

**A2 Biology – Revision Notes**  
**Unit 5 – Environment**

**Energy Flows Through Ecosystems**

1. An autotroph is an organism that can produce energy from inorganic sources:
  - a. Phototrophs – produce energy from photosynthesis/sunlight (plants).
  - b. Chemotrophs – produce energy from simple inorganic processes (usually oxidative processes involving nitrogen or sulphur compounds).
2. Other organisms require an organic source of energy and are heterotrophs. The feeding relationships in an ecosystem are as follows:
  - a. Producers – photoautotrophs (plants).
  - b. Consumers – herbivores, carnivores and omnivores.
  - c. Decomposers (also consumers) – detritivores and saprophytes.
3. Humus is the rotting organic matter in the soil, giving it texture and allowing it to hold more water. It is a sticky mass of dead plants, animals and faeces, which are being broken down by saprophytes (extracellular digestion) and detritivores (intracellular digestion) to release the nutrients.
4. Of the energy reaching the Earth from the Sun, about 99% is reflected or absorbed and re-radiated by the atmosphere, so only 1% actually reaches the surface. Only about 0.1% of this energy strikes part of a plant, and of this, between 0.5% and 1% can be used for photosynthesis (mainly red and blue light is used).
5. Photosynthetic reactions are very inefficient (there is a lot of wasted heat). The energy that can be absorbed and converted into chemical energy is the gross primary production (GPP). This is measured in kJ per m<sup>2</sup> per year.
6. The net primary production (NPP) is the energy that is actually made available to other organisms (primary consumers). The rest of the energy is lost in respiration. This satisfies the relationship  $NPP = GPP - R$ . The NPP varies according to:
  - a. Environmental temperature.
  - b. Type of plants growing and their density.
  - c. Day length and light intensity.
  - d. Availability of soil nutrients.
7. A food chain represents a single feeding relationship in an ecosystem, whereby the arrows point in the direction of energy flow (producer to primary consumer to secondary consumer). Each step represents a trophic (feeding) level. A food web is a combination of many interlinked food chains.
8. Between each trophic level, a maximum of about 10% of the energy in the previous level can be passed on. The rest of the energy is lost in respiration and lost as faeces and urine. Food chains therefore tend to be short, as the energy runs out.
9. An ecosystem is both a self-contained unit and an interactive system. There are massive number of interlinks, so removing one organism will overall have very little (but some) effect.
10. Pyramids of numbers show the relative numbers of organisms at each trophic level in a food chain:
  - a. They are usually pyramid shaped, although are often top-heavy, particularly where parasites are involved, or when the producers are large (e.g. trees).
  - b. Pyramids have the disadvantage that they only show one instant in time – in reality it will change over the year.
11. Biomass is the mass of living tissue in an ecosystem:
  - a. Fresh biomass is the biomass including any water (the sample may be alive).
  - b. Dry biomass is the biomass without water (the sample must be dead).
  - c. To measure the dry biomass of a sample:
    - i. Heat gently and prolonged at 80 to 100°C.
    - ii. Measure the mass, then heat again.
    - iii. Keep recording the mass and heating, until the mass doesn't change.
12. Pyramids of biomass are a more realistic picture of feeding relationships than pyramids of numbers. It can be very difficult to calculate biomass in practice however:
  - a. These are usually pyramid shaped.
  - b. In a marine ecosystem, at certain times of year, the biomass of zooplankton is greater than the biomass of phytoplankton. This is because the producers have a short life cycle, and reproduce as fast as they are consumed, thus can support a temporarily larger biomass of zooplankton due to their high reproduction rate.
13. Pyramids of energy always give a true pyramid, as energy will always be lost at each trophic level.
14. A Sankey diagram can be used to show energy flows, whereby the width of each arrow represents the energy flow along it.

