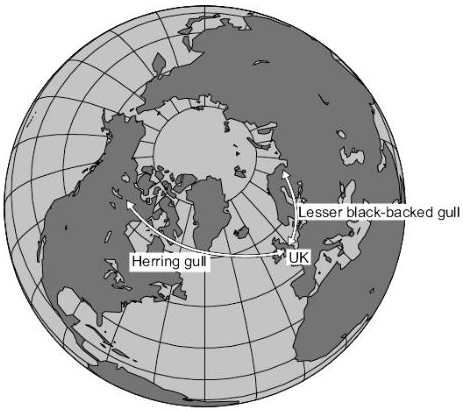
TOP TIPS

Remember!
Evolution is a process that takes a very long time, usually millions of years.
The theory of evolution states that all organisms share a **common ancestor**. The similarities in shape and form of different organisms give us evidence that this is the case.

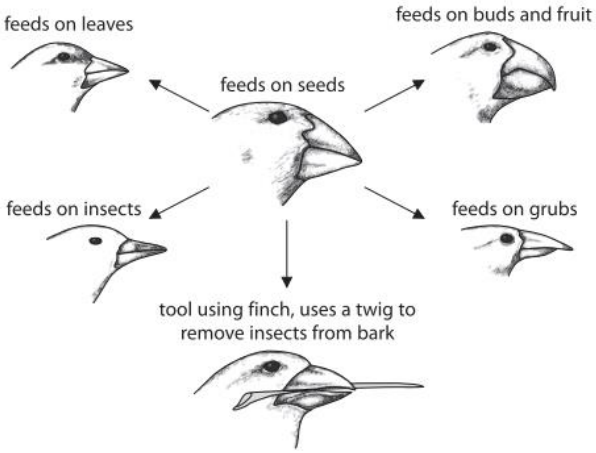
Let's Practice:

1. The diagram to the right shows two species of gull. Herring gull (*Laurus argentatus*, left) and the Lesser black-backed gull (*Laurus fuscus*, right). Both species are now found in the UK but the two species cannot interbreed with each other. Scientists believe that these two species have evolved from a common ancestor. The map shows a view of the Earth from above the North Pole. The map also shows where these two species of gull are found.

Suggest an explanation for the development of these different species [6].



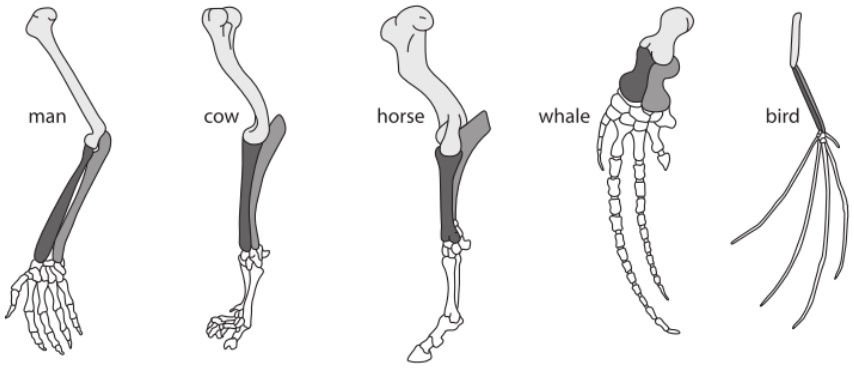
2. Charles Darwin studied finches on the Galapagos Islands. The diagram shows the beak shapes and the food source of some of these finches. Complete the sentence by putting a cross ( ) in the box next to your answer. [1 mark]



These finches show speciation due to the:

- ☐ A Geographic isolation of the Galapagos Islands
- ☐ B Overproduction of offspring
- ☐ C Development of ring species
- ☐ D Survival of the fittest

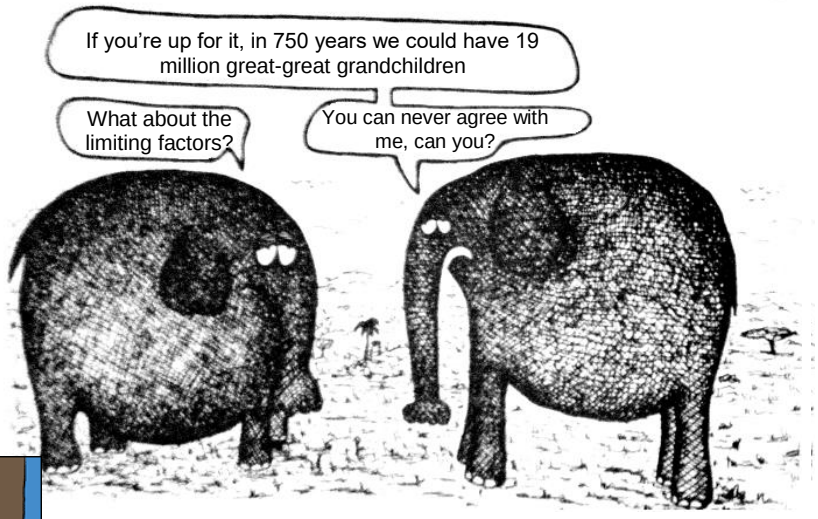
3. The next figure shows the pentadactyl limb of several animals. Describe the reasons why the anatomic similarities between them provide evidence to support the theory of evolution [3 marks].



Mini Assessment 3: Key concepts I must remember when I am talking about evolution

1. Organisms can reproduce in enormous numbers when there are unlimited resources.

2. However, since resources are never unlimited, they become limiting factors which make organisms COMPETE. Not all of the organisms can _____ and _____.



Natural selection does not grant organisms what they "need".

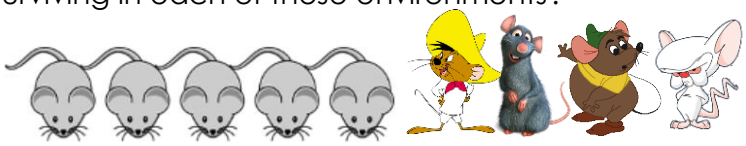
3. Not all organisms of the same species are the same. We are all different, i.e. we have _____.

4. Organisms **DON'T CHOOSE** which variations they are born with (just as you didn't choose if you were going to have curly hair or not). These variations are due to _____.

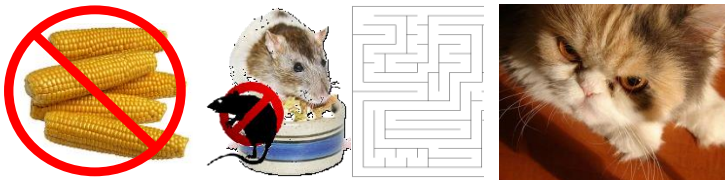
5. Some of these variations can be _____ in some circumstances. However, they might be detrimental in others. **IT ALL DEPENDS ON THE ENVIRONMENT**.

6. Those organisms that have beneficial variations in a given environment will have more probabilities to survive and have offspring. This is called _____ **or** _____.

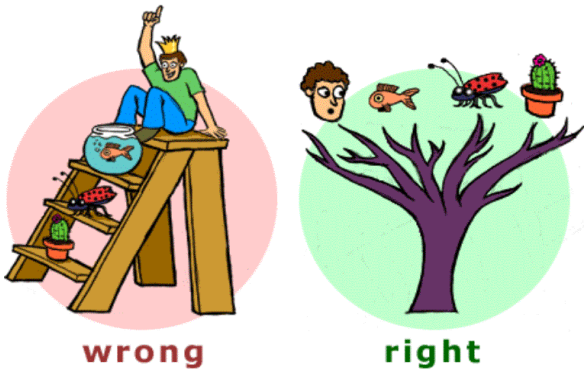
Which mouse in this population has a better chance of surviving in each of these environments?



Environments:



7. After a very long time, the beneficial variations will be present in most of the population or species. This is called **ADAPTATION**. This doesn't mean the species is improving. It just means that it is more adapted to its environment.



8. Given that variations are random and that different variations are beneficial in different environments, if a population gets separated, it will **EVOLVE DIFFERENTLY IN DIFFERENT PLACES**. After a very long time, it will evolve into _____. This is called the **PRINCIPLE OF DIVERGENCE**.

9. Therefore, evolutionary history looks **LIKE A TREE** and should not be represented in a linear way.

What I learned today and what I need to revise still:

Additional Resources:

- **Darwin's trip online game:** http://html.investis.com/R/Rolls-Royce/corp/interactive-games/darwin/darwin.htm
- **Natural Selection simulation:** http://sciencenetlinks.com/interactives/evolution.html
- **More practice questions:** https://www.bbc.co.uk/bitesize/guides/zpkscj6/revision/1

Tutorial 3 – Adaptation

What is the Purpose of Tutorial 2?

- To be able to identify characteristics that give an advantage to an organism
- To be able to explain how adaptations evolve in a coherent manner
- To understand how two organisms can evolve together

Keyword Checklist: Rate yourself red, amber or green

Keyword	Now	End of tutorial
Advantage		
Adaptation		
Variation		
Natural selection or survival of the fittest		
Extinction		
Resistance		
Selective breeding or artificial selection		
Species		
Coevolution		

Identifying advantages

Key concepts to remember

As we said last time, genetic variations are always random. However, sometimes, they offer certain advantages to organisms. Most advantages are in some way related to the following:

- Decreasing **predation**, disease, or environmental challenges
- Increasing an organism's capacity to find, get, or produce food
- Increasing the number of **offspring** produced or the survival rate of those offspring
- Increasing or decreasing the metabolic rate (depending on the environment)

TOP TIPS

Remember!
Even though variations often confer advantages, organisms did not choose them!

Let's Practice:

1. Every October in North America, Monarch butterflies migrate south. This migration is affected by environmental factors and circadian rhythms. The migration of Monarch butterflies is an example of innate behaviour. The migration route is shown on the map. Suggest why Monarch butterflies migrate south in October [2 marks]

_____

_____

_____

2. Eating leaves provides food for caterpillars. Some caterpillars eat leaves containing chemicals that make the caterpillars taste bad. Suggest one advantage to these caterpillars of eating leaves that make them taste bad [1 mark]. _____
_____

3. Some butterflies close their wings when they sense an animal approaching. Explain the advantage of this behaviour [2 marks]. _____
_____

4. Suggest why plants may produce natural antiseptics [2 marks] _____
_____

5. In humans, mature red blood cells do not have a nucleus. Suggest why not having a nucleus in a red blood cell is an advantage [2 marks] _____
_____

Mini Assessment 1:
Before the Industrial Revolution most peppered moths were pale, but there was a mutant form which had dark colouration - the black peppered moth. During the Industrial Revolution, in cities the mutant black peppered moth became more numerous. Which of the following statements could explain why?
a. White peppered moths are bigger
b. Dark peppered moths are bigger
c. White peppered moths are easier to see on dirty tree bark
d. Dark peppered moths are easier to see on dirty tree bark

For my revision list:

Explaining Adaptations

Key concepts to remember

The theory of evolution allows us to build stories that explain how different adaptations occurred in a given population. Building this type of explanation is sometimes hard, because we tend to think first of the advantage and forget that variation comes from **random mutations**. If there are beneficial variations, those might lead to an adaptation. However, **no matter how beneficial a characteristic might be, it won't appear just because organisms "need" it**. On the contrary, if there is a sudden change in the environment and a population does not have any beneficial variations, it can go **extinct**.

A very useful tool for building evolutionary explanations is to use the following guiding questions:
a. How did the characteristic first appear in the population?
b. Is the characteristic beneficial at all? Why?
c. Which individuals in that population are more likely to survive and have offspring?
d. How/why has the characteristic remained in the species?
e. What can happen after a long time if the conditions remain the same?

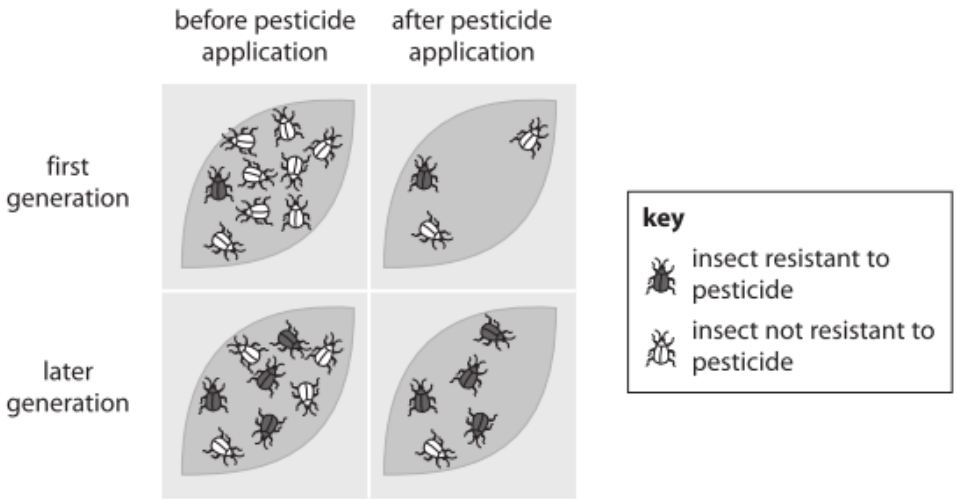
TOP TIPS

Remember!
- Characteristics appear by chance, NOT because organisms need them.
- If they benefit the organisms, then the organisms with the beneficial characteristics will be more likely to survive and have offspring.
- Evolution doesn't make us better! It selects beneficial characteristics for such a long time that we become better adapted to our environment.

Let's Practice:

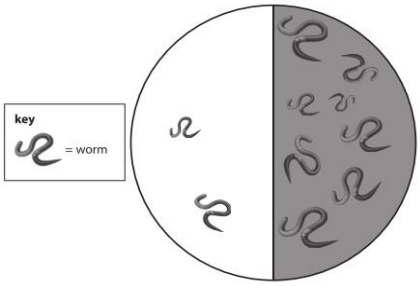
1. Methicillin-resistant *Staphylococcus aureus* (MRSA) is a bacterium that causes infections in different parts of the body. It is tougher to treat than most strains of staphylococcus because it is resistant to some commonly used antibiotics. Explain why and how bacteria like MRSA are becoming resistant to antibiotics like penicillin and what could be done to slow the process down [6 marks]. _____

2. Farmers use pesticides to kill insect pests on vegetables. The diagram shows how some insects may be resistant to a pesticide.



Use the diagram to explain how the presence of resistant organisms helps to support Darwin's theory of evolution [6 marks].

3. Robins eat worms. 10 worms were placed in the centre of a choice chamber. Half the chamber was in the light and half the chamber was in the dark. The diagram shows the position of the worms after one hour. Explain how this behaviour helps the worms to survive and how you think this behaviour evolved. [4 marks] _____



4. The dodo bird lived on the island of Mauritius. It was a large, flightless bird which had no predators. People came to the island, bringing hunting dogs with them. Suggest why there are no dodos living today. [4 marks]_____

5. *Howea forsteriana* and *Howea belmoreana* are two species of palm tree. The two species grow together on a small island in the South Pacific. The table gives some information about these two species of palm tree.

	Howea forsteriana	**Howea belmoreana**
Optimum pH of the soil for growth of the palm tree	pH 8	pH 6
Height above sea level of most common habitat	30 to 60 metres	Above 120 metres
Month when most palm trees flower	October	December
Method of pollution	Wind carries pollen	Wind carries pollen

Scientists believe that these two species of palm tree began to evolve from a single species over 2 million years ago. Suggest how these two different species developed. [6 marks] _____

Mini Assessment 2:
Deer are really fast animals, an adaptation that allows them to survive. Order the following statements from 1-5 to show how they evolved.
_____ After several generations, all but a few deer were born fast.
_____ The number of fast deer started increasing in the population.
_____ One day, a few deer were randomly born a bit faster than the others.
_____ Being fast was beneficial because it allowed those deer to escape predators more effectively
_____ Since the faster deer were more likely to flee from predators, they were more likely to survive and produce offspring.

For my revision list:

Generalising evolution: coevolution and selective breeding

Key concepts to remember

Evolution is not only about one species changing over time. Sometimes, multiple species are involved and they evolve together. This is called **coevolution**. A typical example for this are flowers and their pollinators. The process works in the same way, only with the mutations and adaptations happening to both organisms through time. Remember: these questions will still be useful to construct your explanations for coevolution (you'll just have to think about two species at a time):

a. How did the characteristic first appear in the population?
b. Is the characteristic beneficial at all? Why?
c. Which individuals in that population are more likely to survive and have offspring?
d. How/why has the characteristic remained in the species?
e. What can happen after a long time if the conditions remain the same?

A very similar process occurs for when people develop new crops or animal breeds through **selective breeding**. The only differences are that instead of natural selection, you have a person selecting the characteristics that are better for human needs (that is why selective breeding is also called **artificial selection**). Selective breeding still depends on random mutations as the source of variation from which to select characteristics. However, it is through people's intervention, selecting the seeds/animals with their preferred characteristics, that the variety or species changes.

