Explaining evolution and speciation

L1 Variation and evolution

The Role of Genome and Environment in Phenotype Development

Your **genome** is the complete set of genetic material in your cells. The **genotype** is the combination of alleles an organism has. The **phenotype** is the observable characteristics or traits of an organism, such as height, eye colour, and blood type.

While your genome sets the potential, the **environment** you live in also plays a crucial role in shaping who you are. For example, your genes might make you tall, but if you don't get enough nutrition as you grow, you might not reach your full height potential. This interaction between the genome and environment determines your phenotype.

Causes of Variation

Variation refers to the differences in characteristics among individuals in a population. These differences can arise due to:

1. **Genetic Causes**: These are the differences in the genes inherited from parents. For example, different eye colours in humans are due to variations in genes.
2. **Environmental Causes**: These are the differences caused by the conditions in which an individual develops. For instance, a plant might grow taller if it has access to more sunlight and water.
3. **Combination of Genes and Environment**: Often, characteristics are influenced by both genetic factors and environmental conditions. For instance, a person might have a genetic predisposition to being athletic, but their level of fitness can also be influenced by their diet and exercise habits.

Genetic Variation Within a Population

In any species, there is usually a wide range of genetic variation. This extensive genetic diversity is important because it helps populations adapt to changing environments.

Mutations and Their Effects

Mutations are changes in the DNA sequence. These can happen randomly and continuously. All genetic variations start with mutations. Here's what you need to know about mutations:

- **No Effect on Phenotype**: Most mutations don't change the organism's phenotype. They might occur in non-coding regions of DNA or be silent mutations that don't alter the protein function.
- **Influence on Phenotype**: Some mutations can slightly alter a trait. For example, a mutation might change the shade of hair colour slightly.
- **Determine Phenotype**: Rarely, a mutation can have a significant effect and determine a new phenotype. For instance, a mutation might cause a genetic disorder or confer a new advantage.

Mutations Leading to New Phenotypes

Occasionally, a mutation can result in a completely new phenotype that might be better suited to a particular environment. If this new trait provides a survival advantage, it can spread rapidly through the population. For example, if a mutation in a plant allows it to better survive drought conditions, this trait might become more common in populations living in dry areas.

Independent practice – complete in full sentences in your book

1. What is the genome?
2. Explain the difference between genotype and phenotype.
3. Define variation.
4. Give examples of variation you might see in a population of dogs.
5. What is the cause of the variation below
   A. Brown eyes.
   B. Light brown skin colour
   C. Short hair
6. Define mutation.
7. Are all mutations harmful? Explain the reason for your answer.
8. **Proportions and Percentages**
   A. In a population of 1000 individuals, 40% have a mutation in a particular gene. How many individuals have this mutation?
   B. If 10% of the population with the mutation mentioned above show a new phenotype, how many individuals exhibit this new phenotype?
9. In a study, 300 individuals were found to have a genetic mutation that affects eye colour. If the ratio of individuals with brown eyes to those with blue eyes in this group is 3:2, how many individuals have brown eyes, and how many have blue eyes?
10. In a class of 30 students, the average height is 165 cm. If the heights of the students range from 150 cm to 180 cm, what is the total combined height of all the students?
11. In a genetic study, 60% of a sample population showed variation due to environmental causes, 30% due to genetic causes, and 10% due to a combination of both. If the sample size is 500 individuals, how many individuals fall into each category?
12. A bar graph shows the frequency of different eye colours in a population. If 25% have brown eyes, 35% have blue eyes, 20% have green eyes, and 20% have other colours, calculate the number of individuals for each eye colour in a population of 800.

L2 Natural selection

The theory of evolution by natural selection explains how species evolve from simple life forms that first appeared over three billion years ago. According to this theory, all living species have descended from these early life forms through a gradual process of change.

How Evolution Occurs

Evolution occurs through the natural selection of alleles (different forms of a gene) that result in phenotypes best suited to their environment. Here's a step-by-step explanation:

1. **Mutation**: Mutations creates variation in a population.
2. **Variation in Traits**: These genetic variants cause differences in physical traits (phenotypes). Some variations provide advantages that make certain individuals more likely to survive and reproduce. These beneficial traits are called adaptations.
3. **Environmental Pressure**: Environmental conditions create pressures that affect survival and reproduction.
4. **Survival of the Fittest**: Individuals with advantageous traits are more likely to survive and reproduce.
5. **Reproduction**: These individuals pass their advantageous traits to their offspring.
6. **Change Over Time**: Over many generations, the population changes as advantageous traits become more common. If two populations of one species become increasingly different in *phenotype* that they can no longer interbreed to form fertile offspring, this can result in the formation of two species.

