OCR (B) Biology GCSE

Topic B6: Life on earth - past, present and future

Notes

(Paragraphs in **bold** are higher tier only)

How was the theory of evolution developed?

How does evolution of a species occur?

1. **A random DNA mutation occurs, resulting in new alleles of a gene**. This mutation can be caused by a variety of factors, including exposure to chemicals and radiation. A large amount of mutations will be detrimental to the organism or have no impact on the phenotype. Some mutations will influence the phenotype and even fewer will determine it completely.
2. **Advantageous mutations will result in increased reproductive success for the organism**. Some mutations will increase an organism's ability to survive, making it more able to compete for resources and mates.
3. **The advantageous allele is inherited by the next generation**. When the organism reproduces, the mutated allele will be passed on to the offspring and will be shown in their phenotype.
4. **Over many generations, the frequency of this allele increases**. This is because organisms in the species without the beneficial allele have a lower chance of survival and decreased reproductive success due to competition from those with the allele. This is called **natural selection**, as those with the best traits are selected to pass them on, whilst those without them will slowly die out.
5. **A new gene mutates, and the process continues.** Each time a beneficial mutation occurs, the species becomes more evolved. Eventually, the organisms will change so much from their ancestors that a new species will form.

Selective breeding and speciation

Plants and animals can be **selectively bred** to **display desirable characteristics**. This was first observed by Charles Darwin, who wondered if this process could also have produced new species in the wild. Selective breeding is used in **farming** to **increase efficiency**; animals and crops which produce a **large yield** are selectively bred to promote this characteristic. Selectively bred organisms are very **different to their wild ancestors**, as many of the traits they needed to survive and compete in the wild are not necessary when domesticated, and thus have been bred out of them.

A **species** is defined as a group of similar organisms which can **breed together to produce fertile offspring**. Sometimes, a population will become so evolved that they are no longer able to mate with their ancestors to produce fertile offspring, meaning that they have formed a new species. **Speciation** is more likely to occur if some of the population is **isolated.** For example, an island may be cut off from the mainland due to rising sea levels, resulting in the population of a species being split between the two areas. Due to differences in environments and competition, the two populations will evolve differently and eventually form two different species.

Evidence for evolution

The theory of evolution by natural selection was first developed in the mid 19th century by a number of scientists, predominantly **Charles Darwin**, who took ideas from Alfred Russel Wallace and Jean-Baptiste Lamarck. Evolution theory was based on a number of observations, including:

- **Fossils** - the presence of fossils supports the theory of evolution since fossils found in the oldest rocks contain the simplest organisms, whereas later fossils are made up of more complex organisms, proving that organisms have evolved to become more complex over time. The differences between the organisms present in fossils and living organisms also show that organisms have changed and evolved over time.

(Biology only:)

- **Selective breeding** - desirable traits and new varieties of plants and animals can be produced from selective breeding. This proves that the characteristics of a species can be changed over time.

- **Differences in isolated populations** - two groups from the same species can become isolated due to geographical barriers. Consequently, the two groups evolve differently as they adapt to their different habitats. Darwin observed this when in the Galapagos islands, where tortoises from different islands showed different characteristics depending on the amount of vegetation available to feed on. Tortoises on islands where there was less vegetation available had shells that rose at the front, allowing the tortoises to lift their heads to eat higher food. Tortoises on islands where there was lots of food available on the ground had dome shaped shells, as they would not have to lift their heads to feed. All of the tortoises came from the same mainland ancestor; thus, Darwin saw this as evidence of evolution.

- **Similar anatomy** - many different organisms share a similar bone structure, indicating that they came from a common ancestor. One example of this is the pentadactyl limb, which is a limb with five digits on the end such as the human hand and fingers. This limb is also present in animals such as horses, bats and whales.