TOP TIPS

Remember!

- Natural selection acts at the same time with multiple species, but the process is the same for each individually.
- Selective breeding is very similar to natural selection. The key difference is that it isn't nature, but a person, who selects the characteristics that will be inherited.

Let's Practice:

1. a) The leaves of some species of bamboo plants contain the poison cyanide. Suggest how these bamboo plants benefit from having poisonous leaves [1 mark]. _____

_____

_____

b) The photograph shows a greater bamboo lemur. The greater bamboo lemur is adapted to tolerate cyanide. This means that it can eat bamboo leaves containing cyanide. Explain how the co-evolution of bamboo plants and the greater bamboo lemur could have occurred. [4 marks]

_____

_____

_____

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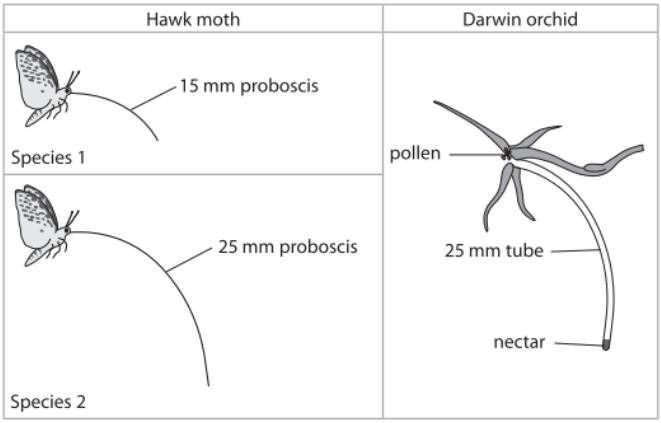
_____

_____

2. The Darwin orchid, *Angraecum sesquipedale*, is a flower found in Madagascar. It is pollinated by a species of hawk moth. Hawk moths feed from orchids using a long tube called a proboscis. Pollen sticks to the head of the hawk moth when it attempts to feed. The diagram shows a cross section of the orchid and two different species of hawk moth.



a) Describe how the co-evolution of the orchid and the hawk moth could have occurred. [3 marks] _____

_____

_____

_____

_____

_____

_____

_____

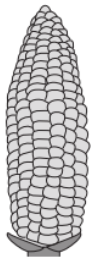
_____

b) Suggest a benefit of this co-evolution to the hawk moth. [1 mark] _____

_____

_____

3. The diagram shows the development of maize cobs over the last 1000 years of cultivation. Describe how scientists can use plant breeding programmes to produce maize plants with larger cobs. [3 marks]

maize cobs				
mean mass of cob /g	15	45	70	90
date	1000 years ago →			Present

_____
_____
_____
_____

4. Explain how the development of new plant varieties and the successful management of pests can be used to increase food production [4 marks]._____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Mini Assessment 3:

Which of the following describes a coevolutionary relationship?

a) The gazelle population of the savannah has evolved to become really fast because faster gazelles have escaped predation and bred more than slower gazelles.
b) Squirrels in areas with pinecones have stronger jaws than squirrels in areas without pinecones.
c) Both finches and parrots are selected for deeper, stronger beaks in years when only large, hard seeds are available.
d) All of the above describe coevolutionary relationships.
e) None of the above, on its own, describes a coevolutionary relationship.

For my revision list:

What I learned today and what I need to revise still:

Something important	Something cool	Something hard that I still need to revise

Additional Resources:

- **Information from the University of California, Berkeley:** https://evolution.berkeley.edu/evolibrary/article/evo_33
- **Information from Stanford University:** https://web.stanford.edu/group/stanfordbirds/text/essays/Coevolution.html
- **Four central points about coevolution:** https://link.springer.com/article/10.1007/s12052-009-0200-x
- **Multiple choice questions on coevolution:** https://global.oup.com/uk/orc/biosciences/evolution/stearns2e/01student/selftest/ch18/

Tutorial 4 – Evidence for Evolution

What is the Purpose of Tutorial 4?

- To feel confident providing evidence for the theory of evolution
- To understand how fossils are used to understand evolution
- To know the methods used to study evolution and feel confident analysing the evidence they provide

Keyword Checklist: Rate yourself red, amber or green

Keyword	Now	End of tutorial
Common ancestor		
Pentadactyl limb		
Evolutionary tree		
Genetic analysis		
Fossil		
Archaea		
Bacteria		
Eukarya		

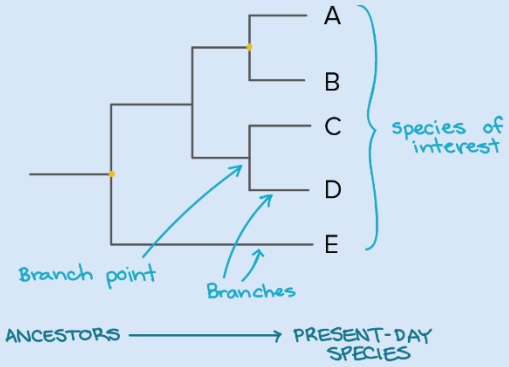
We all come from a common ancestor: evidence from anatomy

Key concepts to remember

One of the key points of the theory of evolution is that we all come from a **common ancestor**. As discussed in Tutorial 2, new species appear when they are genetically isolated, frequently because of a geographical barrier. Since variations are random, if two populations are separate, the variations happening to each will be different. Additionally, if the populations live in different environments, the variations granting advantages will be different, and therefore, natural selection will follow a different path. After enough time, there will be so many cumulative differences that the two populations will have become new species.

Therefore, a key piece of evidence for the theory of evolution is the similarities that exist between the anatomy and the DNA of different, seemingly unrelated organisms. Perhaps the most commonly used example for this is the **pentadactyl limb**, which is just a fancy word for a limb with five digits. Think about it: why would a whale, a bat, and a human have the same number of bones in their limbs, which they use for completely different purposes, if there wasn't evolution by natural selection? The simplest explanation for this similarity is that millions of years ago, we all had a common ancestor with 5 fingers, which evolved, in different places, into different organisms.

One way of representing how a group of species evolved is by making an **evolutionary tree**. The way scientists make them is by analysis which organisms share the most similarities. Present day species are at the end, and every point where the tree branches out represents a common ancestor. The longer the branch, the earlier in time that particular species started evolving from a population of the common ancestor.



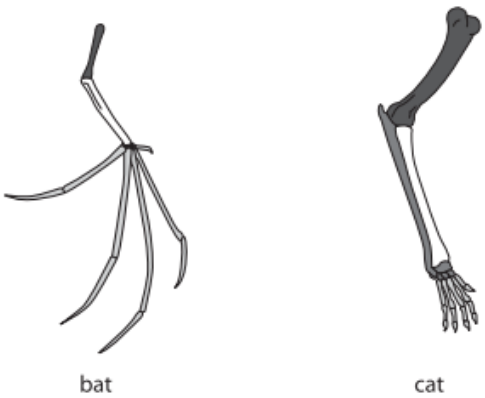
TOP TIPS

Remember!

- The similarities we share with other organisms are a consequence of our having evolved from a common ancestor.
- Each node in an evolutionary tree represents a common ancestor.

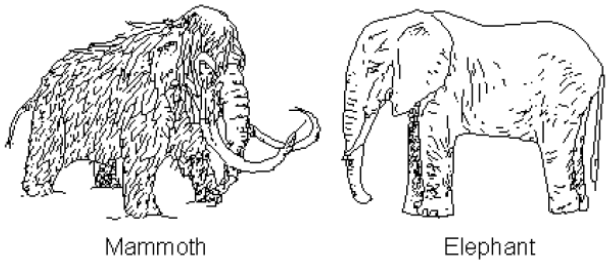
Let's Practice:

1. The figure to the right shows the pentadactyl limb of a bat and a cat.
   a) Describe the structure of a pentadactyl limb [2 marks]
   _____
   _____
   _____
   _____
   _____



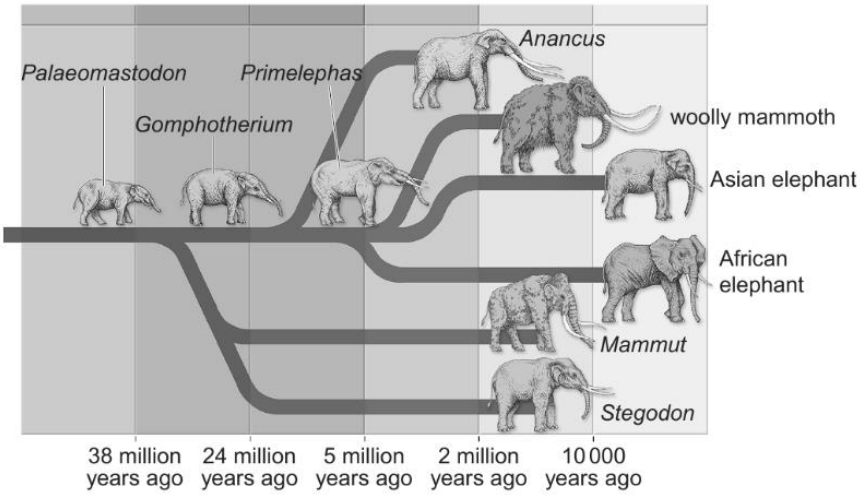
   b) Describe the reasons why the anatomy of the pentadactyl limb suggests that bats and cats evolved from a common ancestor. [2 marks]
   _____
   _____
   _____
   _____
   _____

2. The drawings to the right show a mammoth, a hairy, extinct relation of the elephant which lived in arctic regions; and a modern elephant which lives in tropical areas. Explain, as fully as you can, why the similarities between these two elephants support the idea that both organisms evolved from a common ancestor [2 marks]. _____



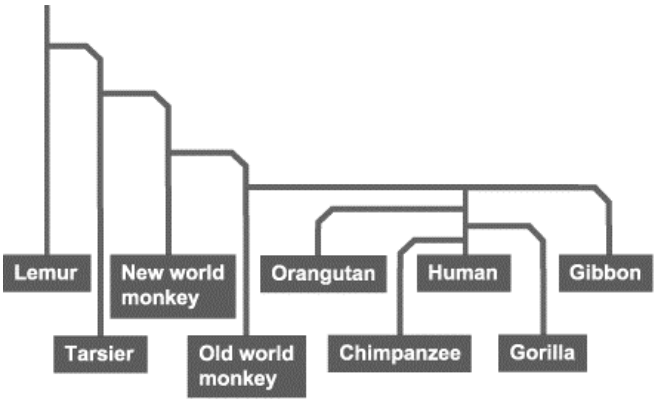
   _____
   _____
   _____

3. The tree to the right shows the evolutionary tree of woolly mammoths and elephants.



   a) Describe one characteristic that evolved in the African elephant [1 marks]. _____
   _____
   _____
   b) Give the name of the common ancestor of elephants and woolly mammoths [1 mark]. _____
   _____
   c) Explain how the similarities between the Asian elephant and the African elephant provide evidence to support the theory of evolution [3 marks] _____
   _____
   _____

4. The tree to the right shows the evolution of some primates, including humans.
   a) State which primate evolved first. [1 mark]
   _____
   _____
   _____

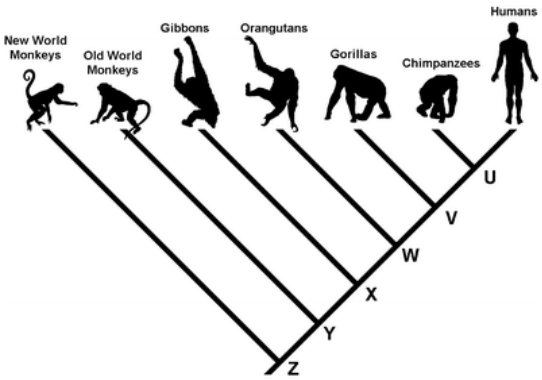


   b) Which primate is most closely related to humans? [1 mark] _____
   _____

   c) Suggest which feature in humans, gorillas, chimpanzees, and orangutans might have led scientists to think they all come from a common ancestor [3 marks]. _____
   _____
   _____
   _____
   _____
   _____
   _____

Mini Assessment 1:

Write whether statements below are true or false. If the statement is false, cross out and correct the wrong parts to make a correct sentence.



____ Old world monkeys and humans share a common ancestor.

____ The closest relatives to humans are chimpanzees and gorillas.

____ The new world monkeys are the ancestors of all other primates in the evolutionary tree

____ Gibbons are the closest relative to new world monkeys

____ Humans are the most recent species to have evolved

____ New world monkeys evolved before the other primates in the evolutionary tree.

____ The opposable thumbs in chimpanzees and humans evolved at different times during evolution

For my revision list:

We all come from a common ancestor: evidence from genetics

Key concepts to remember

Genetic analysis also provide evidence that we all come from a **common ancestor**. If you sequence all or parts of the DNA of different organisms and find that their genes are very similar to one another, even though the organisms are different, this provides strong evidence that the organisms share an origin. The higher the similarity between the organisms, the closer they will be related and the more recently they will have evolved from a common ancestor. For example, humans share 96% of their genome with chimpanzees, 90% with cats, 85% with mice, and 80% with cows. We even share 61% of our DNA with fruit flies.

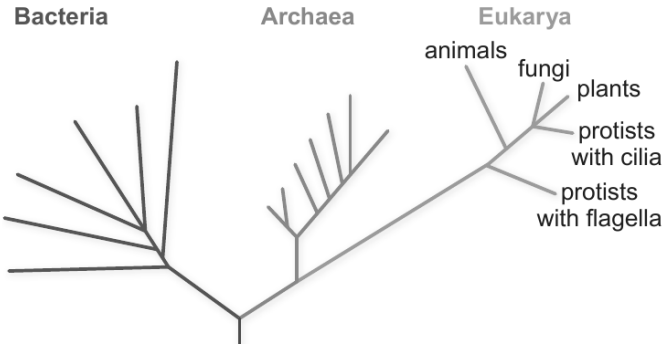
It is thanks to genetic analysis that we know that **Bacteria** and **Archaea** are actually completely different groups of organisms. If you see them under the microscope, they look very similar. However, scientists noticed that Archaea's genes look more like **Eukaryote** genes, because they have sections that are not used to code for proteins, whereas Bacteria use all their genetic information to build their proteins. This led scientists to conclude that Archaea and Eukaryotes shared a common ancestor that was more recent than bacteria.

TOP TIPS

Remember!
The more mutations or genetic differences between two groups of organisms, the further away the two will be in the evolutionary tree.

Let's Practice:

1. The diagram to the right shows the three domain system of classification by Carl Woese.



   a) Which is more recent, the common ancestor of Eukarya and Archaea, or of Eukarya and Bacteria? Explain your answer using the diagram [1 mark].
   _____
   _____

   b) Explain why Archaea are no longer grouped with other bacteria [2 marks] _____
   _____
   _____

2. Genetic analysis provides evidence for evolution. Scientists can sequence genes from different organisms. Describe how this type of genetic analysis provides evidence for evolution. [2 marks]
   _____
   _____
   _____
   _____
   _____
   _____

3. What is meant by "genetic analysis"? [1 mark] _____
   _____

4. There has been debate in history over the classification of the red panda and the giant panda. Based on anatomical evidence, some argued that they should belong to the bear family and others argued that they are more like racoons. Following the development of DNA sequencing technology, pandas have been reclassified with bears; and red pandas, with racoons. Suggest how evolutionary scientists reached this conclusion [3 marks]. _____

_____
_____
_____
_____
_____
_____
_____
_____

Mini Assessment 2:

Which statement is true about genetic analysis?

a) The more differences that two organisms have in their DNA, the longer ago their common ancestor lived.
b) The fewer differences that two organisms have in their DNA, the longer ago their common ancestor lived.
c) Genetic analysis compares the genetic code of different organisms to see how closely related they are in evolution
d) Genetic analysis is the only reliable method to find out if two organisms descend from a common ancestor.

For my revision list:

Evidence from the fossil record

Key concepts to remember

Fossils are key to the theory of evolution, mainly because they provide evidence for the existence of common ancestors. By going back on these intermediate forms, we can get a better picture of the sort of variations that occurred in different areas, and how different organisms started diverging or getting different from their relatives as time passed.

Additionally, fossils allow us to estimate how long ago a species or its common ancestor existed. You can tell how old a fossil is by:

- Finding out the date of the **layer of rocks** next to it. The fossil must be the same age. You can also date the layer (or stratum) of rocks above and below. The deeper something is in those layers, the older it will be.
- If you know the age of another fossil that is in the same place as the one you want to date, because someone found that type of fossil elsewhere, then you can be sure both fossils will be the same age.
- You can use radioactive elements. Since these elements are unstable, they break down as time goes by. By seeing how much of that given element is left in the fossil or the layer of rock around it, you can estimate the age.

Another application of fossils is estimating how big or successful a group of organisms was. If this changes significantly, you can infer that there must have been some environmental change or some other change of circumstances. For example, after Earth was hit by a meteorite 66 million years ago, the number dinosaurs fossilising would have decreased significantly, and you would have had a significant increase in the number of mammals.

