Classification

WHY CLASSIFY ORGANISMS?

Classification in biology is arranging living organisms into groups. There are many advantages gained by classifying organisms.

- **Species identification** – it is easier to find out to which species an organism belongs with organisms classified rather than in a disorganized catalogue.
- **Predictive value** – if several members of a group have a characteristic, another species in this group will probably also have this characteristic.
- **Evolutionary links** – species that are in the same group probably share characteristics because they have evolved from a common ancestor, so the classification of groups can be used to predict how they evolved.

SPECIES AND GENUS

In the classification of living organisms the basic group is the **species**. *A species is a group of organisms with similar characteristics, which can interbreed and produce fertile offspring.* Every species is classified into a **genus**. A genus is a group of similar species.

Each species needs an international name, so that biologists throughout the world can refer to it. The naming of species is called nomenclature. The **nomenclature** that biologists use is called the **binomial system** because two names are used to refer to each species. The key features of the binomial system of nomenclature are:

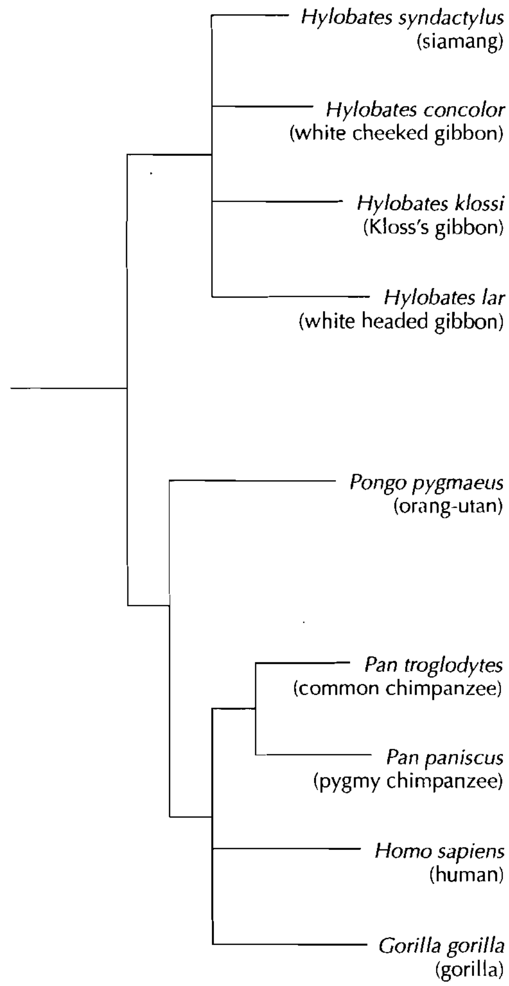
- the first name is the genus name
- the genus name is given an upper-case first letter
- the second name is the species name
- the species name is given a lower-case first letter
- italics are used when the name is printed
- the name is underlined if it is handwritten.

FIVE KINGDOMS

Taxonomists do not always agree about how living organisms should be classified into kingdoms. One system that is widely used has five kingdoms.

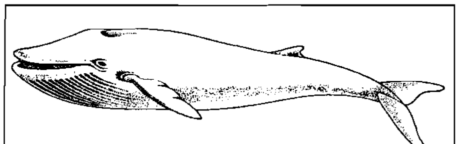
1. **Prokaryotae** – including all types of bacteria.
2. **Protoctista** – including unicellular organisms like Amoeba and algae.
3. **Fungi** – the moulds and the yeasts.
4. **Plantae** – including mosses, ferns, conifers and flowering plants.
5. **Animalia** – including sponges, corals, insects, birds and mammals.

Evidence from DNA sequences used to help in classification



Tree diagram showing relationships between humans and the species most similar to humans, based on comparisons between DNA of each species. Chimpanzees and gorillas were placed in a family with orang-utans, but should probably be placed in the same family as humans according to the DNA evidence.

CLASSIFICATION FROM SPECIES TO KINGDOM



Balaenoptera musculus

A group of organisms, such as a species or a genus is called a **taxon.** Species are classified into a series of taxa, each of which includes a wider range of species than the previous one. This is called the **hierarchy of taxa**.