Example of Natural Selection

Consider a population of beetles with varying colours: green and brown. In a forest, brown beetles are less visible to predators than green beetles. Over time, more brown beetles survive and reproduce, passing the brown colour trait to their offspring. Eventually, the population consists mostly of brown beetles.

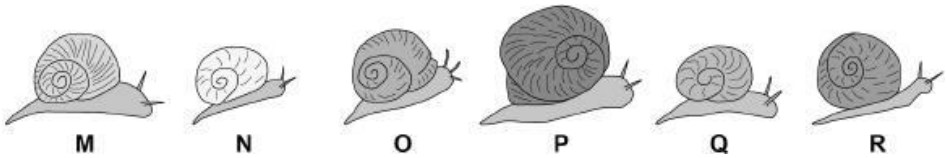
Formation of New Species

When two populations of the same species become so different in their phenotypes that they can no longer interbreed to produce fertile offspring, they have evolved into two new species. This process is known as **speciation**.

Independent practice – complete in full sentences in your book

1. Define evolution.
2. List the main steps involved in natural selection.
3. What are adaptations?
4. Describe survival of the fittest.
5. Explain the term fertile.
6. If two individual breed to produce infertile offspring what does this tell you?
7. Explain how long ears may have evolved in rabbits.
8. A student found six different snails of one species in his garden.

The diagram below shows the snails.



(a) All the snails are different. What scientific term describes differences in characteristics between individuals of a species?

(b) A change in DNA has caused snail **P** to be very different from the other five snails. Suggest why there might be an increasing number of snails similar to snail **P** in each future generation.

9. The drawings show two different species of butterfly.

Amauris *Hypolimnas*

- Both species can be eaten by most birds.
- *Amauris* has an unpleasant taste which birds do **not** like, so birds have learned **not** to prey on it.
- *Hypolimnas* does **not** have an unpleasant taste but most birds do **not** prey on it.

(a) Suggest why most birds do **not** prey on *Hypolimnas*.

(b) Suggest an explanation, in terms of natural selection, for the markings on the wings of *Hypolimnas*.

L3 Selective breeding

Selective breeding, also known as artificial selection, is a powerful technique used by humans to develop specific characteristics in plants and animals. This process has been practiced for thousands of years, ever since humans began cultivating crops from wild plants and domesticating animals for various purposes.

What is Selective Breeding?

Selective breeding involves choosing parent organisms that possess desirable traits and breeding them together. From their offspring, those that exhibit the desired traits are selected and bred. This process is repeated over many generations until the majority, if not all, of the offspring display the selected characteristics.

Why Do We Use Selective Breeding?

Selective breeding is used to enhance traits that are beneficial for humans, either for their usefulness or appearance. Here are some examples:

- Disease Resistance in Food Crops: Farmers often select plants that show resistance to diseases, ensuring healthier crops that can survive environmental challenges.
- Increased Production of Meat or Milk: Animals that produce more meat or milk are bred to maximize food production. For instance, cattle that give more milk or chickens that grow faster and larger are selectively bred to meet food demands.
- Domestic Dogs with Gentle Nature: Certain breeds of dogs are chosen and bred for their gentle and friendly nature, making them suitable as pets and companions.
- Large or Unusual Flowers: Gardeners and horticulturists might breed plants to produce larger or uniquely coloured flowers for ornamental purposes.

The Process of Selective Breeding

1. Selection of Parents: The process begins by choosing parents from a mixed population that exhibit the desired traits.
2. Breeding: These selected parents are bred together.
3. Selection of Offspring: From the resulting offspring, those that best display the desired traits are chosen and breed together.
4. Repetition: This breeding and selection process is repeated over many generations.

If farmers want an organism with two specific characteristics both will need to be selected for, for example a sheep that produces a lot of wool and a lot of meat would require breeding a sheep with a lot of wool breading with a sheep that produces a lot of meat, and choose offspring with both traits.