Nutrient Cycles

1. The flow of energy through an ecosystem is linear (from the Sun, through organisms and then lost), but the flow of matter in an ecosystem is cyclical. A biogeochemical cycle is one involving the movement of materials between producers, consumers and decomposers, but there is also a geothermal component of the cycle where elements pass through rocks, water and air.
2. The carbon cycle:
  - a. Most of the carbon on the Earth is CO<sub>2</sub> in the atmosphere, locked up in rocks as carbonates, and dissolved in water as hydrogencarbonate ions (HCO<sub>3</sub><sup>-</sup>).
  - b. CO<sub>2</sub> in the atmosphere is used by plants in photosynthesis to synthesise new organic material. Digestion of plant material by consumers transfers this carbon to organic molecules within animals.
  - c. Both plants and animals respire to convert the carbon molecules back into CO<sub>2</sub>.
  - d. Combustion of organic matter converts the carbon molecules back into CO<sub>2</sub>.
  - e. Excretion, death and decay of plants and animals return the organic material to the soil, whereby decomposers (bacteria and fungi) break the organic material down into humus.
  - f. Saprophytes and detritivores, feeding on the humus, respire the carbon molecules to release CO<sub>2</sub> gas.
  - g. Arrested decay of plant and animal tissues can lead to fossilisation – the carbon is converted into peat, then lignite, then coal in the case of plants, and into crude oil in the case of animals. These can be oxidised or combusted to release CO<sub>2</sub>.
  - h. Sedimentation of dead organisms can take place to form carbonate rocks over time. Weathering and volcanic activity can gradually release the CO<sub>2</sub> back into the atmosphere.
3. There are five main processes in the nitrogen cycle:
  - a. Assimilation – the building up of organic molecules in organisms. Plants absorb mainly nitrates, which are converted into nitrites in the roots and transported through the xylem to the leaves for protein synthesis. Nitrites are converted into ammonium ions in the leaves, which react with triose sugars to make amino acids. Animals get nitrogen from plants, and excrete excess amino acids as urea, ammonia or uric acid.
  - b. Ammonification – nitrogen compounds in the soil from dead animals, plants and waste products is converted by saprophytes into ammonia. This dissolves in water to produce ammonium ions.
  - c. Nitrification – ammonium is converted into nitrates by chemoautotrophic bacteria, in a series of oxidative reactions. There are two stages:
    - i. Ammonium is converted into nitrites (NO<sub>2</sub><sup>-</sup>) by *Nitrosomonas*.
    - ii. Nitrites are converted into nitrates (NO<sub>3</sub><sup>-</sup>) by *Nitrobacter*.
  - d. Denitrification – removal of nitrogen from nitrites and nitrates to make N<sub>2</sub> gas. The bacteria responsible for this are anaerobes, thriving in waterlogged soil, stagnant water, and other oxygen-starved areas.
  - e. Nitrogen fixation – trapping N<sub>2</sub> gas into a form that plants can use. Nitrogen fixing bacteria use the enzyme nitrogenase to fix nitrogen gas at low temperatures:
    - i. Bacteria may be free-living in the soil (*Azotobacter*).
    - ii. Bacteria may be symbiots, living in the root nodules of leguminous plants (*Rhizobium*). The plants get nitrates from the bacteria, and the bacteria get carbohydrates from the plant.
4. The nitrogen cycle:
  - a. N<sub>2</sub> gas in the atmosphere can be fixed by nitrogen fixing bacteria, the Haber-Bosch process (production of fertilisers) and lightening (as acid rain).
  - b. Organic waste is converted into ammonium ions by ammonification, and that into nitrites and nitrates by nitrification.
  - c. Nitrates are absorbed by plants and assimilated. Feeding of animals involved the intake of organic nitrogen compounds from plants.
  - d. Death of plants and animals, and excretion of animals, returns nitrogen-containing organic waste to the soil.
  - e. Denitrifying bacteria convert nitrites and nitrates into N<sub>2</sub> gas.

Ecological Techniques

1. A quadrat is used to take a sample area within a habitat. The size of the quadrat depends on the habitat (e.g. a woodland habitat may be limited in ground space):
  - a. It is commonly a square of set dimensions, with a smaller grid within it (usually so that one small square is 1%) to give more accurate measurements.

