**Topic 1 – Classification, variation and inheritance**

- **CLASSIFICATION**
  - Classification – sorting organisms into groups based on their characteristics (i.e. according to how closely they are related to one another)
  - At the most basic level, organisms are classified into one of five ‘kingdoms’…
    - Animalia (the ‘animal kingdom’):
      - Multicellular (made of many cells)
      - Heterotrophic feeders - i.e animals get their food by eating and digesting other organisms
      - No cell walls, complex cell structure with nucleus
    - Plantae (the ‘plant kingdom’):
      - Multicellular
      - Autotrophic feeders – i.e plants make their own food through photosynthesis
      - Cell walls made of cellulose (to provide support to plants)
      - Complex cell structure with nucleus
    - Fungi:
      - Multicellular, cell walls not made of cellulose
      - Saprophytic feeders – i.e fungi get their food from dead or decaying matter
      - Complex cell structure with nucleus
    - Prototista: unicellular (made of one cell), complex cell structure with nucleus
    - Prokaryotae: unicellular, simple cell structure with no nucleus
  - **Note** - there is no kingdom for viruses because...
    - They are non-living
    - They’re not made up of cells (no cell organelles)
    - They can only exist inside ‘host’ cells (e.g inside human cells)
  - Living organisms in kingdoms are further divided into 6 sub-categories:
    - Phylum, Class, Order, Family, Genus and Species
    - As you progress from kingdom → phylum → class → order → family → genus → species, the groups are smaller and the organisms share more and more characteristics in common (i.e organisms are more and more alike)
- **Naming species:**
  - An organism’s scientific name has two latin words, made up of the genus and species name – this is called the binomial system:
    - E.g humans are *Homo Sapiens* – ‘Homo’ is the genus, ‘sapiens’ is the species
  - The binomial naming system is in latin…:
    - Because common names given to organisms can sometimes be misleading:
      - E.g robins in America (turdus migratorius) and robins in the UK (erithacus rubecula) are different species
    - So that scientists all over the world can communicate clearly, whatever their language
**VERTEBRATES AND INVERTEBRATES**

- Vertebrates are animals that have a backbone – a supporting rod that runs the length of the body.
- All vertebrates belong to the phylum Chordata.
- Animals that don’t have a backbone are called invertebrates.
- Both vertebrates and invertebrates (phyla – plural of phylum) are divided into smaller groups (classes), according to different characteristics…

**Grouping vertebrates into classes:**

1. Vertebrates can be grouped into classes according to how they absorb oxygen for respiration:
   - Fish – gills to take in oxygen from the water
   - Amphibians – young amphibians have gills but adult amphibians usually have lungs and can absorb oxygen through their moist skin
   - Other groups of vertebrates (mammals, reptiles, birds) have lungs
2. Vertebrates can be grouped into classes according to how they reproduce:
   - Some vertebrates reproduce using external fertilisation – i.e the egg is fertilised outside the body of the female…:
     - Adult female releases eggs into the water, where they’re fertilised by the sperm released by an adult male (fish and amphibians)
     - Other vertebrates reproduce by placing sperm inside the female so that the egg is fertilised inside the body – internal fertilisation…:
       - Organisms which reproduce in this way and then lay eggs are known as oviparous (reptiles and birds)
       - Organisms which reproduce in this way and then give birth to live young are known as viviparous (mammals)
3. Vertebrates can be grouped into classes according to the way in which they regulate their body temperature (‘thermoregulation’):
   - Homeotherms (‘warm blooded’) e.g mammals, birds – have an internal mechanism that keeps their body temperature constant
   - Poikilotherms (‘cold blooded’) e.g reptiles, amphibians, fish – their body temperature changes according to the external temperature

**Some vertebrates are difficult to classify:**

- Some organisms don’t fit perfectly into any class
- Even within a class, some species have different characteristics to the rest:
  - E.g axolotls have gills even as an adult but are still classed as amphibians (even though they respire more like fish)
  - E.g2 sharks use internal fertilisation and give birth to live young but are still classed as fish (even though they reproduce more like mammals)
- It’s important to look at many characteristics when deciding which group to place an organism
• **SPECIES**
  - A species is defined as a group of organisms that can interbreed (i.e reproduce with one another) to produce offspring that are fertile (i.e able to produce offspring of their own)