Benefits of Selective Breeding

Selective breeding has numerous benefits. It can significantly improve the quality and yield of food products, enhance the health and behaviour of pets, and create aesthetically pleasing plants. By focusing on traits, humans can cultivate plants and animals that better meet their needs and preferences.

Risks and Downsides of Selective Breeding

Despite its advantages, selective breeding also has potential downsides, primarily due to 'inbreeding'. Inbreeding occurs when closely related individuals are bred together, which can lead to a higher chance of offspring inheriting harmful genetic defects or diseases. For example, some dog breeds are prone to hip dysplasia or heart problems because of prolonged inbreeding.

Independent practice

1. What is selective breeding also known as?
2. What is the purpose of selective breeding?
3. Describe the process of selective breeding.
4. Does selective breeding take a long time or a short time?
5. Compare selective breeding to natural selection.
6. Explain some of the problems of selective breeding on domestic animals.
7. Define the term inbreeding.
8. Some salmon have genes that result in fewer sea lice attaching to the skin. Describe how fish farmers can selectively breed salmon that sea lice cannot attach to.
9. A cattle farmer has two varieties of cows. Variety A produces a lot of milk. Variety B produces a lot of meat. Explain how the farmer will get cows that produce a lot of milk and a lot of meat. (4)
10. Farmers keep chickens for:

- meat production
- egg production.

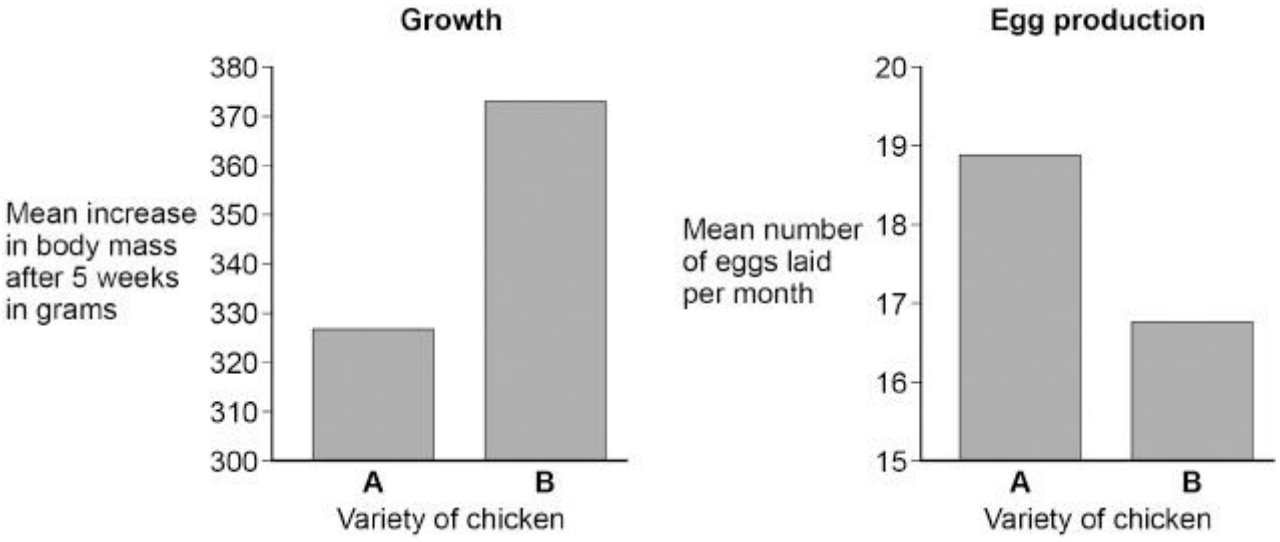
Some varieties of chicken grow more quickly and are more suitable for meat production. Other varieties of chicken produce more eggs.

A farmer keeps two varieties of chicken, **A** and **B**.

The farmer investigated the growth rates and egg-production rates of both varieties.

Figure 1 shows the results.

Figure 1



(a) Suggest **two** control variables the farmer should have used in this investigation.

(b) **Figure 2** shows mean values from 500 chickens of each variety.

Give the reason the farmer used a large number of chickens.