- b. Increasing the size of the quadrat will increase the number of different species found in each quadrat, until this levels off when every quadrat contains all the species. The quadrat size should be taken just before this levelling off.
  - c. A quadrat can be used to map a distribution of where plants are, whereby the position of the plant is taken as its growing point.
  - d. A quadrat can be used to give percentage cover readings, whereby the area covered by the whole plant is taken. This should always add up to 100% – if any plants are covered by other plants, then take quadrats at different levels.
  - e. Random sampling should be used, with random number tables. Numbers of paces can be used, or the habitat can be divided into areas, and those in the sample randomly selected.
2. A belt transect is a strip of quadrats taken across the habitat. A strip of set width is taken across where there is a change in the habitat, and quadrats are taken along the line of the belt.
  3. A line (point) transect is a line or tape that is put along the ground, and the plants that are touching the line are recorded.
  4. A point quadrat is a device on a stand with holes along it at set intervals. A rod is placed through each hole, and the plants in contact with the rod are recorded.
  5. Animals are more difficult to measure, as they tend to be over a larger area. Aerial photographs can sometimes be used, or you can use the release and capture of animals (e.g. leafhoppers):
    - a. Take all the leafhoppers you can find, and put a blob of nail varnish on each.
    - b. The following day, collect all the leafhoppers you can find, and count the number that are marked ( $n_1$ ), and the total number that are recaptured ( $n_2$ ).
    - c. Where  $n_0$  is the number originally caught and marked, and  $N$  is the estimated number in the population, then  $N = n_0 \times \frac{n_2}{n_1}$ .
  6. The profile of a hillside can be measured using metre rules and spirit levels – going along 1m horizontally at a time, measure how much the ground has gone up by.
  7. Abiotic factors can be measured using various devices. If a factor cannot be controlled in an investigation, it should always be measured:
    - a. Thermometer (thermal probe) – measure the temperature of the air or ground (affects enzyme activity and metabolism).
    - b. Hygrometer – measure humidity (affects transpiration and thermoregulation).
    - c. Light meter – measure light intensity (affects photosynthesis).
    - d. PH meter or indicator test – measure pH (affects enzymes and metabolism).
    - e. O<sub>2</sub>-sensitive electrode – measure O<sub>2</sub> concentration in water (varies with temperature).
    - f. Gas analysis – measure CO<sub>2</sub> concentration (affects photosynthesis).
    - g. Anemometer – measure wind speed (affects evaporation and transpiration).

### Populations And Communities

1. An ecosystem is a natural unit (usually uniform conditions) consisting of producers, consumers, decomposers and abiotic components. A habitat is where an organism lives (within the ecosystem). For small organisms, the microhabitat (its immediate location) may be of vital importance.
2. A population is all the organisms in a single species, within an ecosystem. A community is all the organisms of all the species within the ecosystem, based upon dynamic feeding relationships.
3. An ecological niche is a species' 'place' within an ecosystem, in terms of feeding relationships and abiotic factors (the conditions in which it lives). It can also be defined as the totality of environmental factors (the  $n$ -dimensional hyperspace) acting on a species.
4. Populations are not constant, but they will oscillate. This is usually stable, with oscillations about a mean. If an organism is introduced into a new environment, the growth pattern will (roughly) be:
  - a. Lag phase – a time of slow growth, as the organisms adjust to the new environment.
  - b. Log phase – rapid (exponential) growth, due to a lack of limiting factors.
  - c. Slowing of growth – environmental resistance (limit factors) slow the growth rate.
  - d. Population crash – the population size exceeds the carrying capacity of the environment, and so the numbers decrease as organisms die.
  - e. Stable population – the population size oscillates around the carrying capacity.
5. There are four major factors that affect the size and growth of a population:
  - a. Reproductive capacity.
  - b. Competition.
  - c. Predation.
  - d. Disease outbreaks.