The problem with using fossils, though, is that not all organisms fossilise. Hard structures, like bones and shells, are way more likely to fossilise than soft structures. Also, fossilisation needs the right conditions: animals need to have been buried very soon after death. That is why we have more fossils from swampy areas than other places. Since not all organisms (or groups of organisms) fossilised, we say that **the fossil record is incomplete**.

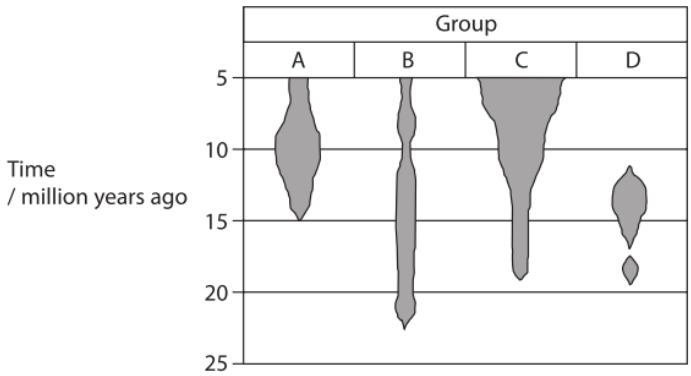
TOP TIPS

Remember!

- The deeper a fossil is in the layers of rock, the older it will be.
- Big changes in the abundance of a certain group of fossils over a given time period could mean there was a big environmental change.
- The fossil record is incomplete because not all organisms are equally likely to have fossilised

Let's Practice:

1. Scientists investigated fossils of four different groups of mammals. The diagram shows how the estimated population of each group of mammals changed from 25 million to 5 million years ago. The width of each shaded area shows the estimated population size, based on the number of fossils found.



   a) Which statement is supported by the information in the diagram? Put a cross in the box next to your answer [1 mark].

   ☐ A Group A contains mammals that came into existence 10 million years ago
   ☐ B Group B contained the largest group of mammals 15 million years ago
   ☐ C Group C is the most recent group of mammals to come into existence
   ☐ D Group D were extinct 10 million years ago

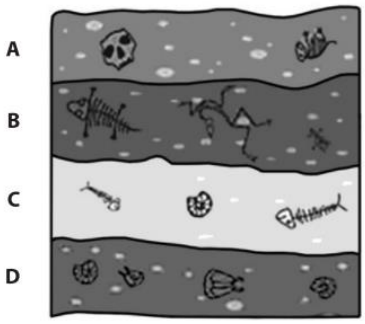
b) Suggest reasons for the change in the estimated population size of group A from 10 million to 7 million years ago [3 marks]. _____

_____

_____

_____

2. The diagram shows fossils in different layers of rock. A B C D



a) Which layer of rock is most likely to contain the oldest fossils? Put a cross ( ) in the box next to your answer [1 mark].

☐ A
☐ B
☐ C
☐ D

b) Use one word from the box to complete the sentence [1 mark].

replication	evolution	speciation	catastrophes

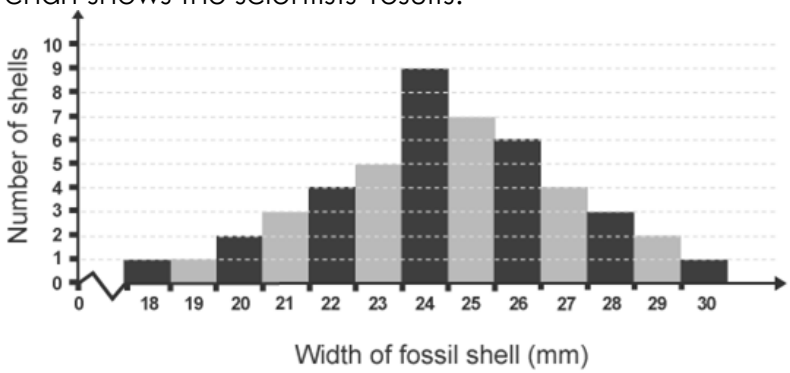
The fossil record provides evidence for _____.

c) Explain why there are gaps in the fossil record for some organisms. [2 marks]_____

_____

_____

3. A species of snail lived 400 million years ago. Scientists measured the width of 49 fossil shells of this snail. The bar chart shows the scientists' results.



a) What is the range of the values for the width of the fossil shells for this species? [1 mark]
From _____ to _____

b) The scientists cannot be sure that this is the full range of fossil shell widths for this species. Why? [1 mark] _____

_____

4. Explain why fossils of dinosaurs are often incomplete. [3 marks]_____

_____

_____

_____

_____

_____

_____

Mini Assessment 3:
Which of the following statements is true about fossilization?
a) It is a common occurrence.
b) It is more common for animals from mountains and forests than for those from deserts and oceans.
c) Small animals with light weight, thin bones are more likely to become fossils than are large animals with heavy, dense bones.
d) The oldest fossils are usually found at the top layers of rocks.
e) None of the above
f) All of the above

For my revision list:

What I learned today and what I need to revise still:

Something important	Something cool	Something hard that I still need to revise

Additional Resources:

- **Evidence of evolution:**
  - https://necsi.edu/evidence-for-evolution
  - https://www.ncbi.nlm.nih.gov/books/NBK230201/
- **Genetic analysis:**
  - https://phys.org/news/2018-05-gene-survey-reveals-facets-evolution.html
  - https://www.nature.com/scitable/topicpage/the-molecular-clock-and-estimating-species-divergence-41971/
- **Dating fossils:** https://www.factmonster.com/dk/encyclopedia/science/dating-fossils

Tutorial 5 – Human Evolution

What is the Purpose of Tutorial 5?

- To understand which characteristics have been beneficial throughout human evolution
- To understand the relationship between different species of hominids and practice their names.
- To understand how scientists study human evolution

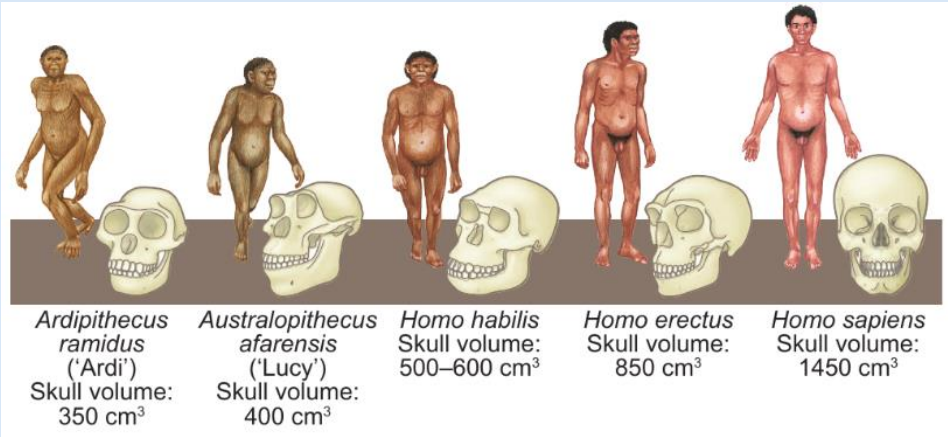
Keyword Checklist: Rate yourself red, amber or green

Keyword	Now	End of tutorial
Hominid		
Ardipithecus ramidus		
Australopithecus afarensis		
Homo habilis		
Homo erectus		
Louis and Mary Leakey		

Identifying advantages in humans

Key concepts to remember

It is easy to think of human evolution as a linear process. However, nothing could be further from the truth. Just as with any other group, we have an evolutionary tree with many branches: there are dozens of species of **hominids**, which started evolving about **4.4 million years ago**.



Even though there have been many different species of hominids, as you can see in the image to the right, throughout all that long and complex evolutionary process, it is possible to identify some **evolutionary trends**. In other words, there have been some characteristics which have been generally beneficial and have been naturally selected over time across the whole group. For example:

- Skull size (and therefore brain size) has gradually increased.
- The proportions of the body have gradually become more suitable for walking completely upright
- Height has increased.

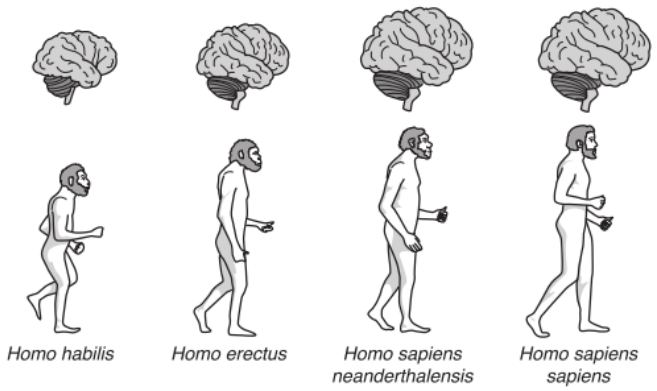
TOP TIPS

Remember!

- Big skulls (with big brains) and walking upright have been beneficial for hominids throughout history

Let's Practice:
(Tip: if you struggle with this section, go back to Tutorial 3: Identifying advantages)

1. The pictures to the right show the evolution of the human brain. Describe how the brain evolved, giving early humans a better chance of survival [2 mark]._____
_____
_____
_____
_____
_____
_____



2. Human evolution has been influenced by parental care. Explain how parental care contributes to evolution. [2 marks] _____
_____
_____

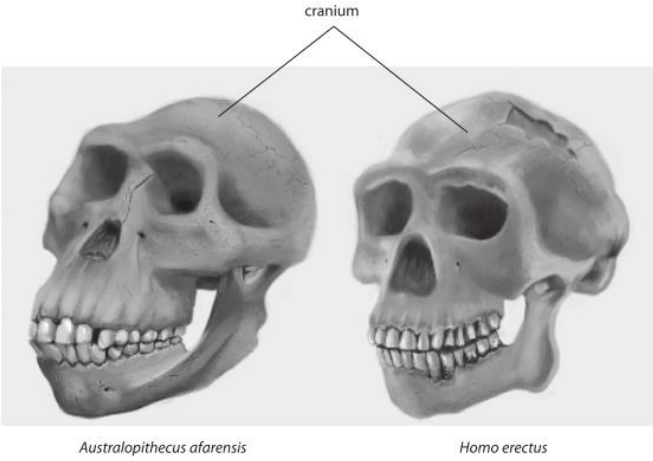
3. Identify two trends in the evolution of humans [2 marks]_____
_____
_____
_____

4. Discuss the changes that have occurred in humans from prehistoric to modern times [3 marks]
_____
_____
_____
_____

5. The photograph to the right shows the skulls of two different early humans.

   a) Suggest why the cranium of Australopithecus afarensis is smaller than the cranium of Homo erectus [1 mark]. _____
   _____
   _____
   _____

   b) Describe one structural difference in another part of these skulls. [1 mark] _____
   _____
   _____
   _____
   _____



Mini Assessment 1: Choose the correct statement: a) Humans are descended from apes. b) Hominids have a smaller skull size than other primates. c) Walking upright has consistently been an evolutionary advantage for hominids. d) Hominids lost their hair because they did not need it.	For my revision list:

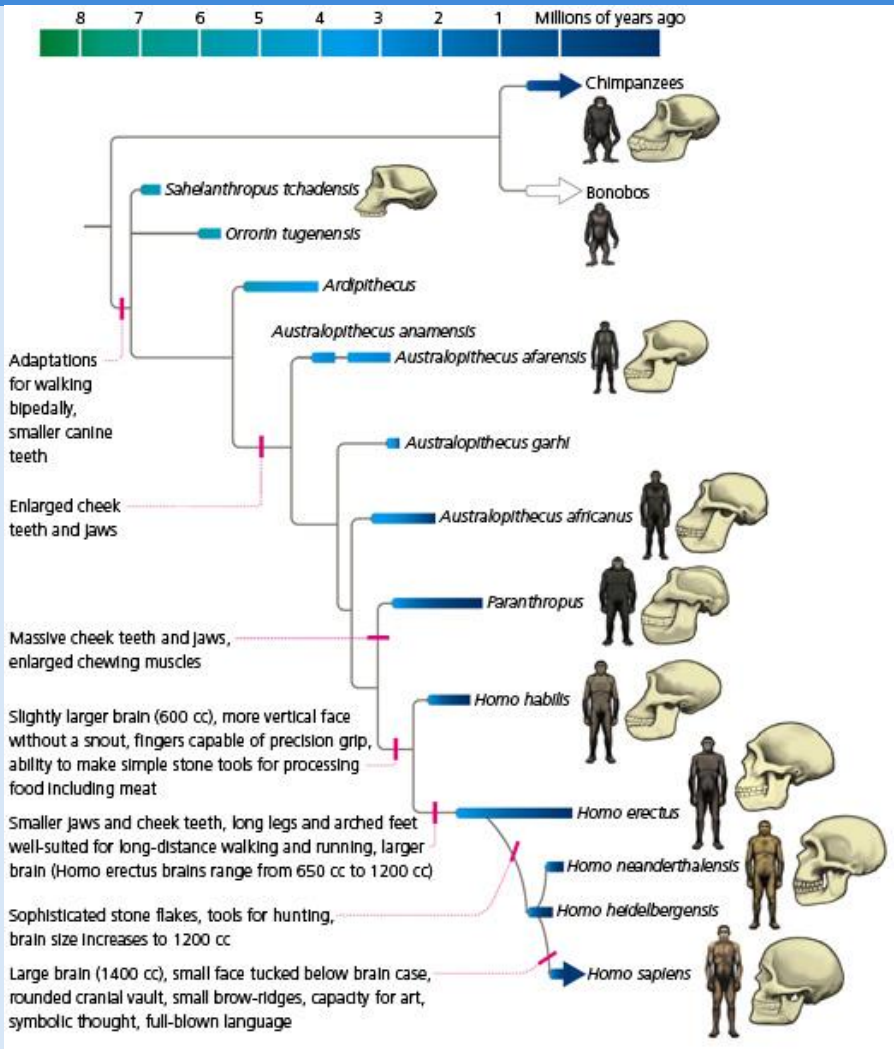
Hominids, hominids, hominids

Key concepts to remember

In the image to the right, you can see an evolutionary tree that will give you an idea of how **hominids** evolved. This tree is constantly changing, as new fossils are discovered. As you can tell, humans share a common ancestor with chimpanzees and bonobos, but we are not descended from them.

There are some key species, and some key representative individuals from those species, which you need to remember from this tree. They are particularly important because of the distinctive features that made them different to the ancestors before them. These are in the table below.

The way all these fossils were dated was by using the techniques covered on Tutorial 4: Evidence from the fossil record.



Species	How long ago?	Key specimen	Characteristics
Ardipithecus ramidus	4.4 million years ago	Ardi	Height around 1.2 m tall and 50 kg. Leg bones show that they may have been able to walk upright. Long arms, long big toes, unclear ability to climb trees given the shape of the feet and pelvis.
Australopithecus afarensis	3.9 - 3 million years ago	Lucy	Height around 1.07 m. Walked upright. Toe bones arranged similarly to modern humans but more curved. Probably able to walk upright and climb. Apelike face proportions and small skull.
Homo habilis	2.4-1.4 million years ago	-	One of the earliest members of the genus *Homo*. Quite short with long arms, but walked upright. Slightly larger skull and smaller face than *Australopithecus*. The *habilis* in its name is because it is one of the earliest hominids to use tools. Discovered in Tanzania by **Louis and Mary Leakey**.
Homo erectus	1.8 – 0.5 million years ago	-	Tall (1.79 m) and strongly built. Discovered in Asia, leading many to believe modern humans came from Asia. However, a 1.6 million-year-old specimen was found by **Richard Leakey** in Kenya, providing conclusive evidence that our common ancestor was African. Earliest humans with modern human-like body proportions: long legs and shorter arms. Adapted to life on the ground, probably able to run long distances. Expanded skull
Homo sapiens	Since 195 000 years ago	You	Modern humans. Evolved in Africa and migrated to the remaining continents. Bigger brains and smaller jaws.

TOP TIPS

Remember!