(c) The farmer wants to produce a new variety of chicken that is good for **both** meat production **and** egg production. Describe how selective breeding of chicken varieties **A** and **B** can produce the new variety of chicken.

L4 Genetic engineering

Genetic engineering is also called **genetic modification** or GM. It involves modifying the genome of an organism by introducing a gene from another organism to result in a desired characteristic.

Applications of Genetic Engineering

1. **Agriculture**:
    - **Disease-Resistant Crops**: Plant crops can be genetically engineered to resist diseases, which helps in reducing crop loss and increasing food production.
    - **Enhanced Fruits**: Crops can also be modified to produce bigger and better-quality fruits.
    - **Genetically Modified (GM) Crops**: These are crops that have had their genes altered to resist insect attacks or herbicides. They generally show increased yields, providing more food per acre of farmland.
2. **Medicine**:
    - **Production of Insulin**: Bacterial cells can be genetically engineered to produce human insulin, which is crucial for treating diabetes.
    - **Inherited Disorders**: Modern medical research is investigating genetic modification to treat or even cure certain inherited disorders by correcting defective genes.

Benefits of Genetic Engineering

- **Increased Crop Yields**: GM crops often produce more food, which can help feed the growing global population.
- **Disease Resistance**: Crops that are resistant to diseases and pests reduce the need for chemical pesticides, which can be better for the environment.
- **Medical Advancements**: Producing human insulin through genetic engineering has made diabetes treatment more accessible and efficient.

Risks and Concerns

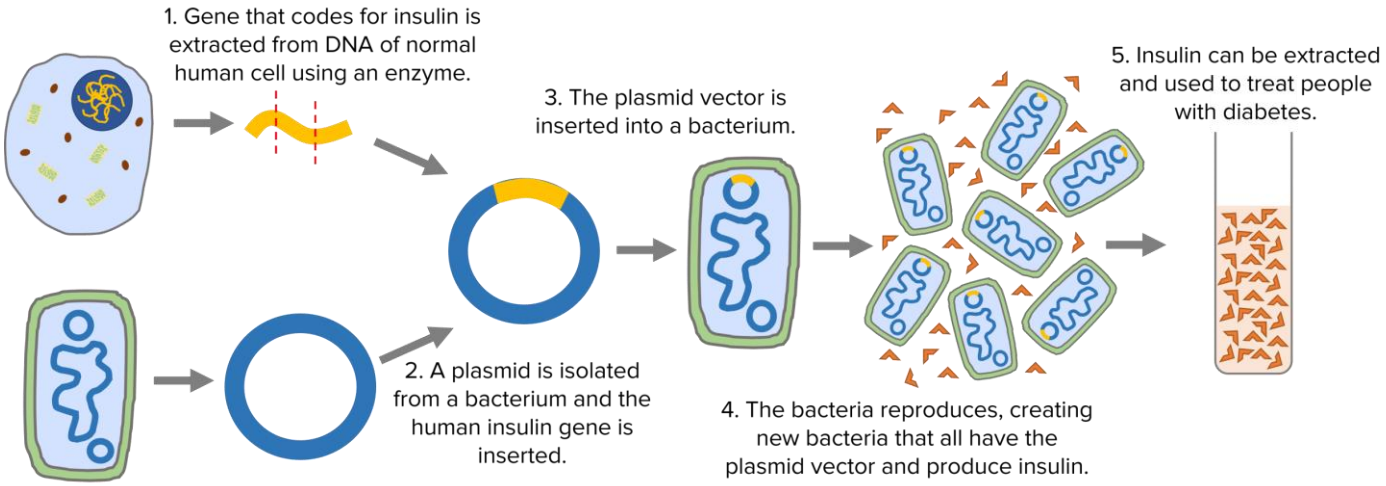
While genetic engineering offers many benefits, it also raises some concerns:

- **Environmental Impact**: There is a worry that GM crops could affect populations of wildflowers and insects, potentially disrupting local ecosystems.
- **Human Health**: Some people are concerned that the long-term effects of consuming GM crops have not been fully explored and may pose health risks.
- **Ethical Objections**: Some individuals and groups object to genetic engineering on ethical grounds, believing that it is unnatural or poses unacceptable risks.

