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1 Living organisms in the environment

[syllabus sections A1.1; 2.1 to 2.7]

Living organisms are best studied in a natural habitat but many animals can be collected and studied in the laboratory and then (if possible) returned to their habitat. Plants should never be dug up and taken to a laboratory or garden. Take only samples of leaves, flowers and fruit. One must always ensure that natural **ecosystems** (plants and animals in a natural community) are preserved. Selected samples of plants and animals can be collected as **specimens** for work in classification and ecology.

Let's have a look at the different ways in which we can classify living organisms.

1.1 Natural classification

Natural classification is the arrangement of living organisms into groups based on overall similarities. The more features organisms have in common, the closer their evolutionary relationships.

Basically, there are five major **kingdoms**; they are Prokaryotes, Protoctista, Fungi, Plants, and Animals (see Fig. 1.1 below). Each kingdom can be divided into **phyla** (singular phylum). Each phylum has major sub-groups called **classes**. Each class is sub-divided into **orders**, orders into **families**, and families into **genera** and **species**. Table 1.1 shows the classification of humans.

Binomial nomenclature was developed by Carolus Linnaeus. It is a method of naming plants and animals using two Latin names: the first being the genus and the second the species. Thus *Panthera leo* (the lion) is one species while *Panthera tigris* (the tiger) is another species of the same genus.

Table 1.1 *The classification of humans*

Kingdom	**Animal**
Phylum	Chordata
Class	Mammalia
Order	Primates
Family	Hominidae
Genus	*Homo*
Species	*sapiens*

1.2 Feeding modes

Living organisms can be placed into two main groups according to their mode of nutrition:

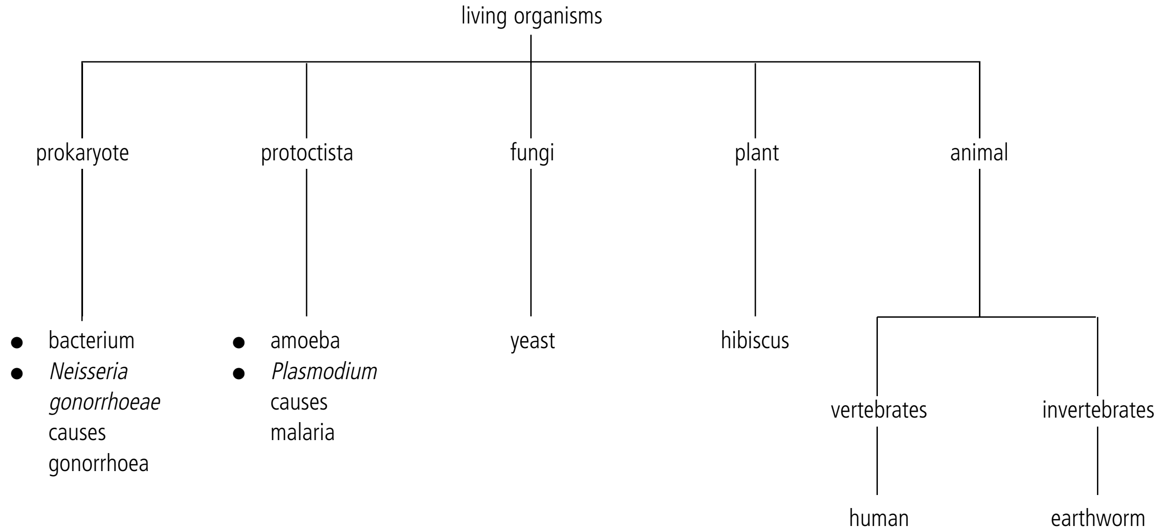
- **Autotrophs** (producers) – synthesise complex organic compounds from simple inorganic compounds (they require an energy source to do this); and
- **Heterotrophs** (consumers) – obtain their required organic compounds by feeding on autotrophs.

(Insectivorous plants use both heterotrophic and autotrophic modes of nutrition.)

Autotrophs can be divided into two further groups:

- **Photoautotrophs** – those autotrophs that use light as a source of energy for the synthesis of organic compounds (e.g. green plants); and
- **Chemoautotrophs** – those autotrophs that obtain energy from chemical reactions to make complex organic molecules (e.g. nitrifying bacteria – see Fig. 2.2 The nitrogen cycle on p. 8).

Fig. 1.1 *The five-kingdom system of classification*



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Excerpt
More information

Heterotrophs can be divided into three further groups:

- **Holozoic organisms** – those heterotrophs that ingest complex organic molecules and digest these to small soluble molecules, which they then use (e.g. mammals);
- **Saprophytic organisms** – those heterotrophs that secrete digestive enzymes onto organic material (parts of, or entire organisms) and absorb the simple molecules produced by the activity of the enzymes into their bodies (e.g. fungi such as *Mucor* (common mould) and *Rhizopus* (bread mould) and bacteria, which are also responsible for the decay of organic material; and
- **Parasitic organisms** – those heterotrophs that live on or in another living organism and obtain food from these organisms (which we call hosts, e.g. bacteria, fleas, love vine, tapeworms).