- Humans don't come from monkeys! We are all primates who share a common ancestor.
- Ardi and Lucy are two key fossils that show us how our early ancestors might have looked like.
- The first hominids to use tools were *Homo habilis*

1. Many fossils of early humans have been discovered in Africa, including Lucy from 3.2 million years ago. Leakey found many early human fossils in Africa from 1.6 million years ago. Describe how Leakey used the fossils and surrounding environment to reach the conclusion that his fossils were from a species more recent than Lucy. [6 marks] _____

2. Use words from the box to complete the sentences. (2)

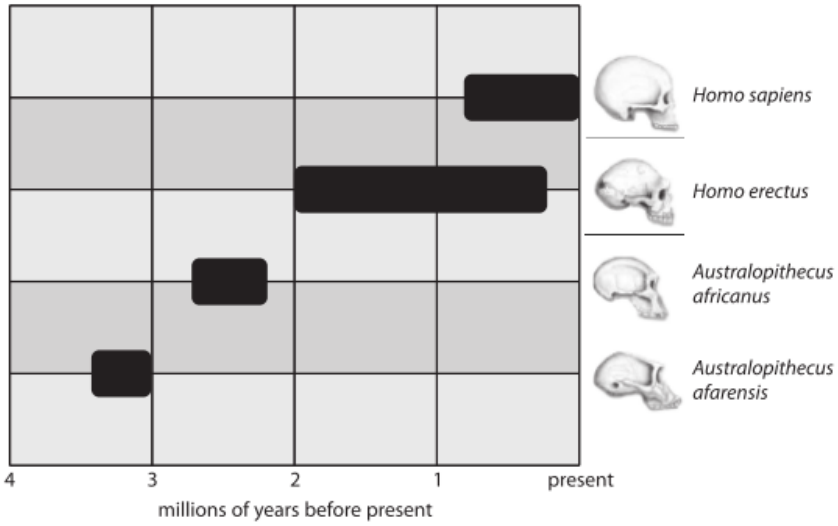
Ardi	million	billion	Lucy	Leakey	thousand

Some of the earliest human-like remains are estimated to be about 4.4 _____ years old. These fossils were named _____.

3. Describe how fossil evidence can be used to show that humans have evolved [2 marks]. _____

4. Explain why scientists cannot be sure that human-like animals, such as Ardi, evolved into modern humans [2 marks] _____

5. The diagram to the right shows the estimated time when early humans and their ancestors existed. In which time period did Australopithecus afarensis exist? Place a cross ( ) in the box next to your answer. [1 mark]



- ☐ A present day to 1 million years before present
- ☐ B 1 to 2 million years before present
- ☐ C 2 to 3 million years before present
- ☐ D 3 to 4 million years before present

6. Describe the evidence for human evolution, based on fossils. Include reference to specific early human fossils in your answer [6 marks]. _____

Mini Assessment 2:

Put these events in order, from earliest to most recent:

____ *Homo habilis* becomes extinct
____ *Ardipithecus ramidus* appears
____ Lucy is born
____ *Homo habilis* appears
____ The first primates appear
____ Ardi is born
____ The first hominids appear
____ *Homo sapiens* appears
____ First members of the genus *Homo* appear

For my revision list:

Other evidence for human evolution

Key concepts to remember

Hominids, unlike other species, started using tools from **3.3 million years ago**. That means that the study of hominids includes not only their body parts, but also their tools. In particular, stone tools developed over time have proved to be incredibly valuable for this purpose.

Just as with fossils, dating different tools can be done by working out the ages of the layers of rock where they find the tool. Also, they can study the technique used to produce the tool. The oldest stone tools are quite simple, whereas the most recent ones would have needed far more detailed work, and would have accomplished shaper edges (in the case of knives and arrowheads). The newer tools also have a greater range of more complex shapes and purposes.

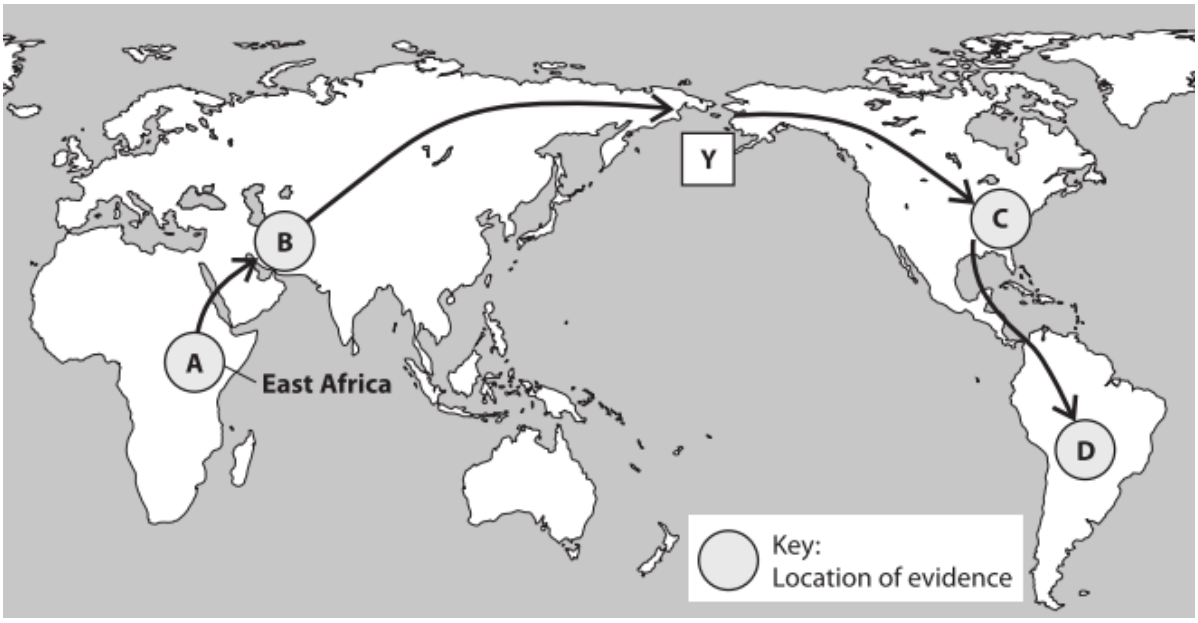
TOP TIPS

Remember!

- The newer the tool, the more sophisticated the work and the sharper the edges.

Let's Practice:

1. Human ancestors are thought to have originated in East Africa. The 'Out of Africa' theory suggests that human migration followed the route shown on the map. Evidence for this theory has been found along the route.



The evidence from the four locations is shown in the table to the right.

evidence		approximate age/ years
arrow head		15 000
flake tool		20 000
jaw bone		50 000
hand axe		190 000

a) Complete the sentence by putting a cross ( ) in the box next to your answer. The hand axe, shown in the table, is most likely to have been found at location [1 mark]:

- ☐ A
- ☐ B
- ☐ C
- ☐ D

b) Describe how the ages of the stone tools could be estimated [2 marks]. _____

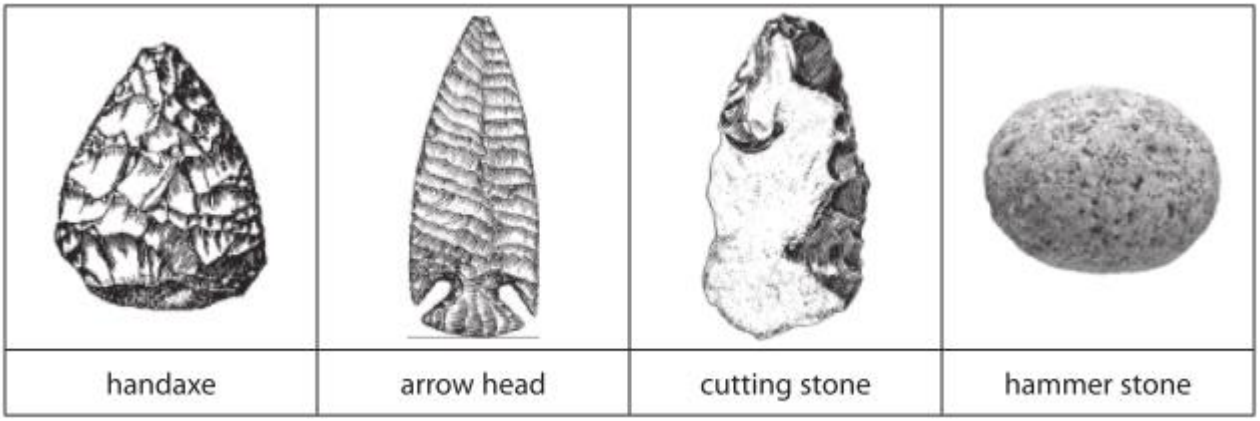
_____

_____

_____

_____

2. The diagram shows four Stone Age tools discovered at different archaeological sites in Europe.



a) Complete the sentence by putting a cross ( ) in the box next to your answer. The Stone Age tool made most recently is the [1 mark]

☐ A hand axe
☐ B arrow head
☐ C cutting stone
☐ D hammer stone

b) Suggest how these tools may have helped early humans to survive. [2 marks] _____

_____
_____
_____
_____

c) Suggest what conclusion we could draw about human evolution from this evidence [2 marks] _____

_____
_____

3. Describe how stone tools developed over time [2 marks] _____

_____
_____
_____
_____

4. The photograph shows some stone tools from different times in the Earth's history. Suggest why there are differences in these stone tools. [2 marks] _____

_____
_____
_____
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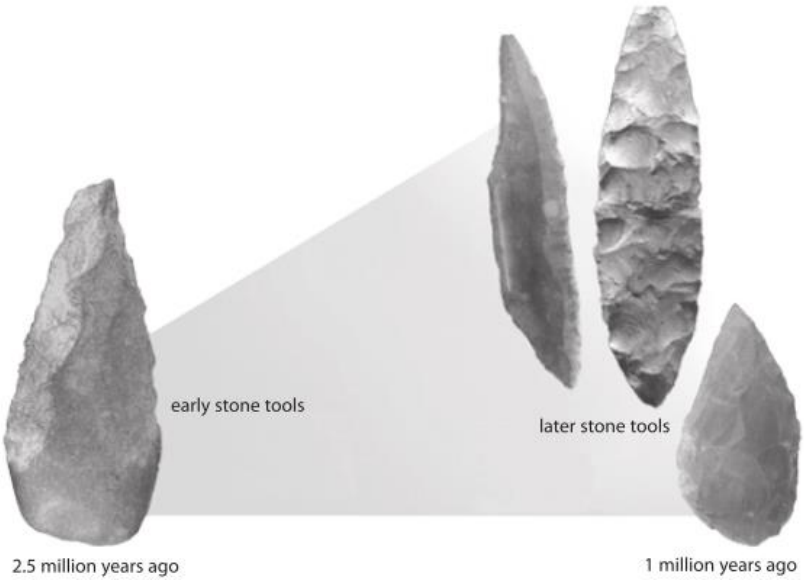
_____
_____
_____
_____



Mini Assessment 3:
Decide whether each statement is true or false. If it is false, cross out the incorrect bits and correct it.

_____ All hominids developed tools.
_____ The newest tools are in the deeper layers of the rock
_____ *Homo erectus* was the first human to have tools.
_____ *Australopithecus* did not have tools that we know of.

For my revision list:

What I learned today and what I need to revise still:

Something important	Something cool	Something hard that I still need to revise

Additional Resources:

- **Overview of human evolution:** https://www.britannica.com/science/human-evolution/Background-and-beginnings-in-the-Miocene
- **Info on different hominids:** http://humanorigins.si.edu/evidence/human-fossils/species
- **Evolutionary trends:** https://sci.waikato.ac.nz/evolution/HumanEvolution.shtml
- **More info and a quiz:** https://www.khanacademy.org/partner-content/amnh/human-evolutio/human-evolution-the-evidence/a/dr-ian-tattersall-pieces-together-the-human-past
- **Louis and Mary Leakey:** http://www.macroevolution.net/mary-leakey.html
- **Short articles on studying stone tools:**
  - https://www.smithsonianmag.com/science-nature/becoming-human-the-origin-of-stone-tools-55335180/
  - https://www.sapiens.org/evolution/homo-sapiens-and-tool-making/

Tutorial 6 – Assessment

Use this space to glue your final assessment

Tutorial 7 – Feedback and reflection

What is the Purpose of Tutorial 7?

- To receive feedback
- To reflect on the feedback and on our own performance
- To write targets for improvement in future revision

Final assessment feedback

What I did well…	What I could have improved on…
•	•
•	•
•	•

One question I still have is…

The answer to that question:

My targets for future work are…

Tutorial 8 – It's not just natural selection!

What is the purpose of Tutorial 8?

- To be able to mention other processes that drive evolution apart from natural selection
- To analyse some links between evolution and genetics

Think!
Having a big, flashy tail does not help peacocks survive. It actually hinders their survival. Can you think about an evolutionary explanation as to why it has those big feathers?

Sexual Selection

You've already learned about a key process in evolution: **natural selection**. In natural selection, the characteristics that get selected and passed on to the offspring are the ones that confer an advantage in terms of survival. However, not all characteristics work that way. Think of the male peacock above. Not only does its long and flashy tail not help him survive: it actually hinders him. It is harder to avoid and flee predators with such a bulky, hard-to-miss tail. However, the beautiful tail is also hard to miss for the peahen. It actually signals that the male is healthy and of reproductive age. Therefore, the males with the biggest, flashiest tails will have a higher likelihood of mating and having offspring. In this case, evolution has nothing to do with survival of the fittest, but with **reproductive success**.

Sexual selection usually occurs when there is fewer members of one sex than the other in a species or population. It is also common on species where parental care takes up a lot of energy and resources. In those species, the parent caring for the children will want to make sure that the other partner is committed enough. That commitment can be shown, for example, by building a nest or bringing presents. In that case, the competition between individuals is not for resources but for **mating partners**. Only the most sexually desirable partners will get to reproduce and have offspring. After millions of years, the characteristics will be present in all of the species. These organisms are adapted, but not to survive, but to mate the most.

Can you think of other examples of sexual selection?
(Tip: remember that, as long as it is heritable, any characteristic –not just physical ones– can evolve.)

What was your favourite(s) example of sexual selection?

Write a bit about it here. If you prefer, you can turn it into a cartoon or comic

Atrophy and pseudogenes: why do fish go blind?

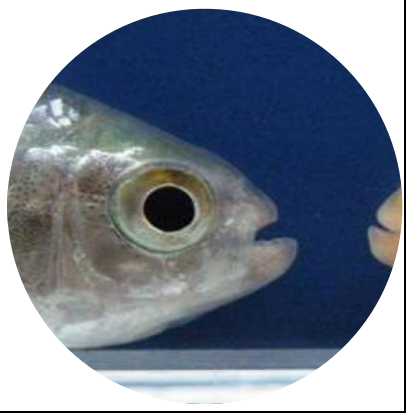
You've already learned that **mutations** are both **random** and **frequent**. Most of them are neither positive nor negative, but neutral, meaning that they won't change the properties of the protein they code for. You also learned that sometimes, if there are **selection pressures** in the environment, some mutations will grant evolutionary advantages. But what if they don't? What if there weren't any selection pressures?

Thinking exercise:
Opsin is one of the key proteins for vision. It changes shape when it absorbs light of a given colour, and that change stimulates the cells that send the message to the brain. Without opsins, quality of vision is significantly reduced. Predict which species will have the most mutations in their opsin genes after 100 million years and why.

a) African elephant. It relies mostly on its sense of smell to survive. It uses his size, his vision, and his keen sense of smell to avoid predators.
b) Nocturnal owl. It depends heavily on his night vision to hunt at night.
c) Fish in a cave with absolutely zero light.

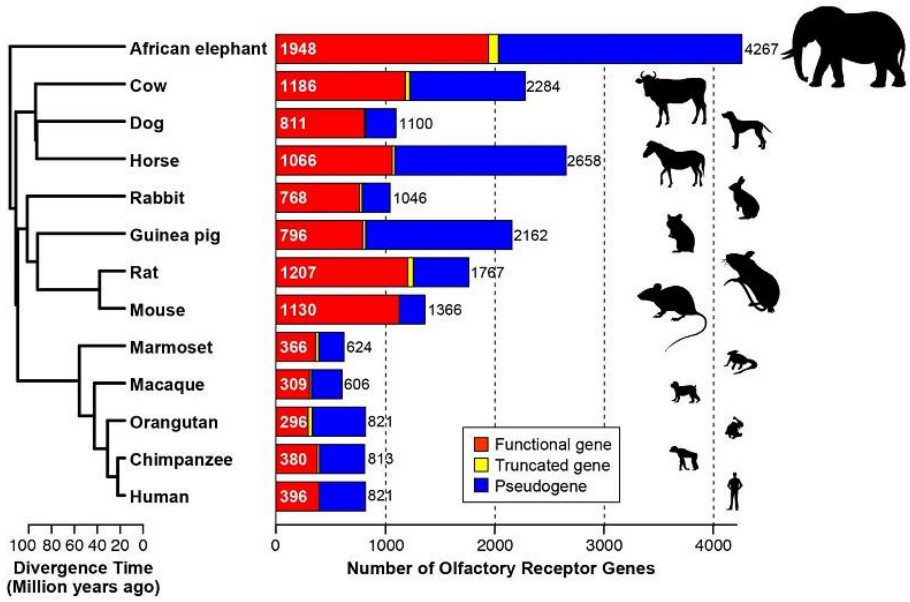
When there are strong selection pressures, any mutation on a key gene can be the difference between surviving and dying. In the example above, the owl cannot afford to lose any of its eyesight. If it does, then the owls with the better eyesight will be the ones to survive. Therefore, even though mutations will happen, the individuals with those mutations will be more likely to die off, keeping the genome of the species relatively stable throughout very long periods of time. However, if there are no selection pressures, the mutations won't make any difference for survival, so they will start to accumulate. After millions of years of mutations, the genes might even become impossible to transcribe or obsolete.