The main steps of genetic engineering:

1. Enzymes are used to isolate the required gene, this gene is inserted into a vector, which is usually a bacterial plasmid or a virus.
2. The vector inserts the gene into required cells.
3. The genes are transferred to animal, plant or microorganism cells, during early development. This allows them to develop with the desired characteristics.

This diagram shows how the genetic engineering of the insulin works:



<u>Independent practice</u>

1. Define genetic engineering.
2. What is genetic engineering also called?
3. Explain the term disease resistant.
4. Why are genetically modified crops useful?
5. In the process of genetic engineering what are used to isolate the genes?
6. What is typically the vector in genetic engineering?
7. At what stage of development is the genes transferred into cells?
8. Describe how scientists can transfer a gene from Bacillus thuringiensis to maize plants.
9. Spiders produce a protein thread which is extremely strong compared to man-made fibres of the same diameter. Scientists can now use bacteria to produce the same protein. How can they do this?
10. Insect pests can be controlled without using chemical insecticides.
    For example, the bacterium Bacillus thuringiensis produces a toxin extremely poisonous to certain species of insects. The gene which produces this toxin has been introduced into tomato plants.
    It gives them built-in resistance to a range of insect pests, but is not poisonous to humans.
    (a) Explain, step-by-step, how the tomato plant is made resistant to some insect pests.
    (b) Give two arguments for and two separate arguments against controlling insect pests in this way.

L5 Resistant bacteria

Evidence for Evolution

Antibiotic Resistance in Bacteria:

- Antibiotic resistance in bacteria is a modern example of evolution in action. It demonstrates how species adapt to their environments and how certain traits can become more common in a population over time.
- Bacteria reproduce rapidly, allowing for quick evolution. Mutations in bacterial genes can produce new strains, some of which may be resistant to antibiotics. These resistant strains survive and reproduce, increasing the population of the resistant bacteria.

How Resistance to Antibiotics Evolves

1. **Rapid Reproduction**:
    - Bacteria reproduce at a fast rate, which means that mutations can quickly spread through a population.
2. **Mutations**:
    - Mutations are changes in the DNA of an organism. In bacteria, these mutations can lead to new traits, such as resistance to antibiotics. These resistant bacteria survive when antibiotics are used, while non-resistant bacteria are killed.
3. **Natural Selection**:
    - The surviving resistant bacteria reproduce, passing on the resistance genes to their offspring. This process is an example of natural selection, where the traits that help an organism survive are passed on to future generations. Over time, the population of resistant bacteria grows, making it harder to treat infections with existing antibiotics.

Reducing the Development of Antibiotic Resistance

To slow down the rate at which antibiotic-resistant strains develop, it is crucial to use antibiotics responsibly:

- **Appropriate Prescription**: Doctors should only prescribe antibiotics when necessary and avoid using them to treat non-serious or viral infections, as antibiotics are ineffective against viruses.
- **Completing the Course**: Patients should complete their full course of antibiotics even if they start feeling better. This ensures that all bacteria are killed and reduces the chance of any surviving bacteria mutating to become resistant.
- **Restricted Use in Agriculture**: The use of antibiotics in agriculture should be limited to prevent the development of resistant strains that can spread to humans through the food chain.

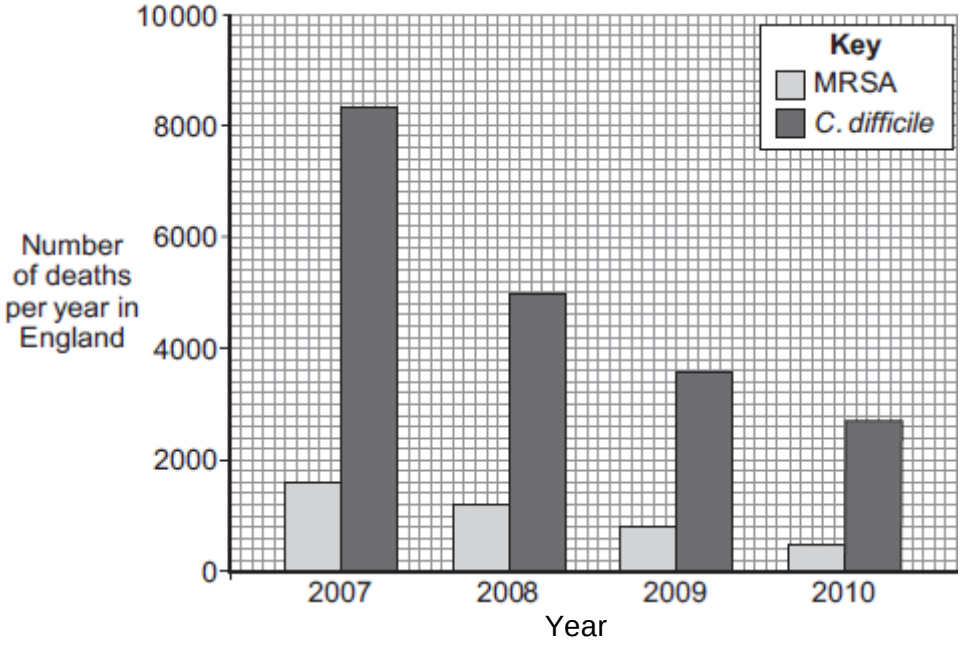
Challenges in Developing New Antibiotics