1.3 Feeding relationships

The following terms describe feeding relationships in the food chain, providing another way of classifying organisms.

Producer – an autotroph (e.g. plants on land and phytoplankton in aquatic environments).

Herbivore – a plant-eating animal (e.g. sheep).

Carnivore – a flesh-eating animal (e.g. shark).

Omnivore – an animal that eats both plants and animals (e.g. humans).

Consumer – herbivores and carnivores are consumers in that they are heterotrophs, which obtain their nutrition from producers.

Predator – any animal that hunts, captures and kills other animals (which we call their prey). Since they kill animals for food, predators are also carnivores (e.g. praying mantises). In a predator-prey relationship, the prey are ideally present in larger numbers than the predator, though the populations of each fluctuate.

Food chain – a feeding relationship between organisms in an environment. The chain begins with producers that trap light energy, converting it to chemical energy. The producers are eaten by primary consumers (herbivores) and these are eaten by secondary consumers. There may be tertiary consumers giving a four-link food chain. The tertiary consumer is sometimes called a top carnivore.

Trophic level – each stage of a food chain is called a trophic level.

Biological equilibrium – this occurs when the numbers of producers and consumers are balanced in a population. The fluctuating numbers of the predator–prey relationship are not in complete equilibrium, but the mean (average) numbers remain constant in what we call **dynamic equilibrium**.

Decomposer – saprophytic microrganisms (bacteria and fungi) that bring about decay. These form an important part of food chains, particularly in the recycling of mineral elements, which they make available for plants. Decomposers are found at all trophic levels since all organisms die and decay.

Food web – a number of food chains that are interconnected.

Energy flow – represents the vital importance of food chains and food webs. All life requires energy and all energy originates from the light of the sun. Green plants incorporate energy. The compounds containing this pass from organism to organism through the food chain, being used and lost in living processes (see Fig. 1.3). In food chains involving humans (e.g. corn ⟶ cattle ⟶ human), only about 0.5% of the energy of sunlight incorporated into the corn plant reaches humans who consume meat. People would obtain more energy per unit mass of the food if they ate the maize.

Current definitions of relationships between organisms are based on the physical **closeness** of organisms relative to each other:

- **Symbiosis** – is defined as the **close** physical interaction between organisms of different species in which both derive benefit e.g. nitrogen-fixing bacteria living in the root nodules of a legume: the plant gets nitrogen from the bacteria and the bacteria get carbohydrates from the plant. Symbiosis is a form of mutualism.

Table 1.2 *Trophic levels*

Trophic level	Food chains		Nutritional classification	Mode of feeding
	Aquatic	*Terrestrial*		
4	Large fish	Bird	Tertiary consumer (carnivore)	Heterotrophic
3	Small fish	Lizard	Secondary consumer (carnivore)	Heterotrophic
2	Shrimp	Cricket	Primary consumer (herbivore)	Heterotrophic
1	Phytoplankton	Pea plant	Producer	Autotrophic

- **Commensalism** – one species gains and the other is unaffected e.g. cattle egrets following cattle can pick up insects disturbed by the cattle moving through a pasture.
- **Mutualism** – may not necessarily involve **close** physical contact. Insects, e.g. bees, feeding on the nectar get a supply of food from flowers, while the flowers benefit from the fact that bees transfer their pollen from one flower to another. Both species therefore benefit.
- **Parasitism** – organisms that live in or on another organism (the host), which often suffers some adverse effect. Many bacteria and all viruses are parasites causing symptoms of disease in the host. Single-celled organisms (protozoa) are sometimes parasites. An example is *Plasmodium*, an internal parasite that lives in the human red blood cell and causes malaria. Fleas are external parasites of dogs and cats. A successful parasite never causes the death of its host.