• **Difficulties with classification:**
  - 1. Variation exists (even within organisms of the same species)
  - 2. Asexual reproduction:
    - Some organisms don’t need to interbreed to produce offspring
    - If we don’t see interbreeding we can’t test whether or not two individuals are the same species
  - 3. Ring species:
    - Sometimes there’s a chain of different populations that can breed with their neighbouring populations but the two populations at the end of the chain can’t interbreed
    - The chain often forms a ring shape → these organisms are called ring species - difficult to divide into separate species
  - 3. Hybridisation in ducks:
    - Mallard ducks can interbreed with closely related species to produce fertile hybrids
    - Fertile hybrids can in turn breed with other closely related ducks to form other fertile hybrids
    - This interbreeding results in the creation of ring species → difficult to classify

• **VARIATION**
  - Differences in characteristics are called variation
  - **Discontinuous variation:**
    - Take a fixed set of values – categories (e.g shoe size, blood group, gender)
    - Discontinuous variation is usually caused by instructions within cells → is called genetic variation
    - Discontinuous data is plotted on a bar graph
  - **Continuous variation:**
    - Values can be any number within a certain range (e.g height, weight)
    - Characteristics that show continuous variation are often controlled by both genes and the environment… e.g:
      - You may inherit a tendency for being tall from parents
      - But diet and lifestyle are also important in determining height
    - Characteristics influenced by the environment (i.e diet/disease/lifestyle) are known as ‘acquired characteristics’ – called ‘environmental variation’
    - Continuous data is plotted on a line graph (usually gives a normal distribution of values – i.e bell-shaped curve)

• **Biodiversity:**
  - Biodiversity is a measure of the total number of different species in an area
  - Areas of greater biodiversity (‘biodiversity hotspots’) need to be protected because they contain a large variety of species within them

• **ADAPTATION**
  - All organisms are adapted to their surroundings – i.e they have variations in their characteristics that allows them to survive in their habitats (places where they live)
  - E.g organisms from polar regions (e.g polar bears) are adapted to the cold:
    - Small ears stop heat loss
Thick fur for insulation...white fur for camouflage in snow
Thick layer of fat for insulation from cold
Large spread out feet → stop it from sinking into the snow

E.g.2 Organisms living near deep-sea hydrothermal vents (e.g. deep-sea Pompeii worms) have the opposite problem:
- Top fluids come out of these vents and cool quickly
- deep-sea Pompeii worms must cope with big temperature changes, complete darkness and huge pressures:
  - Body is adapted to cope with very high pressures
  - No eyes (doesn’t need them because its habitat deep under the sea is in complete darkness – it does have sensitive tentacles, though)
  - Body is covered in a thick layer of bacteria that helps protect it from the heat
  - Spends lots of time inside a paper-like tube to hide from predators

**EVOLUTION**
**Darwin’s theory of evolution by natural selection:**
Organisms produce more offspring than the environment can support:
- Limited resources (e.g. limited food and space) means there’s competition for survival between individuals
- Most offspring die before reaching adulthood

Even within the same species, organisms show variation in their characteristics...:
- Individuals who are well adapted to their environment are more likely to survive, breed, and pass on their genes to their offspring
- Individuals who are less well adapted to their environment are more likely to die → less likely to breed and pass on their genes to their offspring
- Over generations, there is a gradual shift in the variation of characteristics in a species – this is evolution:
  - E.g. if an environment becomes drier, then individuals better suited to drier conditions survive → over time, species becomes better suited to the drier conditions
- This process is called ‘survival of the fittest’ or ‘natural selection’

If the environment changes too rapidly and no individuals have adaptations that help them survive, they all die and the species may become extinct

**New evidence for Darwin’s theory:**
Resistant organisms:
- In the 1940s and 1950s, warfarin was used to poison rats
- However, within 10 years, most rats were resistant to warfarin (i.e. rats were not affected by the poison)
- Explanation using Darwin’s theory:
  - As a result of variation, there were a few rats that by chance had always been resistant to warfarin poison
  - As non-resistant rats were killed by poison, the only ones left to breed were the warfarin resistant rats
  - → their warfarin resistance characteristic was passed on to their offspring → over some years most rats became resistant

DNA research has shown how characteristics are passed on to offspring → this also supports Darwin’s theory of natural selection

**Speciation:**
- The formation of a new species as a result of geographical isolation
Example of speciation:
Darwin noted that although mockingbirds on different Galapagos islands were very closely related, each island had its own species of bird.
Darwin guessed that originally individuals from one species of mockingbird had reached the Galapagos islands.
The environmental conditions on each island were different...
- On each island, those with successful adaptations survived, bred, and passed on their genes to their offspring.
- Each island population of mockingbirds evolved in a different way (to adapt to the specific conditions on each island).