Modern examples of evolution

- **Antibiotic resistance** - Some bacterial strains become resistant to antibiotics as a result of natural selection: firstly, a mutation occurs in a bacterial cell allele which makes it resistant to an antibiotic. Consequently, when that antibiotic is administered, this cell is not killed, whereas cells which have not become resistant are killed. The resistant cell can therefore survive and reproduce, passing on the resistant allele to produce more resistant bacteria. This is proof that bacteria are evolving over time. This can be seen more easily than in animals and plants as bacteria replicate extremely quickly.

- **DNA comparison** - DNA and gene sequences of different species can be compared to find similarities between organisms, even if they appear very different visually.

Differing views on evolution (biology only)

New evidence and observations continue to support the theory of evolution and natural selection, meaning that the theory of evolution is widely accepted as true. Some people do not accept this theory, however. This can be due to **conflicting religious beliefs** or being **unaware of, or not understanding,** the evidence found.

How do sexual and asexual reproduction affect evolution? (biology only)

Asexual reproduction

Asexual reproduction is a process which results in the production of **genetically identical offspring**, known as **clones**. This only requires **one parent**, unlike sexual reproduction. Asexual reproduction occurs predominantly in plants, although some animals such as starfish also reproduce in this way.

Advantages of asexual reproduction:

- **Only one parent is required** - this is helpful for organisms which live in desolate environments where finding a mate is difficult.
- **Can reproduce quickly** - large quantities of offspring can be produced quickly to rapidly populate an area. This helps to dominate a habitat and prevent competition from other species.
- It takes **less energy** to reproduce asexually.

Disadvantages of asexual reproduction:

- **Lack of diversity** - all offspring are genetically identical.
- **Prone to extinction** - as each organism produced is genetically identical, a disease which harms one will be dangerous to all of them, thus is easy for the whole population to be destroyed by one pathogen.
- **Cannot adapt** - organisms are adapted to one specific environment and cannot adapt to changes. If the environment changes, e.g. the temperature rises, they are likely to be killed.
- **Overpopulation** - too many offspring may be produced, which causes overcrowding in a habitat.

Sexual reproduction

Sexual reproduction requires **two parents.** The nuclei of two **gametes**, one from each parent, fuse together to form a **zygote**. Each offspring is **genetically different**. The process of the gametes fusing is called **fertilisation**.

Advantages of sexual reproduction:

- **Wide diversity** - each offspring is genetically unique.
- **Promotes survival** - each organism is unique so disease cannot spread as easily due to resistance.
- **Organisms can adapt** - as each offspring is born with different genes, those with a genetic advantage are more likely to survive and pass their positive traits on to their offspring, whilst those with a genetic disadvantage are more likely to die without producing offspring. This allows the species to evolve through **natural selection**.

Disadvantages of sexual reproduction:

- **Two parents are required** - it may be difficult for some species to find mates, especially when there is an imbalance of males and females in an area or if the species is endangered.
- **Fewer offspring produced** - it takes longer and requires more energy to produce offspring, therefore it is less efficient than asexual reproduction.

How does our understanding of biology help us classify the diversity of organisms on Earth?

The classification of organisms is known as **taxonomy**. Organisms are classified into similar categories to make them easier to study and to compare similar characteristics. The classification system splits organisms into a hierarchy of different levels called **taxa**:

Domain --> Kingdom --> Phylum --> Class --> Order --> Family --> Genus --> Species

Each level becomes more specific, with a large number of organisms in the first taxa and a small amount in the last taxa.

This system was first created in the 18th century, which meant that animals were not originally classified using DNA. Consequently, organisms were placed into categories based on **physical or behavioural similarities**. This method was flawed, however, as **many animals that looked similar were very different genetically**. For example, although hares and rabbits look alike, they cannot interbreed and have a different number of chromosomes. Organisms that live in the same habitat often adapt via **natural selection** to appear alike as it is **beneficial to survival in that environment**, leading to errors when classifying these organisms.