Fig. 1.2 *Food web of organisms in the sea*

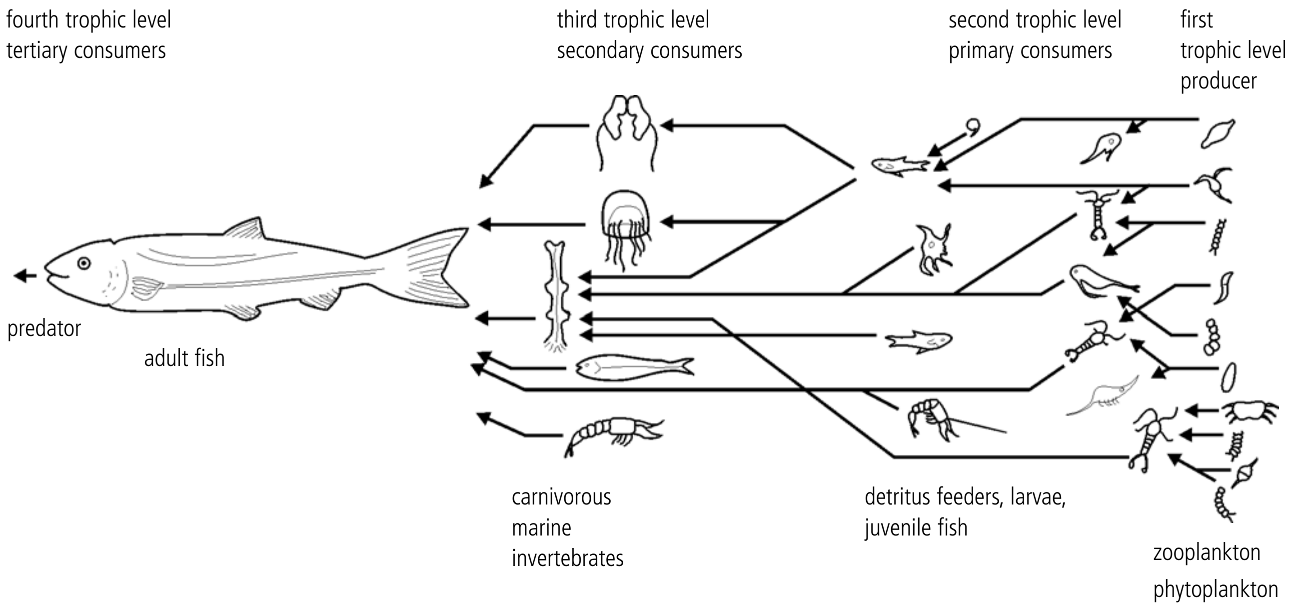
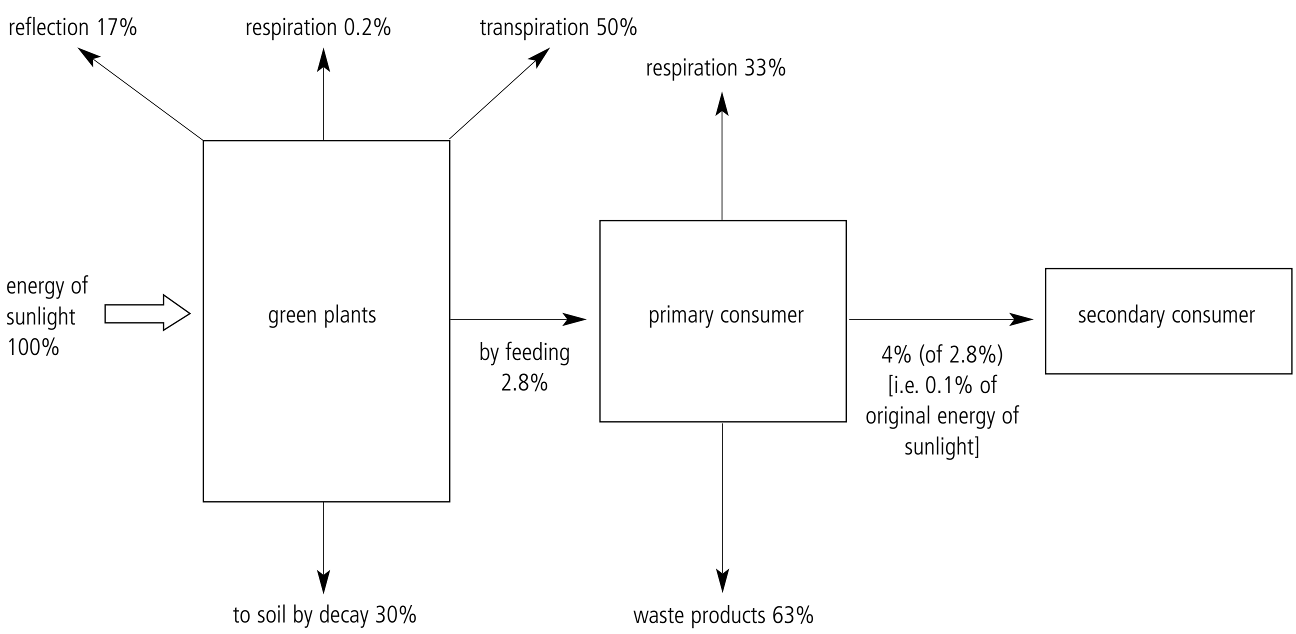