Over time, the mockingbirds on each island became so different that they could no longer interbreed with birds from other islands to produce fertile offspring.
→ new mockingbird species were formed – this process is called speciation.

GENES
Animal cells have a cell membrane, cytoplasm and a nucleus.
Inside the nucleus are long strands of a substance called DNA.
Each strand of DNA forms a structure called a chromosome.
Human body cells contain 23 pairs of chromosomes (46 in total) in their nuclei.
Each chromosome carries a large number of genes.
Each gene does a particular job...e.g:
- Many genes control variations in our characteristics – e.g how we look like.
- Other genes contain information about how likely we are to get certain diseases.
Variation caused by genes is called inherited variation because genes are inherited from our parents.

Alleles:
There are two copies of every chromosome (23 pairs) in a body cell nucleus.
→ there are two copies of every gene.
These gene pairs may contain slightly different instructions for the same characteristic:
- E.g may code for brown eye colour instead of for blue eye colour.
These different forms of the same gene are called alleles.
Each of us can inherit a different set of alleles from our parents (see punnett square below)→ giving each of us slightly different characteristics (this explains why twins can sometimes be very different).

EXPLAINING INHERITANCE
Plants and animal cells produce gametes (sex cells).
Male gametes – sperm in animals, pollen grains in plants.
Female gametes – egg cells in both animals and plants.
Gametes are different from other body cells because they only have one copy of each chromosome (i.e 23 chromosomes in their nucleus...not 46).
→ Gametes only have one allele for each gene.
In sexual reproduction the male and female gametes fuse together → organism formed has 46 chromosomes (23 pairs) in their body cells, with two alleles for each gene (one from the male parent, one from the female parent).

Inheritance terminology:
Dominant alleles - have an effect even if there is just one copy of it.
Recessive alleles - need to be present as a pair to have an effect.
• A dominant characteristic is seen even if just one allele is dominant
• A recessive characteristic is only seen if both alleles are recessive
• This can be shown by drawing a punnett square (see below):
  o A dominant allele is shown by a capital letter (e.g. T)
  o The recessive allele has the lower case version of the same letter (e.g. if dominant allele is ‘T’, then recessive allele is ‘t’)
• The alleles in an organism are its genotype
• What an organism looks like is its phenotype
• If both alleles in an organism are the same, the organism is homozygous (e.g. TT)
• If the alleles are different, the organism is heterozygous (e.g. Tt)
• **Punnett squares:**
  Possible genotypes produced when two organisms breed can also be shown in a Punnett square

![Punnett Square Diagram]

• Parents have the genotype Tt (one dominant allele and one recessive allele)—they are heterozygous dominant
• T is dominant—both parents are tall (the phenotype)
• When gametes fuse, alleles can come together in different combinations:
  o 25% TT (genotype - homozygous dominant, phenotype - tall)
  o 50% Tt (genotype - heterozygous dominant, phenotype - tall)
  o 25% tt (genotype - homozygous recessive, phenotype - short)
    ▪ → there’s a 3 in 4 chance (75%) that offspring will be tall
    ▪ → there’s a 1 in 4 chance (25%) that offspring will be short

• **GENETIC DISORDERS**
• Genetic disorders such as sickle cell anaemia are caused by faulty alleles
• Sickle cell anaemia:
  o It’s a genetic disease that causes red blood cells to clump together
  o The allele that causes sickle cell anaemia is recessive—both copies are needed for people to suffer from the disorder
  o **Symptoms:**
    ▪ Sufferers become easily tired and short of breath
    ▪ Painful joints (because their red blood cells stick together and block blood vessels – can sometimes be fatal)
• Another genetic disorder caused by a recessive (faulty) allele is cystic fibrosis:
  o Lungs get clogged with thick mucus, making breathing difficult and leading to infections
  o Mucus also blocks some of the tubes that carry enzymes to the small intestine to digest food
  o Lack of enzymes able to digest food can result in weight loss

• **Family pedigree charts:**
Family pedigree charts show how a genetic disorder is passed on in a family.

Carriers:
- Doctors can use family pedigree charts to work out the probability of a person inheriting a genetic disorder from their parents – this is pedigree analysis.
- Carriers are individuals who don’t have the disease themselves but can pass it on to their offspring if their partner is also a carrier for the same disease:
  - E.g. a person who is Cc is a carrier for cystic fibrosis because they have a copy of the faulty allele.
  - They don’t have the disease, though, because cystic fibrosis is recessive (both recessive alleles need to be present - cc).
- If both parents are carriers (can find this out by genetic screening), doctors can help couples decide whether to try for a baby or not.