GCSE practice (Tip: use the guiding questions as you used to explain adaptations in Tutorial 3[§].)
Explain why several species of fish living in caves have gone completely blind throughout evolution [6 marks].



[§] a) How did the characteristic first appear in the population? b) Is the characteristic beneficial at all? Why? c) Which individuals in that population are more likely to survive and have offspring? d) How/why has the characteristic remained in the species? e) What can happen after a long time if the conditions remain the same?

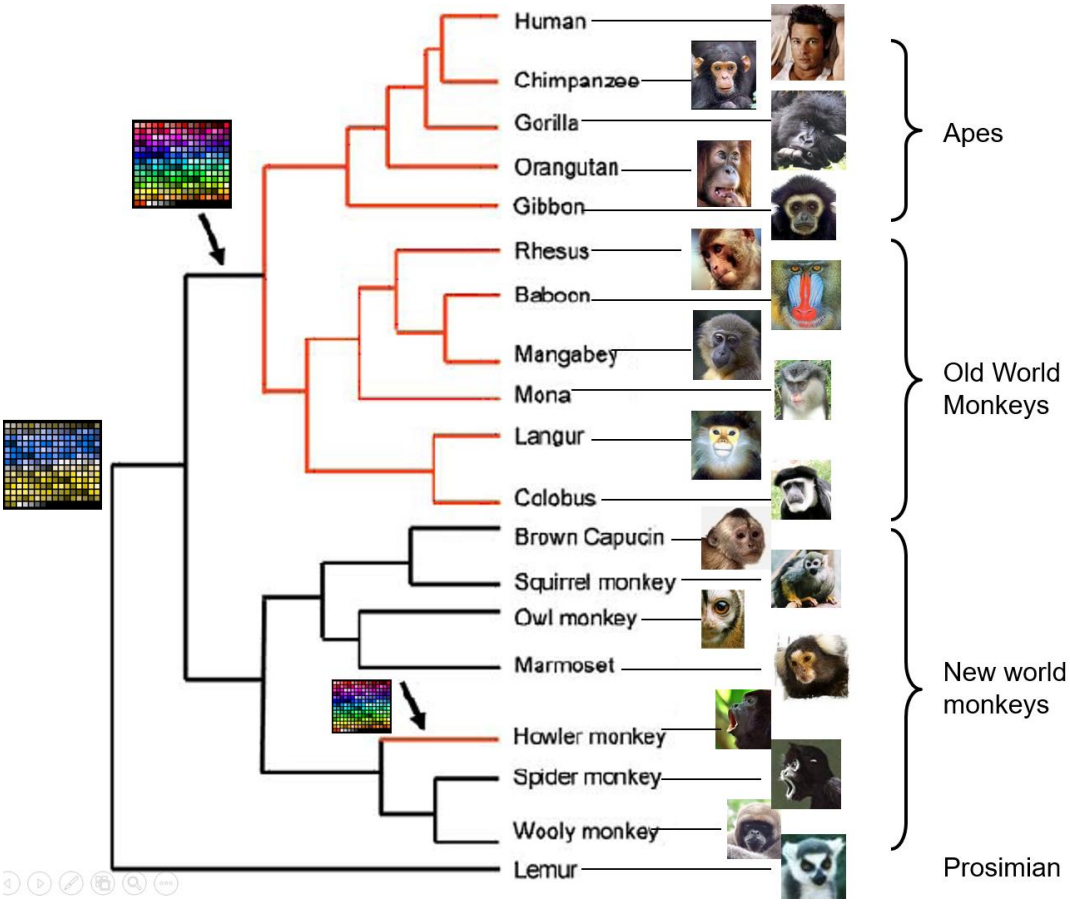
Genetic analysis gives us a very good idea of what selection pressures have shaped the evolution of different groups. The way it does that is by looking for functional genes versus **pseudogenes**. A pseudogene is a sequence of DNA that looks very similar to a functional gene, but that has enough mutations to have lost its function. In other words, so many mutations will have accumulated in that gene that it will have become a gene corpse. In the diagram below, you can see the number of olfactory genes and pseudogenes that different species have.



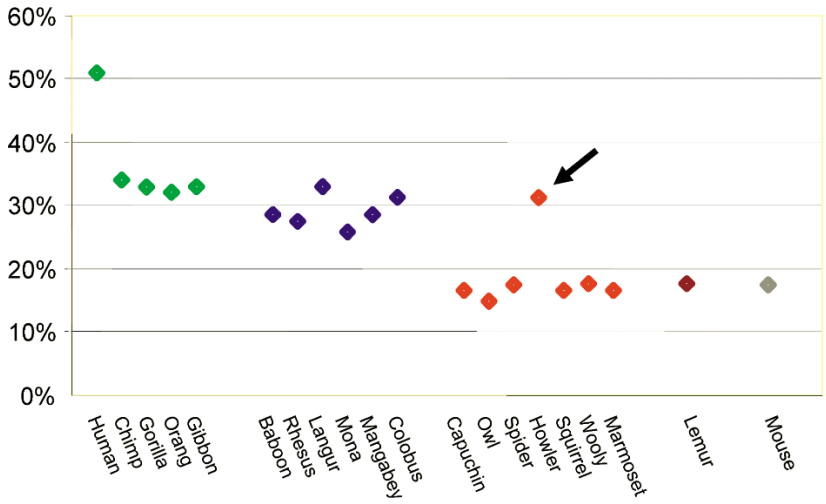
What can you infer from this graph?

Thinking Question: From the diagram above, you can tell that orangutans, chimpanzees and humans have lost most of their olfactory genes. However, the marmosets and macaques have preserved the functionality of a higher proportion of their genes. All those organisms are primates and stem from a common ancestor. Can you think of anything that might have removed the selection pressures from orangutans, chimpanzees and humans, thus allowing the mutations to accumulate?

Below is an **evolutionary tree** of primates. The **common ancestor** of primates could only see in two colours, because it only had two genes for opsins, the proteins responsible for perceiving colour. However, a random mutation occurred, where one of these genes was duplicated. The resulting primates were then able to see in three colours (trichromatic vision). Interestingly, this mutation happened twice in the evolution of primates, one in the common ancestor of apes and old world monkeys, and once in howler monkeys.



Being able to see in three colours was so much of an evolutionary **advantage** that the selection pressures on olfactory genes decreased. In other words: those organisms with great vision and poor smell were more likely to survive that those organisms with poor vision and great smell. That is the reason why you have so many pseudogenes in humans, orangutans and chimpanzees. The graph below tells you the proportion of olfactory pseudogenes in all the primates from the tree above.



What can you interpret from this graph?

Today I learned…

Something important	Something cool	Something hard

Additional Resources:

- **Sexual Selection comic:** https://www.storyboardthat.com/storyboards/arianahuang42/sexual-selection
- **Sexual selection examples:**
  - Angler fish: https://theoatmeal.com/comics/angler and https://www.youtube.com/watch?v=Z-BbpaNXbxg
  - Hienas: https://www.youtube.com/watch?v=PBCNWmU5apE
  - Praying mantis: https://www.pbs.org/newshour/science/praying-mantis-hanky-panky-is-way-weirder-than-you-think
  - Lyre bird: https://www.youtube.com/watch?v=VjE0Kdfos4Y
  - Bird seduction techniques: https://www.youtube.com/watch?v=_H9TyXiXM2k
- **Article "Loss of Olfactory Receptor Genes Coincides with the Acquisition of Full Trichromatic Vision in Primates":** https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.0020005

Homework assignment: Practice your evolutionary explanations

Choose any of the organisms we discussed today. Explain how one of its characteristics either evolved or disappeared. Write it as a 6 mark GCSE answer. If you need to, use the guiding questions suggested in Tutorial 3**.

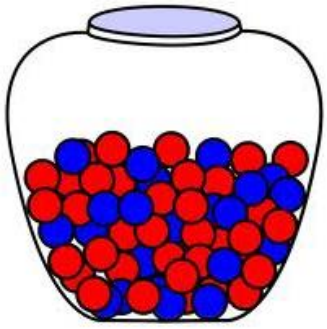
** a) How did the characteristic first appear in the population? b) Is the characteristic beneficial at all? Why? c) Which individuals in that population are more likely to survive and have offspring? d) How/why has the characteristic remained in the species? e) What can happen after a long time if the conditions remain the same?

Tutorial 9 – To gene or not to gene?

What is the purpose of Tutorial 9?

- To understand the importance of chance in evolution (not just on natural selection)
- To be able to explain how gene expression is regulated and how it affects evolution

Evolution can be like a bag of marbles



PROBLEM:
In a bag, you have 10 marbles. Seven of them are red and half of them are white. If I take out two marbles, what is the probability of…?

a) Getting 2 red marbles?

b) Getting 1 red and 1 blue?

c) Getting 2 blue marbles?

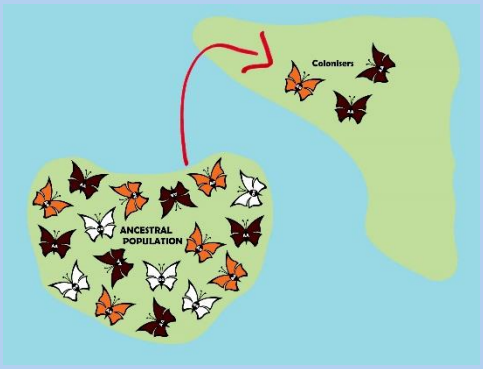
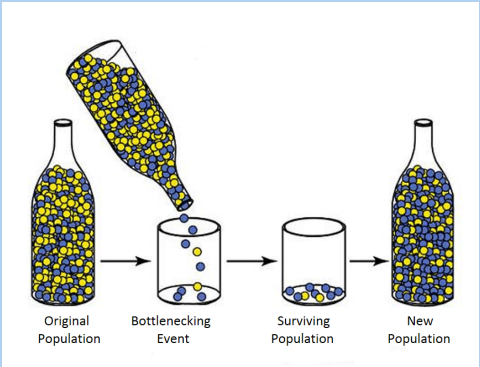
Genetic Drift

Natural selection is a very important process for evolution. However, when it comes to small populations, there can be drastic changes that happen just because of chance rather than selection pressures. For example if you live in a small island and there is a volcanic explosion, the individuals that will die will be those that were closest to the volcano at the time of the explosion, regardless of what characteristics or beneficial variations they might have. If the survivors had a specific genetic variation, it will be inherited to the offspring, drastically changing the proportion of individuals with that characteristic in the population.

We use the term **genetic drift** to describe all the changes in a population or species that are just due to chance.

Thinking question: can you come up with any circumstances that could randomly affect who survives and who dies in a population?

Although genetic drift occurs in any population, it is particularly likely in populations that were founded by a few individuals or in which the population was reduced to a very small number at some time in the past. Complete the table below with the info you find out.

	What is it?	One example?
The founder effect 		
The bottleneck effect 		

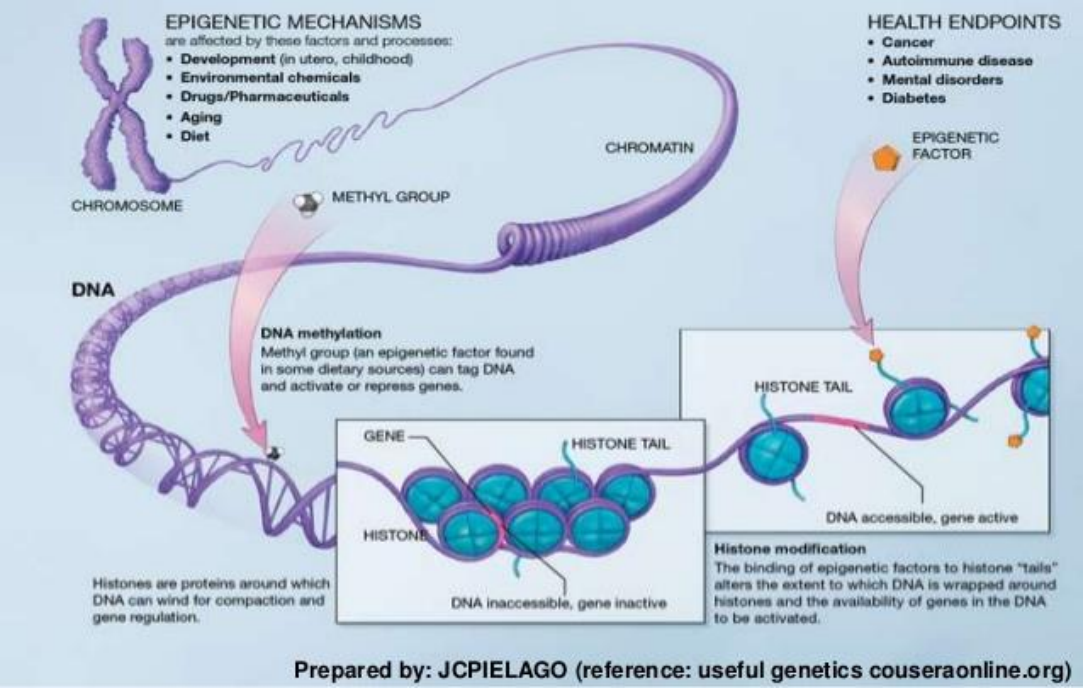
Problem:

Polydactyly is a genetic condition where children are born with six fingers and other physical abnormalities. It is quite rare, with about 1 cases per 60,000 live births. However, the Amish in the USA have a much higher incidence of polydactyly, estimated as 1.7 per 1000 live births. Suggest a reason why this might be the case.

Epigenetics

Remember when we learned about **genetic and environmental variation**? You learned that it is genetic variation that gets inherited to **offspring**. While this is mostly true, in the last 10 years, we have discovered that in some very special cases, environmental variation can actually affect how your genes are **regulated**. And sometimes, when those changes are drastic and happen during pregnancy, they might actually be inherited to your offspring.

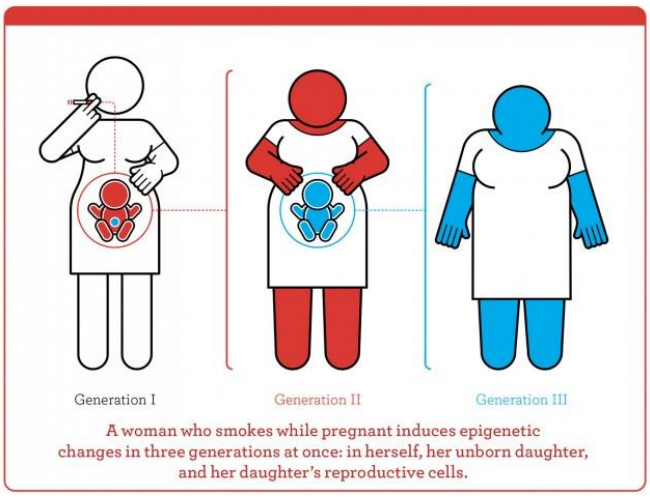
Regulating Gene Expression



Genes are not transcribed and translated into proteins all the time. Imagine having all your genes on at the same time: it would be incredibly wasteful, as you do not need to produce all the proteins coded in your genes at any one time or in any one cell. Therefore, cells have ways of turning genes on and off. These mechanisms have to do with how closely packet the DNA is: if the DNA is too tightly packed together, it will be impossible to read and transcribe. When there are big environmental changes, the packaging of the DNA (and therefore, the genes that are "turned on" and "turned off") can change. We use the term **epigenetics** to describe the study of all the mechanisms used to regulate what genes are expressed. "Epi" is Greek for "before", or "on top on", so epigenetics literally means "on top of your genes".

Recent studies have shown that epigenetic changes can be caused by stress of any type. And while we are not 100% sure, recent studies that suggest that women who undergo stress during pregnancy can actually inherit those changes to their offspring.

What are some examples of epigenetic changes during pregnancy? How could they affect the developing foetus?



Today I learned…

Swap books with someone. Write two questions from this tutorial for them to answer. Give them back their book and when they are done, check their work:

Question 1:

Answer

Question 2:

Answer

Additional Resources:

- **Genetic drift**: https://www.sciencedirect.com/topics/medicine-and-dentistry/genetic-drift
- **Epigenetics:** https://www.youtube.com/watch?v=_aAhcNjmvhc

Homework assignment: Reviewing genetics

Solve the following problem. If you need to remember how to do this type of problem, you can check out this video: https://www.youtube.com/watch?v=i-0rSv6oxSY

Problem: Zoey and Jason are expecting a baby. However, they had some genetic tests and discovered that, even though they are both healthy, they are carriers (their genotype is Aa or heterozygous) of a rare genetic condition called sickle cell anaemia, caused by a recessive allele. What is the probability of their child having sickle cell anaemia? Use a Punnet square in your answer.