Fig. 1.3 *Energy flow through a food chain*



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2 Nutrient cycling

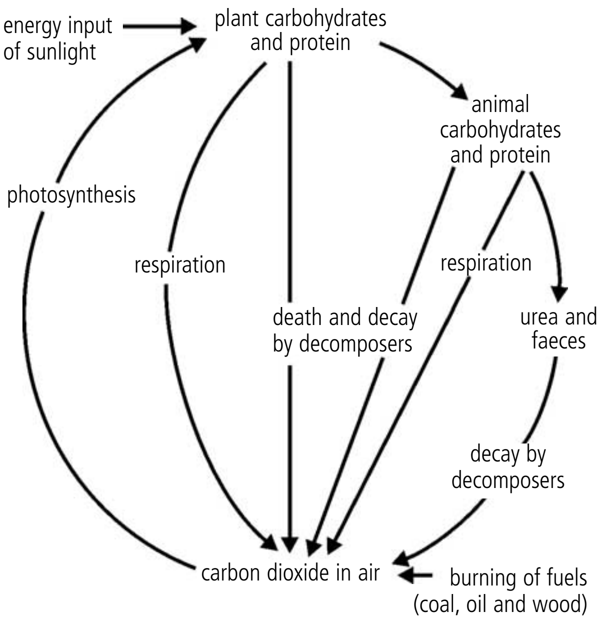
[syllabus section A3.1]

Mineral elements are constantly re-used or recycled in natural environments (e.g. carbon and nitrogen). Decomposers, symbiotic bacteria and fungi are very important to carbon and nitrogen cycles.

2.1 The carbon cycle

The carbon cycle refers to the circulation of carbon atoms in carbon compounds between living organisms and their environment (see Fig. 2.1).

Fig. 2.1 *The carbon cycle*



2.2 The nitrogen cycle

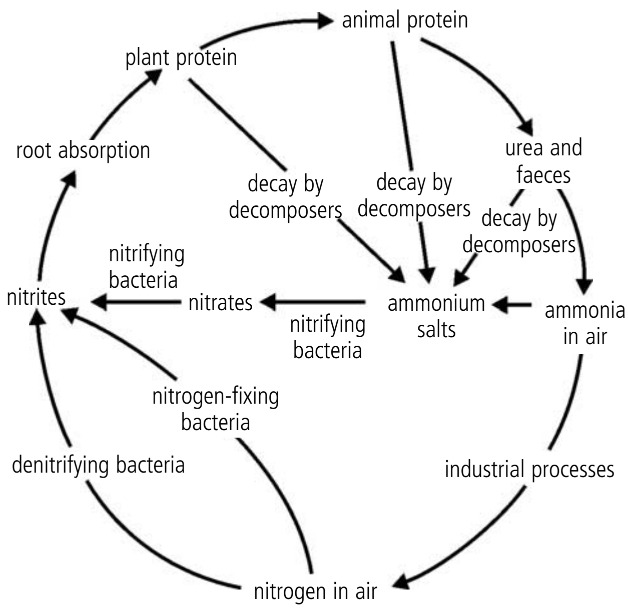
The nitrogen cycle refers to the circulation of nitrogen atoms as gas or within nitrogen compounds in nature (see Fig. 2.2).

Bacteria involved in the nitrogen cycle

Nitrogen-fixing bacteria – convert free nitrogen to nitrates.

1. *Rhizobium* – symbiotic bacteria living in the root nodules of leguminous plants (e.g. pea, bean). They obtain carbohydrates, used as a source of energy, from the plant. The plant receives nitrogen compounds in return.
2. *Azotobacter* – non-symbiotic bacteria living in the soil, needing aerobic conditions.
3. *Clostridium* – non-symbiotic bacteria living in the soil in anaerobic conditions.

Fig. 2.2 *The nitrogen cycle*



Nitrifying bacteria – live in the soil; convert ammonia and ammonium compounds to nitrites and then nitrites to nitrates.

1. *Nitrosomonas* – convert ammonia and ammonium compounds to nitrites.
2. *Nitrobacter* – convert nitrites to nitrates.

Nitrosomonas and *Nitrobacter* are chemosynthetic bacteria. During the oxidation of ammonia and nitrites, energy is released. This energy is used to synthesise simple organic compounds.

Denitrifying bacteria – usually live in soil that is lacking in oxygen, such as waterlogged soils. They break down nitrates and nitrites to obtain oxygen. These bacteria therefore reduce soil fertility by reducing the amount of nitrogen available to plant roots.

2.3 Energy flow through living organisms

Energy is incorporated into green plants and then passed on through food chains from herbivores to carnivores. These organisms eventually die and can be eaten by scavengers or simply rot away due to the action of decomposers (see Fig. 2.3). Note that while energy moves from one organism to the next with associated losses, mineral elements can be recycled.