Today, the same classification hierarchy is still used, although many changes have been made due to the **advancement of technology** and the **improvement of immunology and genome sequencing**, which has allowed **genetic similarities** between organisms to be found. This has helped to clarify evolutionary relationships between different organisms and **reduces the errors** from classifying organisms using physical characteristics alone, since organisms in the same group will have a **very similar genome**. Genome sequencing also shows if two different groups of organisms have a **common ancestor**, and **how recently speciation occurred**.

How is biodiversity threatened and how can we protect it?

Biodiversity within ecosystems

Biodiversity refers to the **number of organisms** and the **variety of different species** within an area, as well as the **diversity in the genes** of these organisms. Human activities can a huge negative impact on biodiversity:

- The **use of chemicals**, such as those in **pesticides**, can decrease the number of species in an environment by killing pest species, reducing biodiversity. Rain can also cause these chemicals, as well as those in **fertilisers,** to wash into water sources, killing organisms and causing **eutrophication**. This can have a knock-on effect, as it will **reduce the amount of prey** for other species, which could also die.
- **Urbanisation and industrialisation** has resulted in **habitat destruction**, as well as vastly increasing the amount of **pollution.** Pollution can lead to **acid rain**, which damages tree leaves and leads to the destruction of forest habitats, and **a rise in the temperature** of some areas, meaning species which cannot adapt will die out. In addition, some factories **pollute water sources**, leading to the death of organisms. An example of this is pollution from factories in China killing pink river dolphins, which are now critically endangered.
- Humans can introduce **invasive species** to an area. These species **prey on existing species** and reduce the biodiversity of an area. An example of this are **Cane toads** in Australia. Cane toads were first introduced in 1937 to reduce the beetle population, which were damaging sugarcane crops. These toads, however, multiplied exponentially and **preyed on many native species**, as well as secreting **poisonous toxins**. Since their introduction, many other species have declined, including native lizards, snakes and crocodiles.

To combat these issues, there is an effort to conserve biodiversity, both locally and globally. **Nature reserves and national parks** can help to maintain biodiversity as well as protect endangered species. Farming can also be carried out in a more **sustainable** way, by **reducing the use of chemicals** and by **managing fishing and logging levels** to help preserve habitats. At an international level, treaties such as the **Kyoto protocol** help to **reduce pollution and manage climate change**. This has varying levels of success, however, as some countries, such as the USA and China, do not agree to these treaties to protect their own economies, despite producing the most pollution.

Human food security (biology only)

Food security refers to the **sustainability and accessibility** of a food source. Different factors can put strains on a food source, including:

- **Increasing population** - the increasing birth rate and decreasing death rate, due to the development of better medicines, results in more people who require food. In addition, more homes and urban areas are needed, which reduces the amount of farmland available to grow crops and farm animals for food.
- **Changing diets** - developed countries typically consume a larger amount of meat. As countries such as China become more developed, the demand for meat increases. This is not sustainable.
- **New pests and pathogens** - these can damage crop production and infect animals, leading to food shortages.
- **Environmental change** - global warming leads to an increase in extreme weather conditions. These include droughts, tropical storms and flash flooding, which can all destroy crops and kill livestock.

To maintain food security, it is important to **conserve the biodiversity and sustainability** of food production. Unsustainable farming practices can lead to long-term problems which **decrease soil fertility**. For example, overuse of chemicals can lead **to soil contamination**, and over-farming can lead to **soil erosion and desertification**, meaning that crops cannot grow. Sustainable practices are important to maintain for more than food security, as farming also produces **raw materials** such as wood, and ingredients for **medicines**.

There are also methods to **increase the yield** from farming. Plants and animals can be **genetically modified** to be **more resilient** to harsh conditions, for example some strawberries have been genetically modified to be frost resistant, which prevents plant death in cold conditions. They can also be **selectively bred** to increase the yield per plant/animal by selecting desirable characteristics. To improve this further, they are grown in **optimum conditions**, e.g. in a greenhouse, so that all their energy is put into growing rather than other activities like keeping warm or searching for food.