Unit 2

Variety of Living Organisms

1. **Variation**
    a. Investigated using quadrats;
        i. Random sampling – of a homogenous area eg a field or wood – use randomly generated numbers as coordinates. The larger the sample size, the better.
        ii. Systematic sampling is used when you want to build a profile of the changes across a habitat eg a seashore. The quadrats are placed along a tape. This is called a belt transect.
    b. Variation is caused by:
        i. Genetic differences. These arise due to
            1. Meiosis – crossing over of homologous pairs during prophase I; independent assortment of paternal and maternal chromosomes during anaphase I
            2. Mutation
            3. Random fertilisation
        ii. Environmental differences
    c. Variation can be:
        i. Continuous – ie phenotype is due to polygenic (many alleles at many gene loci) factors and is affected by environment eg skin colour
        ii. Discontinuous ie two or more alleles at one gene locus; environment has no influence.
    d. Standard deviation: the smaller the range the closer to the true mean you are
2. **DNA**
    a. Structure:
        i. Is a double helix
        ii. Sugar-phosphate backbone. There are two strands running in opposite directions. This is called antiparallel
        iii. Four bases that make up the 'steps' of the DNA 'ladder': purines – adenine and guanine – are long; pyrimidines – thymine and cytosine – are short.
        iv. A can only bond to T (with two hydrogen bonds)
        v. G can only bond to C (with 3 hydrogen bonds)
        vi. This is called **complementary base-pairing**
    b. DNA replication
        i. Is **semiconservative** ie one strand of each parent strand in conserved in each new daughter molecule
        ii. DNA unwinds and unzips
        iii. Free nucleotides of DNA are activated by being phosphorylated (ie having a phosphate group from ATP added)
        iv. The free nucleotides line up with their complementary bases on the parent strands
        v. DNA polymerase joins the sugar-phosphate backbone

c. RNA
    i. There are 3 types: mRNA, tRNA, rRNA
    ii. Is a single strand
    iii. Is found in both the nucleus and the cytoplasm (DNA only found in nucleus)
d. Protein synthesis
    i. DNA unwinds and unzips along the length of the gene
    ii. Free nucleotides of mRNA line up on the antisense strand
    iii. mRNA goes to the RER to a ribosome
    iv. tRNA lines up against complementary bases
    v. amino acids carried by tRNA joined to form a polypeptide
    vi. DNA code is in triplets; a triplet on mRNA is called a codon; a triplet on tRNA is called an anticodon
e. Meiosis:
    i. Prophase I – nuclear membrane breaks down, nucleolus disappears, chromosomes condense and line up in homologous pairs forming a bivalent. There is crossing over between non-sister chromosomes – the points where they cross are called **chiasmata**. Genetic material breaks off and rejoins to the other chromatid; centrioles move to opposite poles; spindle forms
    ii. Metaphase I – bivalents line up on equator of spindle
    iii. Anaphase I – **independent assortment** – ie random separation of maternal and paternal chromosomes; spindle fibres contract to pull whole chromosomes to opposite poles
    iv. Telophase I – nuclear membranes reform, cytokinesis
    v. Prophase II - nuclear membrane breaks down, nucleolus disappears, chromosomes condense; centrioles move to opposite poles; spindle forms
    vi. Metaphase II – chromosomes line up on equator of spindle
    vii. Anaphase II – centromeres replicate; spindle fibres contract to separate chromatids; chromatids pulled to opposite poles, centromere first
    viii. Telophase II - nuclear membranes reform, cytokinesis
f. Mitosis
    i. Prophase - nuclear membrane breaks down, nucleolus disappears, chromosomes condense; centrioles move to opposite poles; spindle forms
    ii. Metaphase – chromosomes line up on equator of spindle
    iii. Anaphase – centromeres replicate; spindle fibres contract to separate chromatids; chromatids pulled to opposite poles, centromere first
    iv. Telophase - nuclear membranes reform, cytokinesis
g. The cell cycle: interphase has 3 stages:
    i. G1 cell grows, organelles are made, proteins synthesised
    ii. S – DNA replicates
    iii. G2: cell carries out her functions, organelles replicate etc
h. Genetic diversity:
    i. The gene pool is all of the alleles in a population
    ii. Selective breeding is breeding of plants or animals for desirable characteristics. It usually results in reduced genetic diversity
    iii. The founder effect: only a few individuals form a new population so

there are very few alleles in the new population so the population is more vulnerable to:

1. Harmful alleles showing up
2. Disease or other types of disaster where a lack of alleles means reduced adaptability

iv. Genetic bottlenecks:

1. Most population wiped out
2. Fewer alleles
3. Do not represent other populations elsewhere
4. Not adaptable to changing conditions

i. Haemoglobin

i. Structure: four polypeptide strands – two alpha and two beta – each with a prosthetic haem group that contains iron (Fe^{2+}). It is a globular protein with the polar R groups pointing outwards so that it is soluble in blood plasma

ii. Oxygen is transported by haemoglobin: oxygen dissociation curves show high affinity of haemoglobin to oxygen at high partial pressure of oxygen and low affinity at low partial pressure: therefore, oxygen dissociates in respiring tissues where oxygen is being used up in respiration so its partial pressure is low

iii. The movement of the curve to the right is called the Bohr shift and is due to more oxygen dissociated even at higher partial pressure of oxygen. This is an adaptation so that more oxygen is made available at higher carbon dioxide concentration ie where there is more respiration, there is more oxygen dropped off by haemoglobin

iv. Haemoglobin varies between types of organism. Some live at very low pO_2 a and have haemoglobin with much higher affinity for oxygen at high pO_2 but much lower affinity at low pO_2

j. Surface area to volume ratio = surface area / volume. The larger the organism the smaller its SA/vol ratio, diffusion is too slow, and therefore there is a need for specialised respiratory and transport systems

k. Gas exchange in fish:

i. Counter current exchange mechanism: water high in oxygen reaches the gills it meets blood with lower oxygen. Oxygen enters blood by diffusion. As oxygen is removed from the water, the water meets blood even lower in oxygen so the diffusion gradient is maintained and oxygen continues to be absorbed

l. Circulatory system: blood vessels have layers:

i. Smooth endothelium to reduce friction

ii. Elastic fibres – so they recoil after being distended

iii. Smooth muscle – for vasoconstriction

iv. Strong connective tissue – prevents blood vessels bursting under high pressure

v. Arteries have thick walls and narrow lumen to carry blood under high pressure and velocity

vi. Veins have thin walls and large lumen to conduct same volume of blood but at slow velocity. They have valves to prevent backflow

vii. Capillaries have walls one cell thick of endothelium with gaps to allow more rapid exchange of substances. They have a v large surface area to increase exchange of substances

viii. Blood leaves heart in pulses. As distance from heart increases, velocity decreases, pulses are smoothed out by elastic tissue. Diameter of blood vessels decreases as they branch, and surface area increases. At capillaries velocity is slow so there is more time for exchange of substances.

m. Tissue fluid formation:
    i. Blood arrives at relatively high hydrostatic pressure
    ii. The water potential gradient is from the tissues into the blood but hydrostatic pressure is greater – water and dissolved substances are forced out of the capillaries into the tissues
    iii. At the venule end, hydrostatic pressure is lower because water has moved out, many proteins are too large to move out so they lower the water potential: water is reabsorbed by osmosis
    iv. Remaining tissue fluid is absorbed into the lymph capillaries