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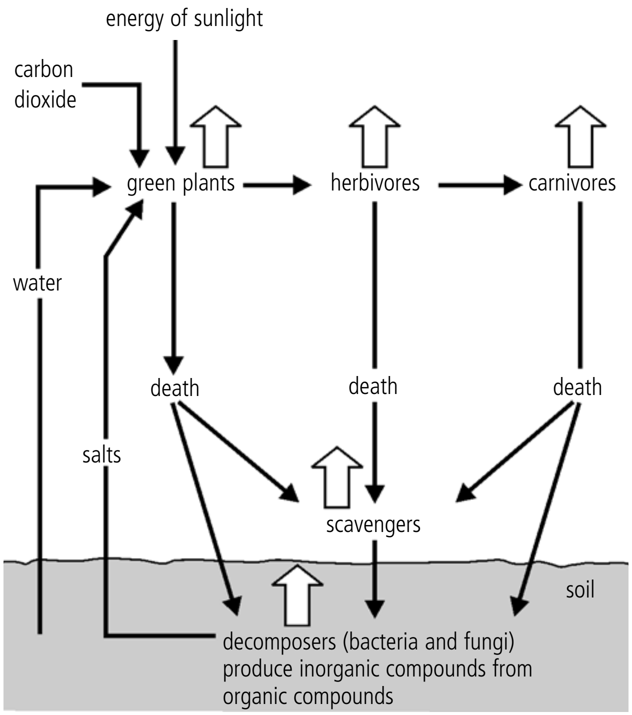
Fig. 2.3 *The cycle of compounds and the flow of energy*



2.4 The interdependence of plant and animal life

1. Plants synthesise all food for animals by photosynthesis.
2. During photosynthesis, plants use carbon dioxide and give off large quantities of oxygen, which is used by animals.
3. During respiration animals give off carbon dioxide that is used by plants for photosynthesis.
4. The death of plants and animals returns mineral salts to the soil that can be used again by plants.
5. Plants can use nitrogenous animal wastes.

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More information

3 The environment and man

[syllabus sections E1.1 to 1.2]

3.1 Some terms

Environment – the sum total of all of the conditions in which an organism lives i.e. the organic or biotic factors (other living organisms needed for food i.e. prey, predators and decomposers) and the inorganic abiotic factors (i.e. light, temperature, relative humidity, rainfall, soil).
Habitat – the particular area in which an organism lives – e.g. the seashore, ponds (aquatic habitats) or woodland, grassland (terrestrial habitats).
Niche – all of the environmental conditions and resources needed for an organism to survive, reproduce and maintain a viable population.
Population – a group of organisms of the same species that live in a particular area or habitat.
Community – a collection of different populations occupying the same habitat. It can range from very large (tropical rain forest) to very small (under a stone in a garden). Large communities contain many small communities within them.
Ecosystem – one or more communities of organisms, in a specific habitat, together with the inorganic components of that habitat such as a pond or a large tree.

3.2 Factors affecting the distribution of organisms

Abiotic or physical factors

Temperature
Organisms will survive in environments where the temperature ranges are within that to which the organism is physically and metabolically suited. Temperature affects the enzyme activity within the organism and therefore also affects metabolism.

Temperatures in terrestrial habitats vary more than in aquatic habitats.

Wind
Allows for the dispersal of seeds and fruits, so allowing organisms to colonise more habitats. However, high winds can damage plants, tearing foliage or toppling plants with shallow roots.

Light intensity
Light is extremely important in any ecosystem. Autotrophs, and so consequently all other organisms, require it. Plants in particular need varying amounts of light e.g. the trees, shrubs, herbs, ferns and mosses, which form clearly defined layers in a tropical rain forest. Seasonal and daily variations affect photosynthesis and transpiration in plants and vitamin D synthesis in humans.

Rainfall
The amount of water received determines the character of the large ecosystems throughout the world, from deserts to forests. Tropical rainforests develop in areas where temperature and rainfall are high. Where there is less rainfall only grasses can develop. Cacti and succulents grow where water is limited.

Humidity
Relative humidity is a measure of the amount of water in the atmosphere. This is a very important factor that influences the distribution of small organisms that have thin outer coverings and that are at risk of drying out in conditions of low humidity, e.g. woodlice under damp wood or earthworms in moist soil.

Edaphic factors
Soil forms an important link between the biotic and abiotic components of terrestrial habitats. Soil conditions such as pH, salinity, and mineral components, organic matter, air content and water content influence plant growth and the distribution of soil organisms.

Biotic factors

The abiotic (physical) factors play a very important part in the distribution of living organisms within an ecosystem, but biotic factors can also have an important effect. The most influential are human activities such as agriculture, forestry, the building of cities, residential communities and the making of roads. These all destroy natural ecosystems. Animals can affect plant communities by grazing, browsing, trampling the vegetation (e.g. large herds of goats can completely destroy herbs and shrubs in a community). Plants can also affect other plants (e.g. large trees produce considerable shade in which no other plants can grow).