Alleles:
A → Healthy
a → Sickle cell anaemia

Zoey: Aa
Jason: Aa

Tutorial 10 – Micro and Macroevolution

What is the purpose of Tutorial 10?

- To appreciate how evolution operates at different scales
- To analyse how intimately connected evolution and genetics are
- To be able to explain how small changes can lead to the appearance of large structures

Let's get started

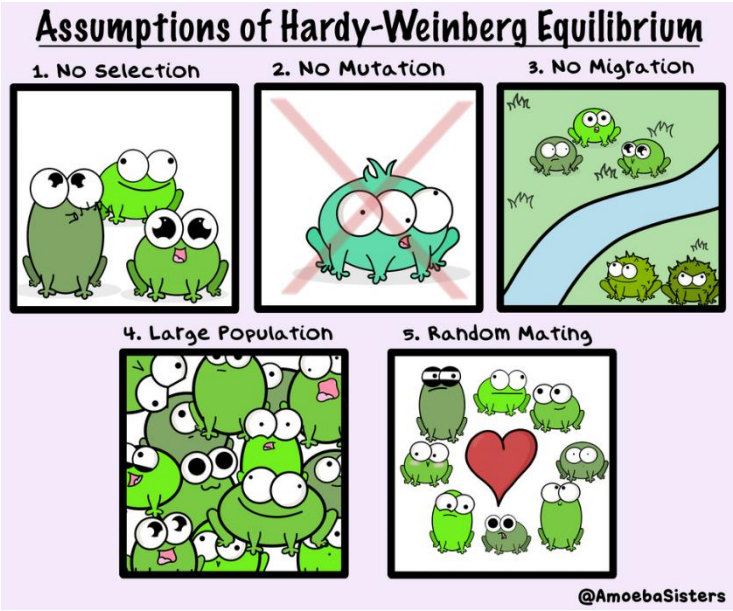
Evolution takes millions of years. How can you know if a characteristic is evolving NOW?

General processes of microevolution

Genes have several variants called **alleles**. For example, earlier we talked about the gene for opsins, the proteins that allow you to see. The gene for opsin has three versions or alleles: the one that allows you to see blue, the one that allows you to see red, and the one that allows you to see green. There are **dominant** alleles, which get expressed always, and there are **recessive** alleles, which are only expressed when you do not have a dominant allele.

If you don't have millions of years to see whether changes occur, you can measure how a gene changes through time.

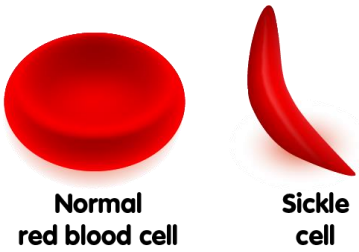
Hardy-Weinberg Principle: If a population is not evolving, the proportion of different alleles should stay the same over time. If the proportion of genes *is* changing, then you can tell that evolution is happening, albeit in a very small scale. Note that you cannot tell what is driving that evolution: it could be natural selection, sexual selection, or genetic drift.



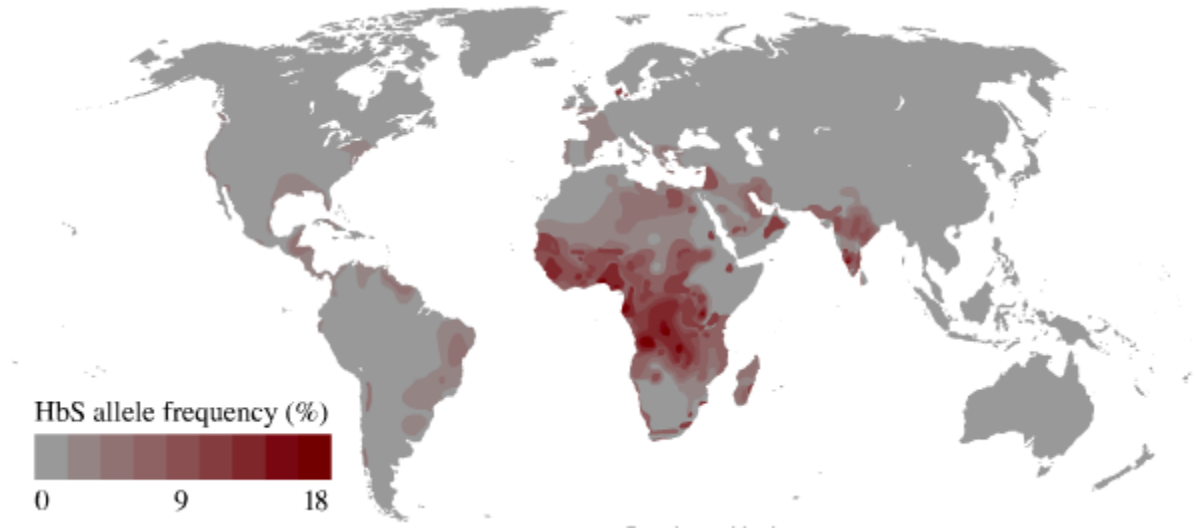
Cool fact: Humans are evolving as we speak, although very slowly. What characteristics do you think are changing?

Sickle Cell Anaemia:

Sickle cell anaemia is a typical example of microevolution happening in humans. It is a genetic condition caused by a recessive allele that causes haemoglobin to fold incorrectly, transporting less oxygen to the body and forming red blood cells that are shaped abnormally (thus the name "sickle cell"). People with this disease are usually weak, have an increased risk of infections, and might have shorter life spans than other people.



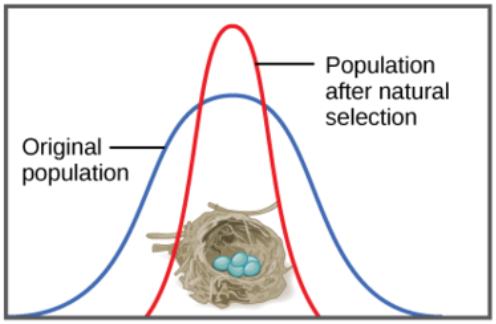
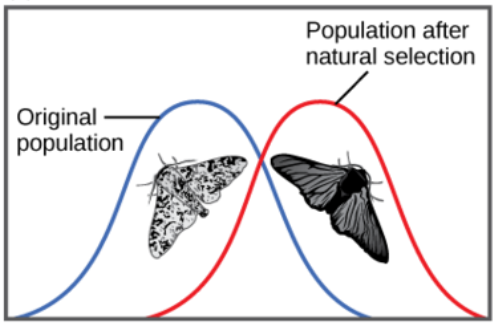
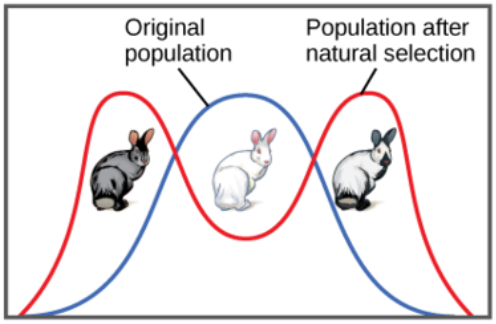
What do you think is happening to the proportion of recessive alleles (for sickle cell anaemia) in the world? Is it in equilibrium? Is it increasing? Is it decreasing? Why?



What is happening with the allele in Africa? Is it in equilibrium, increasing, or decreasing? Why?

Types of selection

If, after analysis the changes happening to a population, you decide that there is natural selection happening, you can identify one of three patterns.

Type of selection	Can you add an example?
(a) **Stabilizing selection**  Robins typically lay four eggs, an example of stabilizing selection. Larger clutches may result in malnourished chicks, while smaller clutches may result in no viable offspring.	
(b) **Directional selection**  Light-colored peppered moths are better camouflaged against a pristine environment; likewise, dark-colored peppered moths are better camouflaged against a sooty environment. Thus, as the Industrial Revolution progressed in nineteenth-century England, the color of the moth population shifted from light to dark, an example of directional selection.	
(c) **Diversifying selection**  In a hyphothetical population, gray and Himalayan (gray and white) rabbits are better able to blend with a rocky environment than white rabbits, resulting in diversifying selection.	

General processes of macroevolution

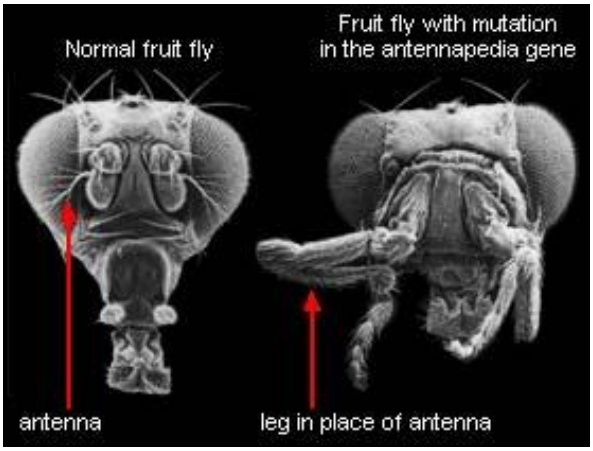
Question:

We've seen how to evaluate whether a species is changing. What sort of evidence could you use to assess whether and how a species or group of species has evolved?

Pattern	What is it? What evidence can you use?	Example
Stasis (no change)		
Character change		
Speciation		
Extinction		

EVO-DEVO: Connecting micro and macro evolution

Some years ago, critics of evolution said that mutations were not enough to explain the appearance of complex structures like wings, which were too convoluted to appear by a mere sum of small mutations. However, this issue was solved when **homeotic genes** were discovered. These are a group of genes that are only active during embryonic development. Their job is to turn on and off other genes, and control where and when different structures are formed and how many times. These genes are expressed in a very particular sequence and only during an embryo's development.



Mutations in developmental genes can lead to the following events:

- Conversion of one body part to another (e.g. legs replacing antennas on flies).
- Duplication of body parts (e.g. the second pair of wings on the second fly)
- Structures growing for longer or shorter than they usually do, independently of the growth rate of other body parts (e.g. the evolution of the bats' wings could have been due to an accelerated growth of the fingers as compared to the rest of their bodies).
- Turning on an off other genes, such as those for colour, or for the production of certain proteins and not others.
- Some parts of the body developing only to juvenile states (e.g. some amphibians keep their gills even after they metamorphose to adult stages)

Today I learned…

One way to know whether something is evolving now	One way of assessing evidence of the "big picture"	The coolest thing I learned today

Additional Resources:

- **EVO DEVO**:
  - Explained in song: https://www.technologynetworks.com/cell-science/coffee-break-videos/evo-devo-despacito-biology-parody-a-capella-science-298864
  - Generalities: https://www.pbs.org/wgbh/nova/article/what-evo-devo/ and https://evolution.berkeley.edu/evolibrary/article/evodevo_01
  - Article: https://www.scientificamerican.com/article/evo-devo-is-the-new-buzzw/
- **Macroevolution:** https://evolution.berkeley.edu/evolibrary/article/evo_48

Homework Assignment: Coevolution Presentation

IN PAIRS: Look up a **cool example** of coevolution and prepare a 5 minute presentation about it. Share that presentation on the google classroom and be ready to present it to the rest of the class. We need one example of each of the following types of coevolution:

Topic	Team
Predator-prey coevolution	
Plant-pollinator coevolution	
Herbivore and plant coevolution	

Tutorial 11 – Coevolution

What is the purpose of Tutorial 11?

- To learn about some cool examples of coevolution and analyse how they must have evolved
- To practice our research skills
- To practice our communication skills

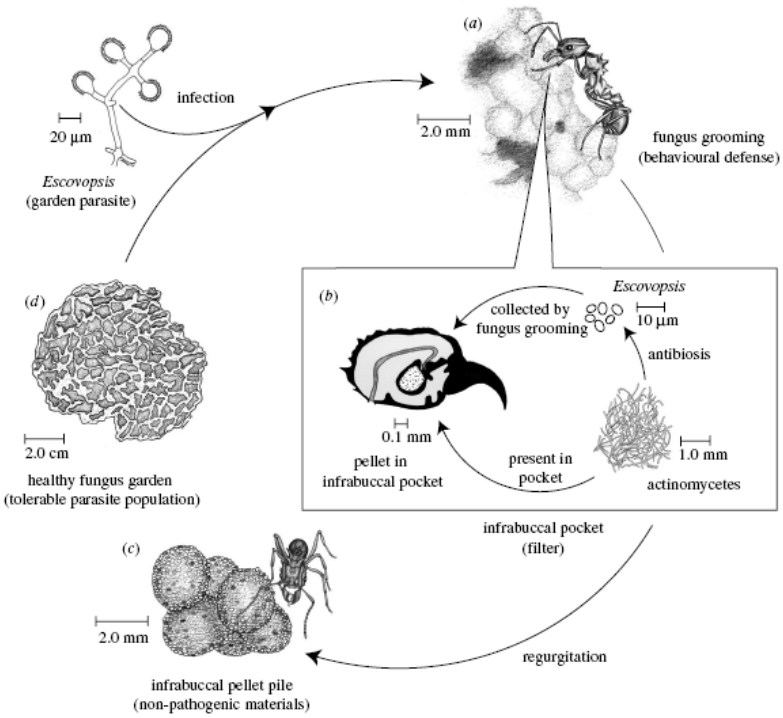
Thinking question: Why is the cheetah so fast? Why is the gazelle so fast? Would either be as fast if they weren't predator/prey?

Coevolution type	Example from the presentations
Predator-prey	
Plant-pollinator	

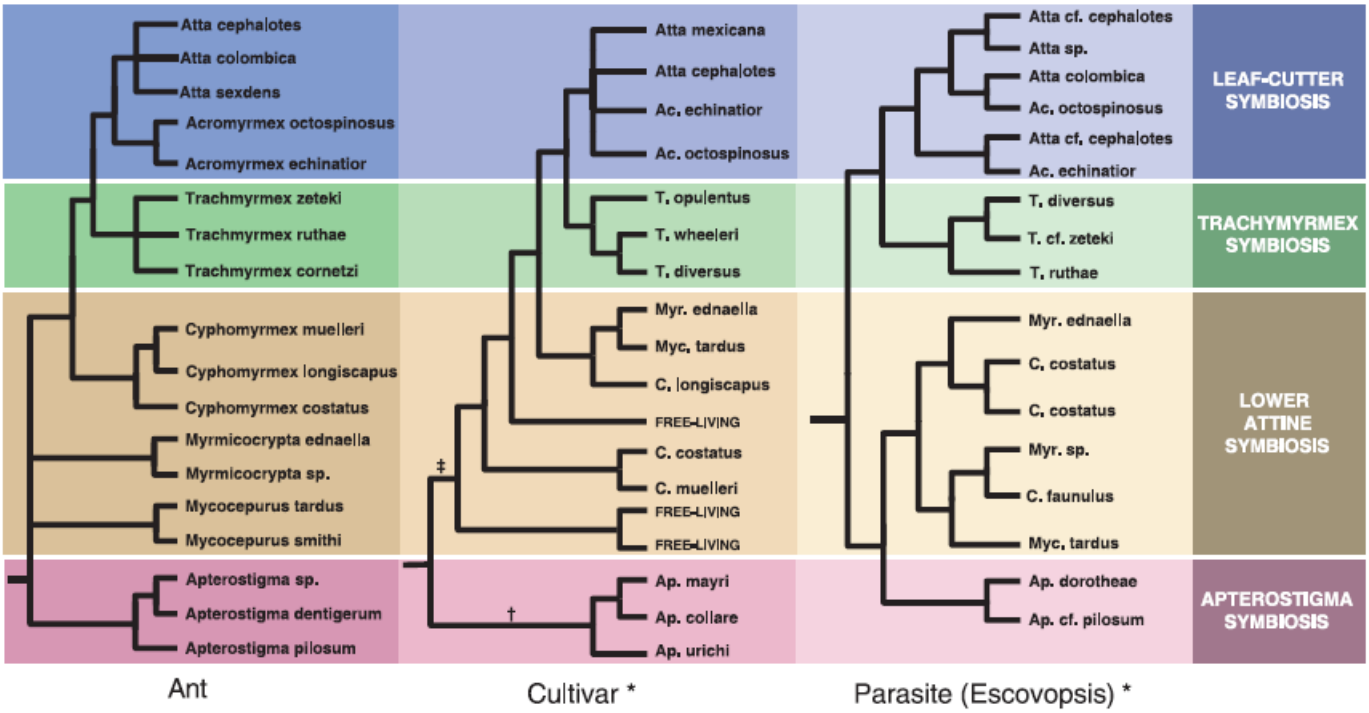
Coevolution type	Example from the presentations
Herbivore-plant	
Mutualistic	

How can you be sure?