6. A density-dependent factor is one that affects a higher proportion of the population when the density is high (mainly biotic factors). Density-independent factors affect the same proportion of the population regardless of the population size (mainly abiotic factors).
7. The reproductive capacity of a population is a measure of how many young can be produced in a given time period. A high reproductive capacity may not mean a high population, as many potential adult organisms do not actually survive – it allows a population to stay constant. Every two organisms need to produce slightly more than two reproducing offspring for the population to remain constant.
8. There are two types of competition:
  - a. Intraspecific – members of the same species compete for the same resources in the habitat. A population will follow a sigmoid curve over time, due to competition for resources. These resources may be:
    - i. Light, water and minerals (plants).
    - ii. Food (animals).
    - iii. Space – plants close together grow tall and spindly, to try to outgrow one another, but are weak. This factor is important in agricultural ecosystems.
    - iv. Reproductive space – animals require somewhere to nest and raise young, and there will be a carrying capacity with respect to this in the habitat. Many animals (e.g. birds) defend their territory vigorously.
  - b. Interspecific – two different species compete for the same limited resource. Direct Interspecific competition is very rare, as two species cannot occupy the same ecological niche for any length of time.
9. Gause's exclusion principle states that stable populations of two or more species cannot continually occupy the same ecological niche in a habitat. This can lead to a definition of a species in terms of the exclusion principle – species exist as a way of preventing direct competition. There are two possible outcomes of direct interspecific competition:
  - a. Competitive exclusion – one species is eliminated (out-competed) by the other species, leaving only one species occupying the niche.
  - b. Character displacement – extremes of each species do not directly compete, and so have a survival advantage. The extremes survive to form closely related sympatric species.
10. Predation is a more important factor with smaller organisms than with large mammals. The number of predators is controlled by the number of prey, so the graph of their populations will follow the same pattern, but there will be a time lag between the change in prey numbers and the change in predator numbers. A particular predator does not rely on one prey though, so the fluctuation in predator numbers is not as great as that of prey. Depending on the predator, it may take the old and the injured, thus not affecting the prey population greatly, or the young and in some cases the adults (greater nutritional value), thus having a greater effect.
11. Disease is a density-dependent factor, which may be devastating to the population of a species. However, some organisms can become immune (through a random mutation), and thus the population can recover. Myxomatosis is a viral disease that was introduced in England in the 1950s. This resulted in about 60 million rabbit deaths, but more recently the rabbit population has once again increased in numbers.
12. Regulation of population size is controlled by the death rate, not the birth rate. Organisms breed to their utmost ability, so in a good year, any extra offspring are eliminated during the following winter, as death in winter is density-dependent. Density-independent natural disasters can also control population sizes, but these are not regular.
13. Opportunistic (fugitive) species are ones with great powers of dispersal, for example some insects. They are subject to catastrophe, but live virtually free from competition between catastrophes. Equilibrium species are two competing opportunistic species (one has a high population whilst the other has a low population).
14. Dispersal is when organisms spread to different areas within their habitat, whereas colonisation is when the species moves to a new habitat. A Venn diagram can be drawn for colonisation:
  - a. Is the species able to get there (dispersal mechanisms)?
  - b. Can the species tolerate environmental conditions (abiotic factors)?
  - c. Can the species obtain essential requirements (biotic factors)?
  - d. There are optimal conditions only where all the above are true (their intersection on the diagram), and the species can colonise the habitat only if its conditions are optimal.
15. Organisms can adapt to live in colder environments:
  - a. Lichens (symbiotic algae and fungi) have less water in their cells, use sugars as antifreeze, and have air spaces between cells for ice crystals to form (so they can survive freezing).