Developing new antibiotics is a costly and time-consuming process. With the rapid emergence of new resistant strains, it is challenging to keep up with the need for new treatments.

Independent practice

1. What does antibiotic resistance mean?
2. Bacteria reproduce quickly which allows for?
3. What is a mutation in a change in?
4. How does antibiotic resistance occur?
5. Doctors give antibiotics to patients to kill bacteria in their bodies. Explain how the overuse of antibiotics has led to the evolution of antibiotic-resistant bacteria.
6. Infections by antibiotic resistant bacteria cause many deaths.
7. The bar chart below shows information about the number of deaths per year in England from *Methicillin-resistant Staphylococcus aureus* (MRSA) and from *Clostridium difficile* (*C.difficile*) over 4 years.

8.



(a) (i) Describe the trend for deaths caused by *C. difficile*.

(ii) Suggest a reason for the trend you have described in part **(a)(i)**. Explain your answer.

(iii) Calculate the percentage change in deaths caused by MRSA from 2009 to 2010.

(iv) Numbers have not yet been published for 2011.

When the numbers are published, scientists do **not** expect to see such a large percentage change from 2010 to 2011 as the one you have calculated for 2009 to 2010.

Suggest **one** reason why.

(b) Before 2007 there was a rapid increase in the number of deaths caused by MRSA. Describe how the overuse of the antibiotic methicillin led to this increase.

L6 Extinction and fossils

Extinctions Extinction occurs when there are no remaining individuals of a species left alive. This means that the species has completely disappeared from the Earth. There are several factors that can contribute to the extinction of a species, and understanding these can help us protect current endangered species.

Factors Contributing to Extinction

1. **Habitat Destruction:** When natural habitats are destroyed by human activities such as deforestation, urbanization, and pollution, species lose their homes and resources necessary for survival.
2. **Climate Change:** Changes in climate can alter the environments where species live, making them uninhabitable. This includes global warming, changes in precipitation patterns, and extreme weather events.
3. **Overexploitation:** This occurs when species are hunted, fished, or harvested at unsustainable rates. Examples include overfishing, poaching, and the illegal wildlife trade.
4. **Invasive Species:** Non-native species can be introduced to new environments, where they may outcompete, prey on, or bring diseases to native species.
5. **Disease:** Epidemics can wipe out species, especially if they have no immunity to new pathogens.

Fossils: the preserved remains or traces of organisms from millions of years ago, typically found in rocks.

Formation of Fossils

1. **Non-decayed Parts:** Fossils can form when parts of organisms do not decay because one or more conditions necessary for decay are missing, such as oxygen, moisture, or warmth.
2. **Mineral Replacement:** When an organism died and is buried by sediment, the soft parts decay but the hard parts are left behind. The hard parts, eg shells and bones, can then be replaced by minerals. This process can preserve the shape of the organism even if the original material is gone.
3. **Preserved Traces:** Fossils can also be traces left by organisms, such as footprints, burrows, or rootlet traces. These trace fossils provide clues about the behaviour and movement of ancient organisms.