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4 Soil

[syllabus sections E1.2 to 1.3; 5.1]

4.1 Soil components

Soil is formed by weathering (the action of water, wind, frost and ice) on rocks. It consists of particles surrounded by water and air spaces. The crumb structure relates to the size of the particles, i.e. sand, clay and silt, together with the amount of **humus** present. Humus is made of decaying plant and animal remains.

The relative proportions of sand, silt and clay determine soil texture. Clays, clay loams and silt loams are most suitable for plant growth. Loams consist of equal quantities of clay and sand with some intermediate particles.

4.2 Soil fauna and flora

Animals constitute the soil fauna while plants form the soil flora (micro-organisms such as bacteria and fungi). Together soil fauna and flora form food chains and food webs with herbivores and carnivores – all supported by decaying plant material. As a result of the *desirable* inter-relationships and activities of these soil organisms, there is:

1 decay of organic matter;
2 release of mineral salts for plant uptake;
3 formation of the appropriate soil structure;
4 breakdown of chemicals and substances (bio-degradable activity);
5 increased aeration and drainage; and
6 fixation of atmospheric nitrogen for use by plants.

Table 4.1 *Properties of sand and clay*

Property	Sand	Clay
Texture	Coarse, particles >0.2 mm	Fine, particles <0.002 mm
Porosity	Large pore spaces, well aerated, drains quickly	Small pore spaces, poor aeration, drains slowly
Water-holding capacity	Poor retention, water not held by capillarity, does not become waterlogged	Good water retention, water held by capillarity and forms a film around clay particles, becomes waterlogged easily, cracks when dry, clumps when wet
Nutrient retention	Low, mineral elements rapidly leached out so that soil becomes acidic	High, not leached, clay particles attract mineral ions

The soil organisms, however, do have *undesirable* activities that may decrease the fertility. They:

1 change available nitrates into nitrogen;
2 compete with crop plants for nutrients;
3 cause injury and disease to root structures; and
4 cause damage and so reduce productivity of crops.

Table 4.2 *Components of soil*

Component	Constituents	Function
Rock particles	Insoluble – gravel, sand, clay, silt and volcanic ash	Soil framework for binding and retention of all other components
Mineral salts	Soluble – compounds of nitrogen, potassium, magnesium, phosphorus, calcium	Provide essential elements in the compounds, e.g. ammonium nitrate, calcium nitrate, calcium phosphate, magnesium, calcium carbonate
Air	Soil air containing oxygen and nitrogen	(i) Oxygen for respiration of plant roots and soil organisms (ii) Nitrogen for nitrogen-fixing bacteria forming nitrogen compounds
Water	Received from rain downwards – upward seepage from under-ground sources i.e. capillarity	(i) Dissolves mineral salts (ii) Absorbed for photosynthesis (iii) Absorbed for plant turgidity (iv) Dissolves nutrients produced by soil organisms
Bacteria and fungi	Bacteria and fungi, including nitrifying, denitrifying and nitrogen-fixing bacteria	(i) Break down organic material forming humus (ii) Form nitrates from ammonium compounds (iii) Fix atmospheric nitrogen
Other living organisms	Worms, arthropods, molluscs	Feed on plant material forming complex food webs. Improve drainage, aeration – their dead bodies contribute more organic material for breakdown to produce salts
Humus	Dead and decaying plants and animals	(i) Provides salts (ii) Retains water (iii) Binds the soil particles

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Excerpt
More information

5 Studying an ecosystem

[syllabus sections E2.1 to 2.2]

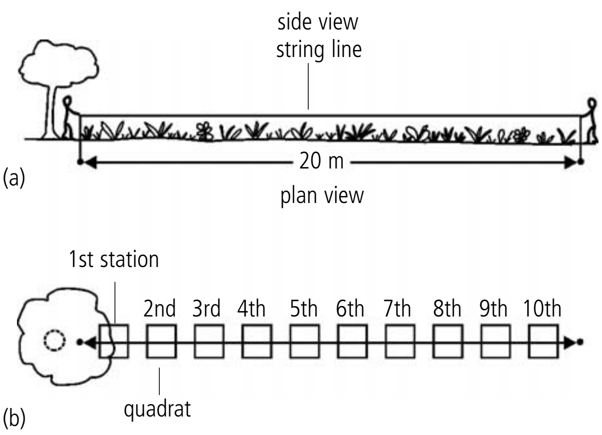
In order to analyse the organisms living in a given habitat, the community structure must be determined. It is not possible to find and count all of the animals and plants, so sampling techniques have been developed to indicate the species present and the numbers involved.