- b. Organisms are only active during warmer periods, then they go into aestivation (shutting down the metabolism).
  - c. Small surface area to volume ratio and thick fat layers, to retain heat.
  - d. Penguins use a countercurrent system to prevent heat loss through their feet.
16. Ecological succession is a series of plant communities that success through time, in which each successive stage is dependant on the one that preceded it:
- a. Hydrarch succession – ‘water commanding’ succession.
  - b. Xerarch succession – ‘dry commanding’ succession.
  - c. Seral stage – each community in the succession.
  - d. Pioneer community – the first community colonising a new site.
  - e. Climax community – final successive community that is self-duplicating and perpetual. This depends upon the habitat and climate.
  - f. Primary succession – succeeds by pioneering new sites.
  - g. Secondary succession – succession occurring on disturbed land, replacing the original community.
  - h. Polyclimax theory – there could be many climaxes.
17. An example of succession (from a bare site to woodland):
- a. Lichens and mosses (pioneer community) colonise boulders and rocks (they can survive very poor soil conditions). They build up pockets of soil and humus.
  - b. Grasses and wild flowers such as daisies grow in the soil pockets.
  - c. Taller flowering plants such as willowherb and foxgloves grow when there is enough soil for their seeds to be established. Root nodules fix nitrogen.
  - d. Bushes and shrubs (woody plants) such as hawthorn and bramble shelter and out-compete the flowering plants for light.
  - e. Fast growing trees such as birch develop.
  - f. Large, slow growing, deciduous trees such as oak can then grow (climax community).
18. Pine forests (evergreen) don’t get much growth underneath, but a thick layer of needles forms. Oak forests (deciduous), on the other hand, may have an undergrowth, so different levels (strata) of plants can be formed (this is particularly true in rainforests).
19. In a wetland environment, reeds develop around the edges to dry out the ponds, then shrubs come and dry out the land further. Eventually you will still end up with woodland.
20. Sand dunes are very unstable when first formed. They are quickly invaded by plants that can survive the harsh conditions – root systems stabilise the sand dunes. These communities give way to marram grass, which in turn gives way to a variety of other species in a fixed dune.
21. Generally, favourable and stable conditions (e.g. rainforest, coral reef) will lead to a high species diversity, whereas harsh environments (e.g. arctic, desert) give a low species diversity.

### **Human Impact On The Environment**

1. Farming maintains the situation of the environment, by producing an arrested climax, whereby the next seral stage in the succession cannot become established.
2. Hedgerows provide a habitat for many organisms, such as birds, insects, rabbits, rodents (voles and mice) and insectivores (shrews). An ancient hedgerow has a much greater species diversity than newer hedgerows (there are more different species of trees making up the hedgerow). Removing hedgerows can have the effect of:
  - a. Enabling farmers to use large machinery more efficiently, increasing the area for crop growth, preventing shading of crops, and removing the need for maintenance. It is economically advantageous for farmers to remove hedgerows.
  - b. Removing the habitat for organisms that are predators to crop pests. Hence there are no organisms to control the pests (e.g. ladybirds spend the winter in hedgerows), and biologically damaging pesticides will be more likely to be used.
  - c. Removing a barrier. Hedgerows are useful to mark the boundaries of land, and also to act as a barrier for animals.
  - d. Removing a windbreak. Hedgerows help to stop wind erosion of soil and damage to stems due to the wind, reduce the rate of transpiration, and reduce the temperature near to the hedge. The height of the hedgerow determines how far this effect goes into the field. Close to the hedgerow, the effect on the crop yield is detrimental (availability of minerals and water is reduced), but the yield increases, due to the wind-breaking properties of the hedgerow, up to a maximum about 10m away from it.
3. Monoculture is the serial growing of a single crop over large areas and over long periods of time. This has the following advantages and disadvantages:

- a. If only one crop can grow in an area, then this crop can be used in monoculture.
  - b. There is an economic advantage for the farmer – only one set of machinery, fertiliser and pesticides are needed.
  - c. The same nutrients are being used up all the time by the crop, so they become depleted over a period of time. The crop fruits are being removed, so the minerals are not recycled.
  - d. Soil structure is damaged by adding fertiliser, and the lack of humus to bind it together.
  - e. Pests and disease accumulate, due to the same crop being there continually.
4. There are two types of fertiliser:
- a. Inorganic – inorganic source of nitrates (aerial parts of the plant), phosphates (roots and fruits), and potassium ions. These can destroy soil structure over long periods, and large amounts can get washed away into waterways. Inorganic fertilisers are expensive, concentrated (may cause osmotic damage), and can cause acidification of the soil. They can, however, be applied with light machinery, their exact composition can be controlled, and they are easy to store and handle.
  - b. Organic – animal wastes, for example manure. This is a slow release fertiliser (nitrate source) that lasts longer. Organic fertilisers are cheap and improve soil quality, but have variable nutrient content, may contain pathogens or metal residues, and require heavy machinery to compact the soil.
5. In winter, when the cows are brought in under cover, the waste must be dealt with. This can be difficult and expensive. The cows can be kept on:
- a. Straw – absorbs the waste, and decomposes to form manure. This must be well rotted when used, as the bacteria are taking in nitrogen for their own growth, thus fresh manure will starve the plants of nitrogen.
  - b. Concrete – the waste must be removed from the floor. It can be used in methane generators, or dried off to form manure. If the waste goes into the soil, nitrites and nitrates can get into the water supply. Nitrate from slurry has the same problem as inorganic fertilisers (leach into waterways).
6. When large amounts of fertiliser are leached into the waterways, eutrophication can take place:
- a. Algae feed on the fertiliser, leading to rapid growth (algal bloom).
  - b. These algae die and decompose – the bacteria require oxygen, and in the dark all the algae require oxygen for respiration.
  - c. This starves the fish of oxygen (the fertiliser may also be poisonous).
  - d. In anaerobic conditions, the bacteria break down proteins into hydrogen sulphide and marsh gas (methane), which is highly flammable.
  - e. Blue-green algae can also grow due to the extra nutrients in the water. They produce cyanide, which is exceedingly toxic to all life.
7. The biochemical oxygen demand (BOD) is a method of assessing the quality of a water sample by assessing bacterial activity (it is the amount of oxygen that the microbes require):
- a. Take two samples of water from the site.
  - b. Measure  $[O_2]$  in one of the samples immediately.
  - c. Completely seal the second sample (air-free) and incubate it in darkness (no photosynthesis) at  $20^\circ\text{C}$  for five days.
  - d. Measure  $[O_2]$  in the second sample. The difference between the two is the standard BOD.
8. Pesticides are chemicals that kill pests, and hence are vital for the economic success of the farmer (increases the crop yield):
- a. Herbicides – kill weeds that out-compete with the plant crops.
  - b. Fungicides – kill common crop diseases (e.g. potato blight and mildew).
  - c. Insecticides – kill insect pests (e.g. aphids).
  - d. Molluscicides – kill mollusc pests (e.g. slugs and snails).
9. In order for a pesticide to be used, it must be cheap enough to manufacture, stable and easy to store. It should be safe to administer, only affect its intended target, and should be biodegradable by decomposers into harmless products. No pesticide is perfect however, and all have some effect on the environment (e.g. it cannot be both stable and biodegradable).
10. DDT (organochlorine) is a very effective insecticide, but it is not biodegradable:
- a. DDT is fat-soluble, so gets incorporated into the fatty tissues of organisms, as most can only excrete water-soluble chemicals.
  - b. In waterways, DDT is absorbed by algae, which are consumed by small animals, and they in turn are consumed by larger animals.
  - c. As the DDT cannot be excreted, the concentration in the organisms at each trophic level multiplies – this is the process of bioaccumulation.