The fossil record – collection of fossils documenting the history of life on Earth
Fossil remains have been found in rocks of all ages. Fossils of the simplest organisms are found in the oldest rocks, and fossils of more complex organisms in the newest rocks. This supports **Darwin's theory of evolution**, which states that simple life forms gradually evolved into more complex ones.

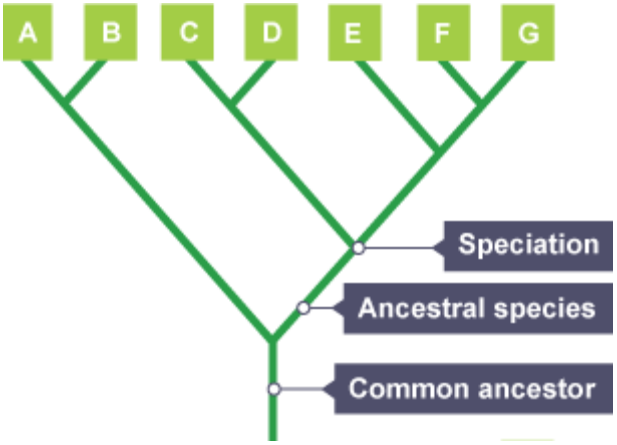
Evidence for early forms of life comes from fossils. By studying fossils, scientists can learn how much (or how little) organisms have changed as life developed on Earth.

There are gaps in the fossil record because many early forms of life were soft-bodied, which means that they have left few traces behind (as the soft parts of organisms can decay). What traces there were may have been destroyed by geological activity. This is why scientists cannot be certain about how life began.

Fossils provide a snapshot of the past and allow us to study how much or how little organisms have changed as life developed on Earth.

Evolutionary tress – Further evidence for evolution

Evolutionary trees are used to represent the relationships between organisms. Branches show places where *speciation* (Formation of a new species) has occurred, and a new species has evolved.



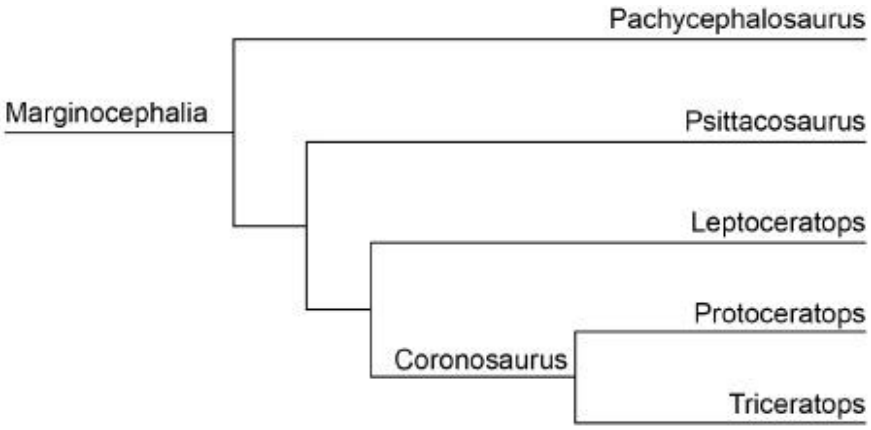
In this evolutionary tree, species A and B share a recent common ancestor. Species A is therefore most similar to species B.

Species F and G also share a recent, yet different, common ancestor, which itself shared a common ancestor with species E. All seven species share a common ancestor, probably from the distant past.

The information is collected from a variety of sources such as fossil records to DNA sequences.

Independent practice – complete in full sentences in your book.

1. The dodo bird is extinct, what does this mean?
2. Suggest a reason why elephants are at risk of extinction.
3. Suggest a reason why polar bears are at risk of extinction.
4. Improve this definition of fossil. “A fossil is from a dead animal”
5. Suggest why some fossils have been found in glaciers.
6. State what happens to the remains of an organism after it gets buried in sediment?
7. Why are there limited fossils of the early life on Earth?
8. What does an evolutionary tree represent?
9. Below shows an evolutionary tree drawn from the fossil record in the 1970s.
   The evolutionary tree is for a group of dinosaurs.



(a) Scientists in the 1970s did radiocarbon dating on all the fossils. Which fossil gave the earliest radiocarbon date?

(b) Suggest which **two** types of dinosaur fossils showed the most similar features.

(c) Give **one** reason why this evolutionary tree might **not** be correct.