3. **Starch and glycogen:**
    a. Are energy storage molecules
    b. Are made of alpha glucose only
    c. Starch has two polypeptides:
        i. Amylase: straight, 1,4 glycosidic bonds only
        ii. Amyolpectin: branched; 1,4 and 1,6 glycosidic bonds
        iii. Is found in plants only
    d. Glycogen is very highly branched, has 1,4 and 1,6 glycosidic bonds and is found in animals and in fungi and bacteria
4. **Cellulose**
    a. Beta glucose has its functional hydroxyl groups pointing down at carbons 1 and 4
    b. This means that when it joins by condensation every other molecule needs to be inverted
    c. Cellulose is straight unbranched and and adjacent chains join together by the formation of many hydrogen bonds. This makes for a very strong structure of microfibrils
    d. Cell walls: primary cell walls are made of microfibrils of cellulose laid down in random orientation; secondary have microfibrils laid down in the same orientation
5. **Plant cells:**
    a. Have all the same organelles as animal cells except centrioles
    b. The also have:
        i. Chloroplasts:
            1. Double membrane
            2. Liquid interior called stroma
            3. Membranes containing chlorophyll called thylakoids
            4. Stacks of thylakoids called grana
            5. Starch grains, oil droplets and small loops of DNA
        ii. Cell walls. Adjacent cells walls are cemented together with calcium pectate and hemicelluloses
        iii. Large central vacuole surrounded by a membrane called a tonoplast. It

is filled with cell sap and is used to keep the cell turgid

c. Specialised plant cells:
    i. Xylem: dead cells with strong lignified walls. They have no cytoplasm and the end walls have broken down to give a continuous tube. Pits in the walls are un-lignified areas where water can enter and leave. They conduct water from the roots to the leaves
    ii. Root hair cells are cells with thin walls and an extension that increases surface area for absorption of water and minerals. Nitrates are absorbed by active transport
d. Leaf structure:
    i. Waxy cuticle – transparent to allow light through, prevents evaporation of water
    ii. Upper epidermis: thin and transparent to allow light through
    iii. Palisade mesophyll: long cells with long axis at right angles to angle of incidence of light: maximum light absorption; many chloroplasts pushed close to cell wall by large central vacuole – short diffusion distance; thin walls
    iv. Spongy mesophyll: many chloroplasts; air spaces for rapid diffusion of gases
    v. Lower epidermis: thin, transparent
    vi. Guard cells: contain some chloroplasts; when water potential is low in guard cells, water enters, cells become turgid and stomatal pore opens
e. Gas exchange in leaves:
    i. Stomata open during day to allow carbon dioxide in for photosynthesis
    ii. Oxygen produced as wasted product of photosynthesis is used in respiration; excess oxygen is excreted
    iii. At night, photosynthesis stops but respiration continues. Oxygen used up, carbon dioxide excreted. Stomata shut to prevent excess water being lost.
f. Transpiration
    i. Transpiration is the loss of water by evaporation from the aerial parts of the plant
    ii. Water potential in root hair cells is lower than soil water because of active uptake of nitrates. Water in by osmosis
    iii. Water potential gradient across root: water moves through:
        1. Apoplast pathway through cell walls until it reaches the Casparian strip in the endodermis
        2. Symplast pathway through cytoplasm of adjacent cells via plasmodesmata, down a water potential gradient
    iv. Water enters xylem. Water is polar:
        1. Adhesion means water is attracted to cellulose walls
        2. **Cohesion** means water is attracted to other water molecules
        3. Water is lost from leaves so there is a water potential gradient away from the xylem of leaf: water leaves xylem
        4. Cohesion means that water is pulled up xylem in a transpiration stream. This is called **cohesion-tension theory**

5. Root pressure creates high hydrostatic pressure which assists movement of water up the xylem

g. Factors affecting transpiration
   i. Transpiration can be measured with a potometer.
      1. Potometer is filled with water
      2. Leafy shoot is cut under water to prevent air entering xylem
      3. Shoot inserted into potometer and airtight seal made
      4. Syringe is used to move air bubble along capillary tubing to starting point.
      5. Rate of water loss measured as mms^{-1} or $mmmin^{-1}$
      6. Volume of water lost is distance x πr^2 where r is the radius of the capillary tubing and distance is distance moved by bubble
   ii. Light: stomata open for photosynthesis so more water lost by transpiration
   iii. Temperature: the higher the temp, the more kinetic energy the water has, the faster the rate of evaporation
   iv. Humidity: the higher the humidity the less steep the diffusion gradient, the less water lost by transpiration
   v. Wind speed: the higher the wind speed the less water outside the stomata in transpiration shells, the steeper the concentration gradient the more water lost by transpiration