To make sure that two (or more) species coevolved, you need to make an evolutionary tree. Dr. G's favourite example is the one for Attine ants. These ants are one of the very few organisms in the world that practice agriculture: they farm their own fungi. This ability started evolving about 50 million years ago and is present in around 200 species. The fungus grows in underground chambers. If their fungus get ill, the whole colony of ants can die. Therefore, there are actually 4 types of organisms participating in this coevolutionary process: the ants, the fungus they farm (Lepiotacea), a fungal disease called *Escovopsis* that makes the farmed fungus ill; and an antibiotic-producing bacteria that the ants carry in their mouths.



The fact that all four species live so close together and depend on each other so intimately provide strong evidence for coevolution. However, if you analyse the evolutionary trees of the species, there is no doubt that they coevolved:



Task

Choose any of the organisms we discussed today. Explain how the organisms coevolved. Write your text as a 6 mark GCSE answer. If you need to, use the guiding questions suggested in Tutorial 3[††].

[††] a) How did the characteristic first appear in the population? b) Is the characteristic beneficial at all? Why? c) Which individuals in that population are more likely to survive and have offspring? d) How/why has the characteristic remained in the species? e) What can happen after a long time if the conditions remain the same?

Today I learned…

Turn what you learned today into a mind map:

Homework Assignment: Draft final assignment

1. Read what you are doing for your final assignment.
2. Select what group of organisms you want to write about and write it here:

3. Write an introduction for it (use Appendix 5 as an example)
4. Write as much as the assignment as you can before the deadline
5. Send it to me on our Google Classroom so I can give you feedback

Final Assignment

Title: How did [select a group of organisms] evolve?

Deadline for draft:

Date and time for my feedback:

Deadline for completed assignment:

Details:
For your final assignment, you must write an essay of around 2,000 words (if you go over, make sure it is worth reading), arguing for your point of view about how a specific group of organisms evolved (for example: primates, hominids, different species of bears, marsupials). You need to find out as much as you can about that group of organisms, examine the evidence, and decide which processes of the ones that we discussed, could have shaped different adaptations and characteristics of that group of organisms.

This is an exercise for writing critically; therefore, the essay should not consist of a list of facts, but rather an argument supported by those facts. Remember: an essay is a persuasive, not an informative text. Therefore, your academic opinion or argument should be stated early and clearly and be developed throughout your whole essay. Don't wait until the conclusion to state your opinion!

Your essay should demonstrate:

- Understanding of concepts and technical issues relating what you learned in the course, especially natural selection
- Knowledge of the evolutionary processes that shape certain characteristics
- Knowledge of the strength of evidence supporting alternative points of view and analyses
- Ability to critically analyse the evidence

You are not expected to "solve" the issue or come to a decisive view, but you are expected to make a critical analysis of matters, giving weight to alternative approaches and demonstrating respect for rigorous argument, including research-based evidence.

You can decide on the structure of the essay. However, you are advised to include the following sections:

- An introduction that summarises the feel/contents of the essay.
- A main body with subtitles for each section you need. Make sure that you are building the argument throughout the whole essay, and not just at the end.
- A strong conclusion that brings together the different arguments from your essay.
- You need a minimum number of 10 reliable references for this assignment. Each needs to be appropriately referenced (see Appendix 6)

PLEASE READ APPENDICES 3-6 SO YOU GET THE IDEA OF HOW TO WRITE AN ESSAY.

Mark Scheme Table

Skills	1st (70–100)	2:1 (60–69)	2:2 (50–59)
Knowledge and Understanding	o All content included is relevant to the general topic and to the specific question/title o Good understanding of all the relevant topics, such as variation, natural selection, fossil evidence, genetic drift, etc. o Scientific terms are defined and used accurately throughout o Clear justification on how the content included is related to the specific issues that are the focus of the assignment	o Most of the content included is relevant to the general topic and to the specific question/title o Good understanding of most the relevant topics o Scientific terms are used accurately but not always clearly defined. o o Adequate justification on how the content included is related to the specific issues that are the focus of the assignment	o Some of the content included is relevant to the general topic and to the specific question/title o Good understanding on some of the relevant topics but occasional confusion on others. o Scientific terms are used mostly accurately with occasional confusion and often not defined. o Some justification on how the content included is related to the specific issues that are the focus of the assignment
Research and Evidence	o Inclusion of rich sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas o Use evidence/calculations to support claims/assertions/ ideas, consistently clearly and convincingly o Further reading: inclusion of at least 10 reliable sources (see appendices 5 and 6) o The risks and benefits of GM crops are effectively analysed and appropriate assumptions/conclusions are reached	o Inclusion of adequate sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas o Use evidence/calculations to support claims/assertions/ideas, mostly clearly and convincingly o Further reading: There are 10 sources but one or two are not very reliable o The risks and benefits of GM crops are analysed and the assumptions/conclusions that are reached are mostly appropriate	o Inclusion of some sources of research findings, data, quotations or other sourced material as evidence for the claims/ ideas o Use evidence/calculations to support claims/assertions/ideas, at times clearly and convincingly o There are fewer than 10 sources of information OR more than two are unreliable. o There is an attempt to analyse the risks and benefits of GM crops is and draw assumptions/conclusions
Developing an Argument	o A point of view or position in relation to how the selected group of organisms evolved is consistently clear, and is developed effectively and consistently throughout the essay o Argument exceptionally well-developed and well-justified o Content is analysed effectively to support the argument	o A point of view or position in relation to how the selected group of organisms evolved is adequately clear, and is well-developed in most of the essay. o Argument clear and well-developed and position justified o Analysis of content to support the argument	o A point of view or position in relation to how the selected group of organisms evolved is somewhat clear and is well-developed in parts of the essay o Argument clear but not well-developed o Some analysis of content to support the argument

Critical Evaluation	o Moved beyond description to an assessment of the value or significance of what is described o Evaluative points are consistently explicit/systematic/reasoned/ justified o Effective critiques on the reliability of sources provided o Consistently demonstrate clear, analytical and logical steps to solving problems	o Mostly description but some assessment of the value or significance of what is described o Evaluative points are mostly explicit/systematic/reasoned/justified o Some evidence of critiques on the reliability of sources provided o Some examples of solving problems but not consistently clear, analytical and logical	o Only description with minimal assessment of the value or significance of what is described o Evaluative points are at times explicit/systematic/reasoned /justified o Limited evidence of critiques on the reliability of sources provided o Demonstrate clear steps to solving problems but not consistently analytical or logical
Structure and Presentation	o Ideas are presented in paragraphs and arranged in a logical structure that is appropriate for the assignment. o The text has appropriate subheadings for each section. o The introduction clearly outlines how the essay/report will deal with the issues o The conclusion summarises all the main points clearly and concisely and answers the title question. o All methods are clearly structured, clear to follow and correct o If they are used, tables and graphs are effectively constructed including appropriate headings, units and scales. o All sources are referenced correctly in an agreed, consistent format (See Appendix 6)	o Ideas are presented in paragraphs and arranged in a structure that is mostly appropriate for the assignment o Most of the sections have appropriate subheadings o The introduction adequately describes how the essay/report will deal with the issues o The conclusion summarises most of the main points clearly OR does not quite answer the title question o Methods are mostly structured, clear to follow and correct o If they are used most tables and graphs are well constructed o Most sources are referenced correctly in an agreed format	o Ideas are presented in paragraphs and arranged in a structure o There are very few subheadings o The introduction mentions how the essay/report will deal with the issues o The conclusion summarises some of the main points clearly and does not answer the title question. o Methods are not always structured, clear to follow and correct. o If they are used, some tables and graphs are well constructed but contains some errors o Some sources are referenced correctly in the agreed format with occasional errors
Language and Style	o No spelling, grammar or punctuation errors o Writing style consistently clear, appropriate for scientific documents and easy to follow o Accurate and consistent use of technical language and vocabulary	o Minimal spelling, grammar or punctuation errors o Writing style mostly clear, appropriate for scientific documents and easy to follow o Some attempts of using technical language and vocab alary, but not always accurate	o Some spelling, grammar or punctuation errors o Writing style moderately clear, appropriate for scientific documents and easy to follow o Use of simple language and vocabulary effectively but struggles to use technical language

Draft Assignment Feedback

Space to glue your feedback

Tutorial 12 – Feedback and reflection

What is the Purpose of Tutorial 12?

- To receive feedback
- To write targets for improvement in school lessons.
- To reflect on the programme including what was enjoyed and what was challenging.

Final assessment feedback

What I did well…	What I could have improved on…
•	•
•	•
•	•

My target for future work is…

Reflecting on Uni Pathways

What did you most enjoy about Uni Pathways?
•
•
•

What did you find challenging about the programme?	How did you overcome these challenges?
•	•
•	•
•	•

Uni Pathways – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at GCSE
2:1	60-69	Performing to a good standard at GCSE
2:2	50-59	Performing to an excellent standard at Y9
3rd	40-49	Performing to a good standard at Y9
Working towards a pass	0-39	Performing below a good standard at Y9
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of PhD Tutor	Paulina Guerrero Gutiérrez		
Title of Assignment	Genetically Modified Crops: Are They The Answer?		
Name of Pupil			
Name of School	Debden Park High School		
ORIGINAL MARK / 100		FINAL MARK / 100	
DEDUCTED MARKS		FINAL GRADE	

If marks have been deducted (e.g. late submission, plagiarism) the PhD tutor should give an explanation in this section:

Key Learning Priority 1 -	
What you did in relation to this Key Learning Priority	How you could improve in the future
Key Learning Priority 2 –	
What you did in relation to this Key Learning Priority	How you could improve in the future
Key Learning Priority 3 –	
What you did in relation to this Key Learning Priority	How you could improve in the future
Resilience Comment	
How you showed learning resilience during the course	How you could build learning resilience in the future

Appendix 1 How to Write an Essay?

First things first: What is an essay?
The following comes from the University of Canberra[‡‡]:

> An essay is a piece of writing that methodically **analyses** and evaluates a topic or issue. Fundamentally, an essay is designed to **get your academic opinion on a particular matter**.

Many students get confused about the word 'opinion' in academic writing, and think that academic writing should just stick to reporting the facts and forget about opinion altogether. However, there are important differences between an academic opinion and a personal opinion, and it's important to grasp these when you're putting together an essay:

	Academic opinion or ARGUMENT	Personal opinion
Determined by	Conducting research, examining evidence, analysing reliable references	Gut feelings, personal experiences or own world-view
Characterised by	OBJECTIVITY: Logic and rational thinking	SUBJECTIVITY: Guided by emotions, personal experiences or individual character
Can you defend it?	YES: by citing credible evidence and laying out a reasoned argument	it's hard to say that one person's 'gut feeling' or worldview is any more valid than another's, so personal opinions are very hard to defend and validate objectively

Writing a great essay is not about simply surveying and re-telling existing ideas. Instead, a good essay takes into account various opinions and points of view and puts forward an argument that reflects the writer's informed opinion. Before you begin planning any essay, then, it's **crucial to have a clear idea of what you think about your topic**; you need to have a position, argument, or clear stance on a topic that you defend with evidence and argument.

Remember:

An essay is	An essay is not
A piece of writing that gives your informed opinion based on reliable references and research. AN ESSAY IS A PERSUASIVE, NOT AN INFORMATIVE PIECE OF WRITING.	• A summary • An informative piece that does not say your opinion or that only says your opinion in the conclusion. • Copying or summarizing a bunch or articles and then commenting on them. • A personal opinion that is not based on research or reliable references.

In the following page you can find some dos and don'ts of an essay.

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‡‡ Writing an essay. (ND). University of Canberra Student Resources. Retrieved January 29, 2015 from http://learnonline.canberra.edu.au/mod/book/view.php?id=178430.

Appendix 2 – Some Tips on Essay Writing

I have no idea where to start! Help!

Here are some tips for writing long essays or texts:

- Start by talking to someone about what you would like to write about in your essay.
- When you're done talking, jot down the key things from that conversation, with bullet points.
- Use those bullet points to structure your thoughts. Decide what your sections are going to contain.
- Play around with the bullet points. Group them in themes that make sense and once they are grouped together, define your subheadings.
- Once you have subheadings and 2-3 bullet points for what you want each section to say, start putting words down on the page. They don't need to be good words. Just put them down.
- Write in the references as you go along or you will get lost.
- Now modify those words to make them sound academic.
- Remember: the key to make a good text is to draft and re-draft as many times as necessary!

What should I include in my introduction?

Usually, an introduction needs to do 4 things. Make sure you:

- **Catch the reader's attention:** usually you do this by starting with a catchy opening sentence or even a quotation as an epigraph.
- **Give the reader enough background information** to know what it is that you are talking about: here you will touch on the very simple key things that the reader should know. It is not the place to write 3 paragraphs about a particular method, but just a few sentences with context and key definitions.
- **State your argument** and the key reasons why you support said argument.
- **State your sections** so the reader knows how it is that you are getting where you are going.

There are some examples of good and bad introductions on Appendix 4. Make sure you check them out!

What are useful tips for the main body of my essay?

- Remember that everything needs to **link to your main argument**. Some useful phrases to make sure this happens are:
    - This adds further evidence to…
    - This confirms that…
    - This suggests that…
    - This relates to my argument because…
    - This exemplifies how…
    - This is a key example of…
    - This shows the ways in which…
- You need to show that you are supporting your side of the debate not because you're ignorant of the other side, but because you've analysed everything and you've reached a well-thought conclusion. In other words, **you need to show that you are not biased**. Therefore, you need to include points that might disagree with your main argument, but guide the reader in deciding why they are not as important. Some helpful phrases for this would be:
    - Some critics have stated…. However…
    - It has been pointed out that… Nevertheless, when one considers…
    - So and so has argued… Although "x" is a fair concern, I would argue that…
    - 'X' outweighs 'Y' because…

What should I include in my conclusion?

- The conclusion will depend on what you have written about. However, a good place to start is by **reminding the reader what your argument is.** Some useful phrases to do so are:
    - In this essay, I have argued that…
    - This essay has suggested/argued/discussed…
    - Genetically modified crops are [complete one sentence that summarises your essay]
- Following that, you should summarise the main points you have made throughout your essay.
- Discuss or mention the importance or implications of what you have written about.
- Finish off with a strong statement that brings your point home.
- Remember: the conclusion is not the place to make any new arguments! It is your last chance of convincing the reader of your academic opinion.

Appendix 3 – Essays Dos and Don'ts

✓	X
Be analytical and give your opinion based on solid evidence from credible sources or references.	Make a plain summary about what you read or give your opinion only in the conclusion
Read a lot and get your own idea or decide your standpoint. Then make an outline about how to argue that. Finally, decide where in that outline you can use your references.	Make a summary of each individual reference, and jump to the next with phrases such as "moving on". This makes a repetitive and poorly structured text.
Plan the structure of your essay ahead and make sure it includes an introduction, a main body and a conclusion.	Write everything as it comes into your mind, being repetitive and not having a logical flow.
Focus your essay in a specific topic of the subject you want to explore. Do not try to cover everything, because you will run out of space.	Try to include absolutely everything you know in the essay. The broader the topic, the less you will have the space to engage in critical analysis. You'll use up all the words just mentioning things with no depth.
Argue your point throughout the WHOLE essay. You can use sentences such as "this relates to my argument because"; "this gives further evidence to"; "this suggests"; etc.	Write your argument only in the introduction and/or the conclusion and forget about it during the rest of the text.
Include critical analysis: consider the idea, weigh up the evidence, and be prepared to explain why you find the evidence convincing.	Take everything you read as fact, without asking yourself why it is worthy of your trust.
Make sure your introduction has the following: • Interesting/catchy opening sentence • Some background for the reader to know what you're talking about (don't assume the reader is familiar with your topic!) • What your argument is going to be (For example: "In this essay, I will be arguing that…") • Give the reader an overview of what you're going to say in each section (In my first section, I will explore…)	Make an introduction that only has definitions, and that does not state your argument or the overview of what you're going to say.
Make sure your conclusion: • Sums up and links everything you have said. • Answers the question that was set in the essay.	Don't answer the question. THIS IS ONE OF THE MOST COMMON MISTAKES, SO BE CAREFUL.
Use your own words. An essay is about what YOU think.	Plagiarize. Be aware that copying and pasting, EVEN IF YOU CITE YOUR REFERENCE is considered plagiarism unless you include it inside quotation marks.
If you are giving a fact or figure, say where you took the information from, even if you wrote it yourself. Use appendix 3 to learn how to cite.	Don't give your references or just include them in the reference list.
Use quotations if you need them to support what you're saying, always putting them between quotation marks and referencing them properly. Direct quotations should never be more that 20% of your text.	Quote more than 20% of your essay or copy whole articles, EVEN if you are giving the reference for them.
Use academic language and formal style: • Avoid colloquial phrases that sound like speech (Well, in this essay I'll tell you how awesome GM crops are) • Avoid contractions (don't, aren't, it's) • Avoid subjective descriptions • Try to avoid the second person ("You might be asking yourself: why should I care about this?")	Write in the same way you talk, with colloquial phrases, contractions, and subjectivity.
Make drafts, proofread and edit	Get into last-minute stress and turn in something full of typos and poorly structured.
Use the same formal, legible font throughout the whole essay, and have a 1.15 or 1.5 line spacing.	Use funky fonts or have different fonts throughout the essay that make it look as if you copied and pasted and didn't bother to check it first.