- d. The level of DDT becomes high enough to kill the higher consumers. Thus the entire food web is disrupted. DDT can also build up in humans in the same way.
11. There are three main types of herbicide:
    - a. Pre-emergence herbicides – kills the weeds as they germinate (before they have chance to establish). This improves the chance of proper crop development. Paraquat is very effective, however it is extremely toxic to humans.
    - b. Post-emergence herbicides – kills the weeds that are already grown, but requires killing the weeds without destroying the crop. Monsanto genetically modified soya beans to be resistant to Roundup, so that it could be used. Auxins can be used, so that the leaves grow very quickly, outgrow themselves and die – work on broad-leafed plants but not grasses.
    - c. Systemic herbicides – chemical that gets into the system of the plant, e.g. glyphosphates – absorbed by the leaves and transported to the roots. Used for destroying very persistent weeds with established root systems.
  12. Fungicides are applied either to the leaves of a plant, or to the seeds before they are grown. Many contain heavy metals (e.g. mercury) that are extremely toxic to humans and other animals. Systemic fungicides are less toxic to humans. Bordeaux mixture is a mixture of lime and copper salts, used to spray potatoes to prevent potato blight (bruised, rotting spots on potatoes).
  13. Insects can do a great deal of damage to crops:
    - a. Reduce the crop yield by eating or spoiling part of the plant that is wanted.
    - b. Destroy the crop yield by killing or eating photosynthetic material.
    - c. Spread disease to photosynthetic parts of the plant by acting as vectors (e.g. aphids).
  14. There are two groups of insecticides:
    - a. Broad spectrum – kills a wide range of insects.
    - b. Narrow spectrum – tends to target one or two specific species.
  15. Insecticides can have an effect in five main ways:
    - a. Stomach poisons – insecticides are sprayed onto the crop, so that insects ingest the poison when they feed on the crop.
    - b. Contact poisons – absorbed through the exoskeleton of the insect (e.g. DDT).
    - c. Systemic poisons – the poison is incorporated into the plant, to harm insects that suck the sap of the plant (e.g. aphids).
    - d. Fumigants – vapour in the air is produced, which is taken in by the insect's tracheal system (very useful in greenhouses with an enclosed space).
    - e. Soil insecticides – used for insects that feed on the roots of plants.
  16. Biological control can be used to control pests, by introducing a predator into the ecosystem:
    - a. There is no build up of resistance as with chemicals.
    - b. Not all the pest will be destroyed though, as a small number must still be there to keep the predator alive.
    - c. The predators must be carefully chosen, as if there is no population control of the predators, then they may cause more damage.
  17. Farmers can use the following strategies to minimise environmental damage:
    - a. Use more organic manure, improving the soil structure and decreasing the amount of leaching of nutrients.
    - b. Apply chemical fertilisers in the main growing season, for maximum absorption.
    - c. Leave crop stubble over the winter so there is less bare soil to blow away.
    - d. Leave areas of wilderness to allow vegetation to regenerate.
    - e. Stop destroying hedgerows.

### Statistical Tests

1. Statistics can be used to disprove or support a hypothesis, but not to prove it. A null hypothesis is a testable hypothesis that states that whatever you are testing has no effect.
2. The  $\chi^2$  test is used to determine if there is a difference between two or more sets of measurements, which consist of frequency data related to a number of specific categories. It tests for differences between the observed values and the expected values (from biological theory or a null hypothesis):
  - a. For a table, the number of degrees of freedom (how many other possibilities each data value can be) is given by  $n = (\text{number of rows} - 1) \times (\text{number of columns} - 1)$ .
  - b. The value is calculated from 
$$\chi^2 = \sum \frac{(O - E)^2}{E}$$
.
  - c. If  $\chi^2$  is high, then there are likely to be two distinct populations, whereas if  $\chi^2$  is small, the results are most likely two extremes of the same population.

- d. The 95% certainty value should always be used.
3. The student t-test is used to determine if there is a significant difference between the means of two samples. The samples should be from a normally distributed population, and there should be at least 15 values in each sample (if the samples are small, or the graph shows a definite skew, use the Mann-Whitney U-test):
- The number of degrees of freedom is given by  $n = (n_1 + n_2 - 2)$ .
  - The value is calculated from  $t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$ .
4. The Mann-Whitney U-test determines the significance of a difference between two medians. The sample size must be greater than 7, but the population doesn't have to be normally distributed:
- Arrange measurements from each sample in rank order (lowest to highest).
  - Combine the measurements from both samples into one set of data in rank order, giving equal measurements an average rank order.
  - Add together the rank values for each of the samples.
  - Calculate the values of  $U_1$  and  $U_2$ :
    - $U_1 = n_1 \times n_2 + \frac{1}{2} n_2 (n_2 + 1) - \sum R_2$
    - $U_2 = n_1 \times n_2 + \frac{1}{2} n_1 (n_1 + 1) - \sum R_1$
5. Spearman's rank correlation test is used to determine if there is an association between two variables, and to determine the strength of that correlation. There must be at least 7 pairs of measurements:
- Rank the data for each of the variables.
  - Calculate the difference between the rank values for each pair of variables.
  - Square the differences and add the together.
  - Calculate the correlation coefficient from  $r_s = 1 - \frac{6 \sum d^2}{n(n^2 - 1)}$ .