h. Xerophytes: plants that tolerate drought conditions have special adaptations
   i. Thick waxy cuticle to reduce evaporation
   ii. Stomata on lower side of leaf only: less heating by light so less transpiration
   iii. Stomata in pits, or leaves roll, water evaporates into a contained space and creates a humid microclimate, reducing transpiration gradient
   iv. Hairy leaves – like iii
   v. Reduced area of leaves, increased volume therefore smaller surface area to volume ratio

6. **Classification**
   a. Binomial classification means having two names: genus and species. Genus is written with a capital letter, species with lower case eg *Homo sapiens*
   b. Classification is hierarchical ie in smaller and smaller groups
   c. Kingdom, phylum, class, Order, Genus, Species
   d. Taxa (groups) are by homologous structures, not analogous ones
   e. Phylogeny: grouping organisms by genetic similarities
   f. Species: two organisms that can interbreed to produce fertile offspring are of the same species
   g. Different species often have different numbers of chromosomes. During meiosis, homologous pairs cannot form so meiosis cannot happen – no gametes are formed
   h. Base sequences can be compared to establish relationships between organisms
   i. DNA hybridisation: DNA from two species has radioactive probes attached and is heated to separate the DNA strands. When it cools it can form hybrids with DNA from the other species. The more DNA the two species have in common, the more hydrogen bonds form between them. The more hydrogen bonds there are, the higher the temperature needed to separate the strands again.
   j. Amino acid sequences in proteins can be compared

k. Immunological comparisons: when serum from the first species is injected into another one, antibodies against it are made. These antibodies are extracted. They are then injected into a third species. Some of the antibodies will bind to their corresponding antigen. The more bonding there is, the greater the relationship.

7. **Genetic variation in bacteria**
    a. Mutations arise by addition, deletion or substitution of bases
    b. Bacteria can pass mutations by vertical transmission: from generation to generation by binary fission
    c. Conjugation passes genetic information on plasmids between bacteria, even those of a different species, through sex pili
    d. Antibiotic resistance:
        i. Mutations allow bacteria to have alternative metabolic routes so they are not killed by antibiotics
        ii. If these mutations are on plasmids they can pass both by vertical and horizontal transmission
        iii. Antibiotic resistance becomes more widespread as the bacteria that are resistant become more common so the alleles for resistance increase in frequency
        iv. MRSA is a bacteria, *Staphylococcus aureus* that is resistant to the antibiotic methycillin. It is found endemic in hospitals and in communities such as the homeless. It is usually harmless to healthy people but can kill those who are very old, immunosuppressed or who are vulnerable due to surgical wounds etc.
        v. Resistant TB is increasingly widespread because of the rise in numbers of TB due to HIV

8. **Species diversity**
    a. Diversity index: the higher the figure, the greater the diversity
    b. Biodiversity is diversity of genes, habitat and species
    c. Agriculture has become more mechanised and chemical dependent. This has meant loss of hedgerows – and therefore habitat loss for many species – pollution eg eutrophication
    d. Eutrophication:
        i. Nitrates leach into the water table, rivers and streams
        ii. Nitrates cause algae to grow on the surface of the water
        iii. This blocks out light to species underneath
        iv. Plants underneath die and are decayed by bacteria
        v. Bacteria use up oxygen: fish die
    e. Deforestation
        i. Loss of habitats, and habitat fragmentation
        ii. Loss of nutrients from the soil: no organic matter to keep this
        iii. Loss of soil bacteria
        iv. Heavy rain compacts soil and causes erosion
        v. Soil gets into rivers etc and causes flooding
        vi. Less transpiration so less rainfall
        vii. Less carbon dioxide removed from air: global warming increases

viii. Less oxygen added to air