Appendix 4 – The Good, the Bad, and the Ugly Introductions

THE GOOD

Tomatoes with an extended shelf life, wheat containing pesticides, and a larger yield with heightened levels of nutrients; these are just three of many incentives that come with the use of biotechnology in the farming industry. Various forms of genetically modified crops have been available to the public since 1994 and as massive steps have been made in the world of technology, new doors have been opened, and new possibilities have been created. While these crops could essentially solve the huge problem that is world hunger, they bring with them a range of both scientific and ethical issues: ranging from the patents that have prohibited their use to only the farmers that can afford to pay a yearly fee, to damaging local eco-systems.

While genetically modified crops offer such a large range of advantages, I do not believe that they are the answer because almost all of the rights to these crops are owned by multi-national corporations, which in the long run are likely to use the patents that have been put in place, by their lawyers, to exploit countries with weak economies. Where genetically modified crops could be used to save millions, it seems that instead they have been turned into an income for these corporations. As the world becomes more and more subject to globalisation, this use for them will only increase. This is why I do not believe that genetically modified crops are the answer. In this extended piece of writing I will explore the science behind this technology and the range of both positive and negative issues that have been brought with it. In the first section, I will give an overview of the technology and how these crops are obtained. In the second section, I will continue by discussing the ethical implications this technology is having in the world. This will be followed by an analysis, in the third section, about the advantages and disadvantages that they have, emphasizing the main problems with current patent laws. Finally, I will argue the changes that need to be put in place for this technology to have the effect it was intended for.

THE BAD

The aim of this essay is to examine whether or not genetically modified crops are more beneficial to society than natural crops. Genetically modified crops are the key element of this analysis, and they are crops which have been scientifically altered in order to develop a more advanced species (EFSA, 2014). This is conducted by inserting certain genes into the DNA of the a species and altering genetic materials. The many different factors regarding the benefits and costs of genetically modified crops will be discussed throughout this essay. The social and economic effects will be amongst them, as well as the impact on the environment.

THE UGLY/WORSE

In this essay I will be explaining what GM crops are and what the process* is, I will also be discussing the controversy this topic of GM crops has caused in many parts of the world. I will also be mentioning the advantages and disadvantages of genetically modified crops, as there are several arguments. Genetically modified crops can be defined as crops copied from genetically modified organisms that have specific changes introduced in their DNA to create an unclear but stable change.

Comment [PAUX1]: Starts with a catchy opening sentence.

Comment [PAUX2]: The paragraph is well written, has no typos, the text flows really well, and it shows the pupil has a clear idea on some of the main issues in the subject.

Comment [PAUX3]: Here is the main argument of the essay.

Comment [PAUX4]: This sentence lets me know more or less accurately what the essay will cover.

Comment [PGG5]: This bit gives the structure of the essay, and one can see how the author will argue his main point.

Comment [PAUX6]: Although this is stating the aim, it is not telling you the main argument of the essay. Besides, "traditional" would be a more adequate term than "natural".

Comment [PAUX7]: This is not a great definition, even if it has a reference.

Comment [PAUX8]: There is a typo

Comment [PAUX9]: Just as with the previous example, this section needs to mention what will be covered in each section. It should also be clear why it adds to the main argument.

Comment [PAUX10]: Boring first sentence.

Comment [PAUX11]: Which process? This is not specific/clear. What is that asterisk doing there?

Comment [PAUX12]: Bad use of grammar in this sentence.

Comment [PAUX13]: What is the main argument? Which are these "several arguments" that exist? What will be covered in the essay?

Comment [PAUX14]: This definition is very, very wrong.

Comment [PAUX15]: The text in the paragraph as a whole does not flow.

Appendix 5 – Using Reliable Sources

There is no definitive rule on what counts as "reliable" information, however, here are some rules of thumb that you can use:

- **Reliable sources of information have editors:** that is, a group of people that check what was written by the authors and fact-check it. Print books, magazines, journals, and newspapers all have them. Wikipedia and blogs do not. Since THIS HANDBOOK does not have an editor, you should not take it as a reliable source of information.
- **Reliable sources tend to list their authors**, unless they're big organisations (like the World Health Organisation), in which case, they might list the organisation itself as the author.
- **Reliable sources are written by highly experienced people**: it's not the same to get info from a Nobel Prize winner than from your cousin who is studying for his A-levels.
- **Reliable sources of** information are more interested in the quality of their information than in the amount of items that they sell, whatever those items may be (more newspapers, a product, etc.).

The following table might help you make more informed decisions:

TYPE OF SOURCE	RELIABLE	NOT RELIABLE
What someone said	• Personal communication with an expert on the subject (like an interview with a scientist) • Things mentioned in documentaries, if those documentaries come from a good source like the BBC	• What my parents, teachers, friends, politicians, and non-experts said
Printed sources	• Scientific journals and books • Science communication magazines and books • Textbooks • Newspaper articles from serious newspapers: The Independent, The Guardian, The Times, etc. • Dissertations or theses	• The handbook you have in your hands, as well as any hand-outs from class • Newspaper articles from tabloids like The Daily Mail, The Sun, The Star, The Metro, etc.
Web sources	Sites from: • Universities (.edu or .ac) • Government (.gov) • Professional Associations of scientists or other experts (usually .org, but check to make sure) • Sites ending in .com, .co, and .org ONLY if: o Sites from academic publishers o News agencies (like the BBC) o Science websites ONLY if they list their authors and have references for their content. o If they're the website of a corporation or a charity, they are a valid source for the opinions of the corporation or charity, but cannot be taken as "objective" facts. For example: Monsanto's and Greenpeace's web pages.	• Wikipedia • Answers.com, yahoo answers, wiki answers • Social media • Blogs • Most .com or .co sites, unless they're on the exceptions to the left Don't trust websites that do not list their authors or their references!

Appendix 6 – Referencing Correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important, because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

How do I reference Using Numbers?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

1. **A marker in your assignment**: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].
2. **Bibliography**: This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.
   a) **Websites** – Author's surname and initial (if possible), date of article (if available; otherwise write n.d. for no date), title of the article, title of the web page, website address [date you accessed it, in square brackets].
   E.g. Snow D, n.d., 'How did so many soldiers survive the trenches?', BBC iWonder, http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].
   b) **Books** – Author's surname and initial, date published, *title of book* (in italics), city, publisher, pages where the information came from.
   E.g. Dubner S and S. Levitt, 2006, *Freakonomics*, New York, Harper Collins, p. 7-9.
   c) **Print Articles** – Author's surname and initial, year, 'title of the article' (with quotation marks), *where the article comes from* (newspaper, journal etc.), volume or section, pages, date of the article.
   E.g. (from a newspaper): Kennedy M, 2014, 'The lights to go out across the UK to mark First World War's centenary', *Guardian*, World News, p. 25, 10 July 2014.
   E.g. (from a scientific journal): Blocker D, Wahl-Alexander Z, 2018, 'Using sport education in a university physical activity course', *JOPERD: The Journal of Physical Education, Recreation & Dance*, vol. 89, no. 2, pp. 56-61.

Example: Referencing Using a Numbered Referencing System

The following is an example of how to cite using numbers. It comes from the first paragraph of Dr. Guerrero-Gutiérrez's PhD dissertation. Don't worry, though: in a PhD, each paragraph contains many references. You only need a minimum of 10 references for your whole assignment (but the more, the better!)

Introduction

> 'Indigenous peoples have the right to establish and control their educational systems and institutions providing education in their own languages, in a manner appropriate to their cultural methods of teaching and learning.'
> - Article 14 of the UN Declaration on the Rights of Indigenous Peoples [1]

Indigenous people have the right to a quality education.

If we lived in a perfect world, the full stop at the end of that sentence would have been all that was required of this dissertation. That sentence would stand on its own, unaided by a heavy thesis presenting evidence that all of us, as humans, have the right to be treated fairly, not regardless, but because of who we are. However, the truth is that all around the world, indigenous people have been disenfranchised from traditional formal education. For centuries, the main approach to educating ethnic minorities was trying to erase their identities, forcing them to assimilate into the dominant culture in order to fully participate in society [2-7]. It was believed at the time that providing opportunities for indigenous peoples to 'integrate' into the westernised societies was something beneficial, as it would bring progress and modernity to people that were left stagnant in the past [8, 9]. However, the concept of social justice has evolved, and there is now some recognition that the way of creating true equality is not by erasing people's differences, forbidding their native languages, making them abandon their customs, and forcing them to fit into the dominant paradigm of the world. Instead, it is now acknowledged that human difference is vital, and for it to flourish, it is necessary to create an environment that welcomes and embraces diversity, and that places it at the very core of new multicultural dialogue [10].

References

1. The United Nations General Assembly, 2007, 'United Nations Declaration on the Rights of Indigenous Peoples: resolution adopted by the General Assembly', www.un.org/esa/socdev/unpfii/documents/DRIPS_en.pdf [January 9, 2018]
2. Bastiani Gómez J, Ruiz-Montoya L, Estrada Lugo E, Cruz Salazar T, Aparicio Quintanilla JA, 2012, 'Política educativa indígena. Práctica docente, castellanización, burocracia y centralización de la educación como limitaciones del éxito pedagógico en la región Ch'ol, Chiapas', *Perfiles educativos*, vol. 34, no. 135, pp. 8-25.
3. Sámano Rentería MÁ, 2004, 'El indigenismo institucionalizado en México (1936-2000): Un análisis'. In: Ordóñez Cifuentes JER, editor, *La Construcción del Estado Nacional: Democracia, Justicia, Paz y Estado de Derecho*, Jornadas Lascasianas. XII, México D.F, Instituto de Investigaciones Jurídicas, UNAM, pp. 141-58.
4. Deyhle D, Swisher K, 1997, 'Research in American Indian and Alaska Native Education: From Assimilation to Self-Determination', *Review of Research in Education*, vol. 22, pp. 113-94.
5. Prochner L, 2004, 'Early childhood education programs for indigenous children in Canada, Australia and New Zealand: an historical review', *Australian Journal of Early Childhood*, vol. 29, no. 4, pp. 7-16.
6. McDowell DW, 1980, 'The impact of the national policy on education on indigenous education in Nigeria', *International Review of Education*, vol. 26, no. 1, pp. 49-64.
7. Takeda N, Williams JH, 2008, 'Pluralism, identity, and the state: national education policy towards indigenous minorities in Japan and Canada', *Comparative Education*, vol. 44, no. 1, pp. 75-91.
8. Aikenhead GS, Ogawa M, 2007, 'Indigenous knowledge and science revisited', Cultural Studies of Science Education, vol. 2, no. 3, pp. 539-620.
9. Breidlid A. 2013, Education, indigenous knowledges, and development in the global South: Contesting knowledges for a sustainable future, New York, Routledge.
10. Bertely Busquets M, 1998, 'Educación Indígena del siglo XX en México', In: Latapí Sarre P, editor. *Un siglo de educación en México II*, Biblioteca Mexicana, Ciudad de México, Consejo Nacional para la Cultura y las Artes, Fondo de Cultura Económica, pp. 74-110.

How do I reference using APA style?

In-text citation: This system is similar to the previous one that uses numbers. However, instead of including the number, you include the author and year in a parenthesis. If there is more than one author or there is no author, the next chart will help you write the parenthesis correctly:

What are you citing?	HOW TO REFERENCE
The text is in your words, but the information was taken from this source.	The European Union is very specific about how to regulate GM crops, and it is very hard for a new product to be approved. It takes up to 2 years (Davidson, 2009).
An exact quote (it has to be in quotations)	"The EU has the probably strictest regulations in the world for the presence of GMOs in food and feed" (Davidson, 2009, p. 94).
The author's name is included in my text	Davidson (2009) says that the European union has the strictest set of rules in the world for GMOs.
A direct quote from something without page numbers (webpage or kindle book)	Short articles: "Someday we will be able to go to Mars" (Myers, 2000, para. 5). → para = paragraph number E-books or kindle books with no page numbers: "Someday Martians will come to Earth" (Myers, 2000, ch. 5, para. 4) → ch = chapter
More than one author	2 authors: (Myers & Stevenson, 2006) 3 or more authors: (Myers, *et al.*, 2006) → *et al.* goes in italics. It means "and others"
An association is the author	(Monsanto, 2013) (American Psychological Association, 2014) the first time you cite, then (APA, 2014)
There is no author	Cite in text the first few words of reference (usually the title) and the year. Use double quotation marks around the title or abbreviated title: ("New Child Vaccine," 2001).

Reference List: Again, this is just a list of the references you have used in your assignment. Since the APA style does not have numbers, you write your references in alphabetical order. Just as before, include as much information as you have about the reference. The list below gives what should be included for different sources with examples.

TYPE OF SOURCE	HOW TO REFERENCE
Book	Author, A. A. (Year of publication). *Title of work: Capital letter also for subtitle*. Location: Publisher. (Note: INCLUDE ALL AUTHORS, even if they are many.) Schunk, D.H. & Zimmerman, B.J. (2008) Motivation and Self-Regulated Learning. Theory, Research and Applications. Oxfordshire: Routledge
Chapter in Book	Author, A. & Author, B. (Year of publication). Title of chapter. In A. A. Editor & B. B. Editor (Eds.), *Title of book* (pages of chapter). Location: Publisher. Evagorou, M. & Osborne, J. (2010) The role of language in the learning and teaching of science. In J. Osborne and J. Dillon (Eds.), *Good Practice in Science Education: What Research has to say* (pp. 135-157). Madenhead: Open University Press.
Journal or magazine article	Author, A. A., Author, B. B., & Author, C. C. (Year). Title of article. *Title of Periodical,* volume number (issue number), pages. Airey, J. & Linder, C. (2006) Language and the experience of learning university physics in Sweden. *European Journal of Physics* 27(1), 553-560
Newspaper article (print version)	Author, A. A. (Year, Month day). Title of article. *Title of Newspaper*, pages. Schwartz, J. (1993, September 30). Obesity affects economic, social status. *The Washington Post*, pp. A1, A4.
Newspaper article (electronic version)	Author, A. A. (Year, Month day). Title of article. *Title of Newspaper*. Retrieved date. From URL. Brody, J. E. (2007, December 11). Mental reserves keep brain agile. *The New York Times*. Retrieved from http://www.nytimes.com
Webpage with author	Author. (Date published if available; n.d.--no date-- if not). Title of article. *Title of web site*. Retrieved date. From URL. Landsberger, J. (n.d.). Citing Websites. In *Study Guides and Strategies*. Retrieved May 13, 2005, from http://www.studygs.net/citation.htm.
Webpage without author	Title of article. (Date published if available; n.d.--no date-- if not). *Title of website*. Retrieved date. From URL. New child vaccine gets funding boost. (2001). 9 *News*. Retrieved March 21, 2001, from http://news.ninemsn.com.au/health/story_13178.asp

Example: Referencing Using APA Style

The following is the same example from page 51, but cited in APA style.

Introduction

> 'Indigenous peoples have the right to establish and control their educational systems and institutions providing education in their own languages, in a manner appropriate to their cultural methods of teaching and learning.'
> - Article 14 of the UN Declaration on the Rights of Indigenous Peoples (2007, p. 7)

Indigenous people have the right to a quality education.

If we lived in a perfect world, the full stop at the end of that sentence would have been all that was required of this dissertation. That sentence would stand on its own, unaided by a heavy thesis presenting evidence that all of us, as humans, have the right to be treated fairly, not regardless, but because of who we are. However, the truth is that all around the world, indigenous people have been disenfranchised from traditional formal education. For centuries, the main approach to educating ethnic minorities was trying to erase their identities, forcing them to assimilate into the dominant culture in order to fully participate in society (Bastiani Gómez, Ruiz-Montoya, Estrada Lugo, Cruz Salazar, & Aparicio Quintanilla, 2012; Deyhle & Swisher, 1997; McDowell, 1980; Prochner, 2004; Sámano Rentería, 2004; Takeda & Williams, 2008). It was believed at the time that providing opportunities for indigenous peoples to 'integrate' into the westernised societies was something beneficial, as it would bring progress and modernity to people that were left stagnant in the past (Aikenhead & Ogawa, 2007; Breidlid, 2013). However, the concept of social justice has evolved, and there is now some recognition that the way of creating true equality is not by erasing people's differences, forbidding their native languages, making them abandon their customs, and forcing them to fit into the dominant paradigm of the world. Instead, it is now acknowledged that human difference is vital, and for it to flourish, it is necessary to create an environment that welcomes and embraces diversity, and that places it at the very core of new multicultural dialogue (Bertely Busquets, 1998).

References:

Aikenhead, G. S., & Ogawa, M. (2007). Indigenous knowledge and science revisited. *Cultural Studies of Science Education*, 2(3), 539-620.

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Notes

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Why fish go blind and other evolutionary curiosities
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