5.1 Sampling of plants

Line transect

A line transect is a tape or string that is run along the ground between two sticks. The plant species that actually touch the string are identified and recorded in a field notebook.

Fig. 5.1 *(a) Setting out a line transect for ground flora (b) Positioning of quadrats along a line transect*



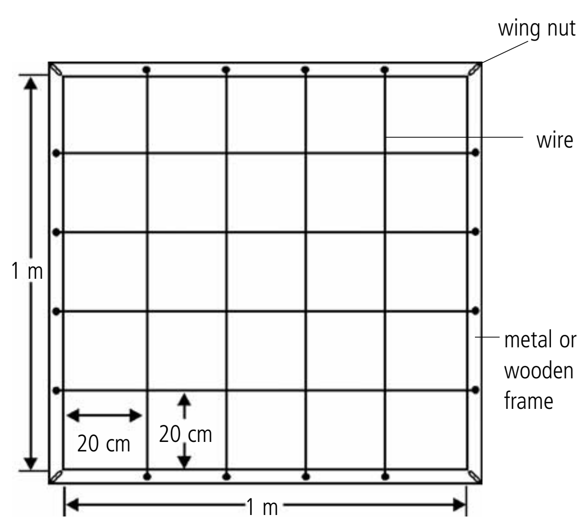
Belt transect

A belt transect is a strip of chosen width across the habitat, made by setting up two line transects, say 1 m apart. Another method is to use a line transect and then a quadrat frame spaced along it (see below). In both methods the plant species are recorded along the line of the belt transect.

Quadrat

A quadrat is a frame (wood or metal) that forms a square of known area (0.25 m^2 or 1 m^2). The species within the frame can be recorded. A quadrat may be used without a transect in order to obtain a random sample of an area. This is done by throwing the quadrat in a random fashion and recording the species within it each time it falls.

Fig. 5.2 *Quadrat frame (1 m^2) with wire sub-quadrats (each 400 cm^2) forming a graduated quadrat*

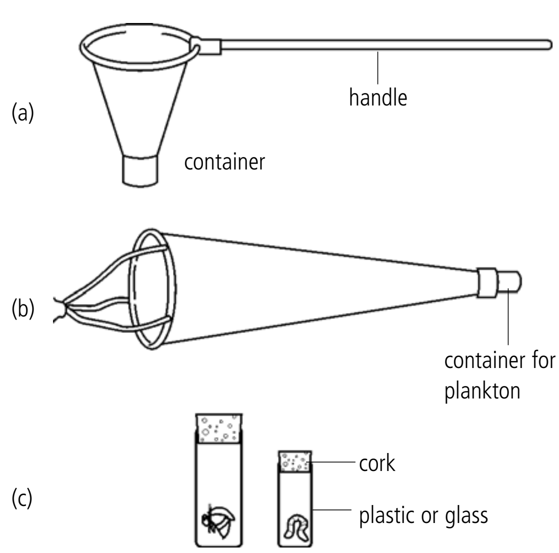


5.2 Sampling of animals

Nets

Various types of net can be used according to the type of habitat, e.g. trees or water. A sweep net consists of a nylon net attached to a handle that can be swept through grass and bushes to catch insects and spiders. Plankton nets have very fine mesh with a small jar or bottle attached to the rear of the net. This can be swept through water to catch minute floating animals and plants.

Fig. 5.3 *(a) Sweep net for use in land or water habitats (b) Plankton net for floating organisms in water (c) Specimen bottles*



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Excerpt
More information

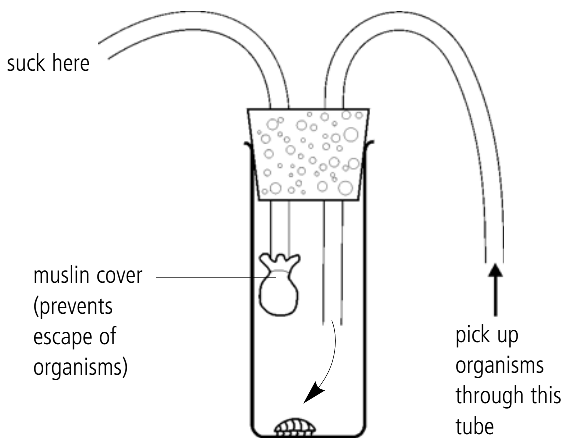
Beating tray

A beating tray is simply a sheet of fabric of known area held under a branch of a tree or shrub, which is beaten with a stick. The organisms fall into the sheet and can be collected.

Pooter

A pooter is an apparatus used to collect small organisms from a beating tray or net (see Fig. 5.4).

Fig. 5.4 *A pooter for collecting small organisms*



5.3 Estimating population size

In all population studies it is essential to be able to estimate the number of organisms within a given area of the habitat (ground or water). The methods employed are determined by the size and mode of life of the organisms.

There are three aspects of species distribution that can be calculated:

1 **Species density**: the number of members of a given species within a given area e.g. 10 m^2 (obtained by randomly thrown quadrats);
2 **Species frequency**: a measure of the chance of finding a given species with any one throw of a quadrat (if a species is found only once in ten throws of a quadrat it has a frequency of 10%);
3 **Species cover**: the proportion of ground covered by any one species, so that it can finally give the area covered by the species as a percentage of the total area. A metre square quadrat is used and an estimate is made for each species within the frame.

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6 Natural populations

[syllabus sections E3.1 to 3.2]

6.1 Some terms

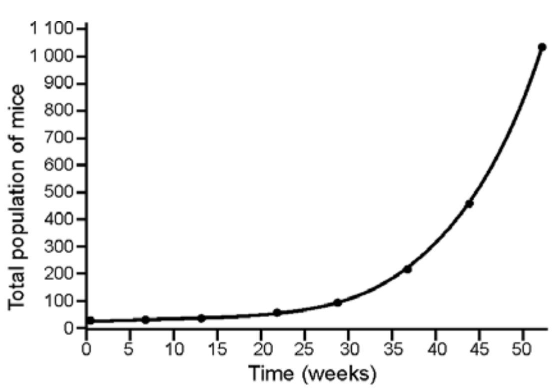
Population – a number of organisms of the same species that live in a given area.
Population size – the number of individuals in the group.
Carrying capacity – the maximum population size that can be supported indefinitely by a particular environment.
Limiting factors operate to check animal populations. These include:

1. food, water or oxygen supply;
2. availability of light;
3. predators and parasites of the species;
4. lack of shelter or availability of space;
5. diseases of the species;
6. accumulation of toxic waste;
7. climatic conditions; and
8. natural disasters, e.g. hurricanes, flooding, volcanic eruptions.

A population allowed to grow unchecked will produce a curve of growth as shown in Fig. 6.1. This is easily demonstrated by counting species that are small and can be grown in the laboratory, e.g. bacteria, yeast or small mammals (e.g. mice). As can be seen from the graph, such unchecked population growth would result in high numbers. In nature, however, natural checks stop the curve of growth rising continuously (i.e. toxic substances accumulate in bacterial colonies, alcohol accumulates in yeast colonies and food runs out in mouse colonies).

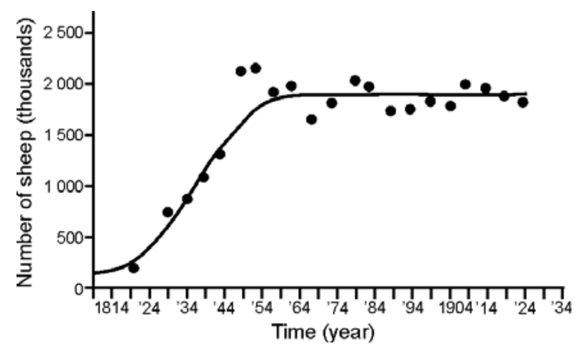
Fig. 6.2 shows an example of this in a colony of sheep introduced into the island of Tasmania in 1814.

Fig. 6.1 *A population of mice growing with no limiting factors*



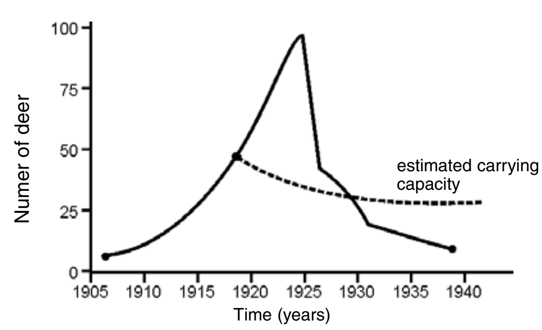
After 50 years, the growth curve of the population levelled out when the limiting factors of food and disease became effective.

Fig. 6.2 *Growth of population of sheep introduced into Tasmania – limiting factors begin to operate after 50 years*



A similar example from America (see Fig. 6.3) shows the growth of a population of deer on a plateau after their predators (mountain lions, wolves and coyotes) had been removed. There was plenty of food for the deer and their numbers increased rapidly. The population eventually overshot the carrying capacity of the region and, due to lack of food and disease, the numbers crashed down. After a time, as the food supply improved, their numbers would again increase up to the carrying capacity of the region.

Fig. 6.3 *Population growth and crash of an isolated colony of deer on the Kaibab plateau, Arizona*



This type of **predator–prey relationship** is very important in a natural habitat and Fig. 6.4 shows an example of this with the lynx (a type of large cat) and the hare in North America. Notice that:

1. the rise in **number of the predators lags behind** that of the **prey**, i.e. the hares have to increase first before the lynx can take advantage of the increased food supply;