	Animal example Balaenoptera musculus – the blue whale (left)	Plant example Sequoia sempervirens – the coast redwood (right)
Species that are similar are grouped into a genus	Genus Balaenoptera	Genus Sequoia
Genera that are similar are grouped into a family	Family Balaenopteridae	Family Taxodiaceae
Families that are similar are grouped into an order	Order Cetacea	Order Pinales
Orders that are similar are grouped into a class	Class Mammalia	Class Pinopsida
Classes that are similar are grouped into a phylum	Phylum Chordata	Phylum Coniferophyta
Phyla that are similar are grouped into a kingdom	Kingdom Animalia	Kingdom Plantae

Sequoia sempervirens

Identifying living organisms

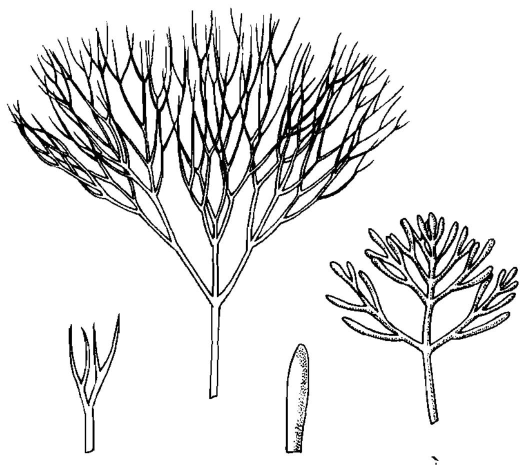
USING KEYS TO IDENTIFY ORGANISMS

The first stage in many ecological investigations is to find out what species of organism there are in the area being studied. This is called **species identification**. This can be done using **keys**.

Keys for species identification are usually constructed in this way:

- the key consists of a series of numbered stages
- each stage consists of a pair of alternative characteristics
- some alternatives give the next stage of the key to go to
- some alternatives give the identification.

Leaves of aquarium plants



Identifying aquarium plants using a key

Many aquatic plants in aquariums in biology laboratories belong to one of these four genera:

- *Cabomba*
- *Ceratophyllum*
- *Elodea*
- *Myriophyllum*

All of these plants have cylindrical stems with whorls of leaves. The shape of four leaves is shown in the figure (left). A key can be used to identify which of the four genera a plant belongs to, if it is known to be in one of them.

1. Simple undivided leaves . . . . *Elodea*

   Leaves forked or divided into segments 2

2. Leaves forked once or twice to form two or four segments . . . . *Ceratophyllum*

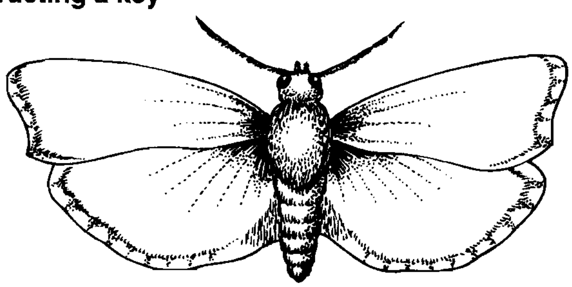
   Leaves divided into more than four segments 3

3. Leaves divided into many flattened segments . . . . *Cabomba*

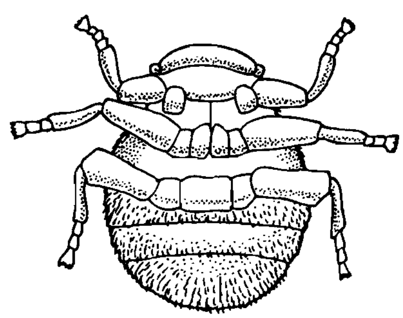
   Leaves divided into many filamentous segments . . . . *Myriophyllum*

Some species of Elodea have recently been moved by taxonomists to other genera:
Elodea densa is now *Egeria densa*.
Elodea crispa is now *Lagarosiphon major.*

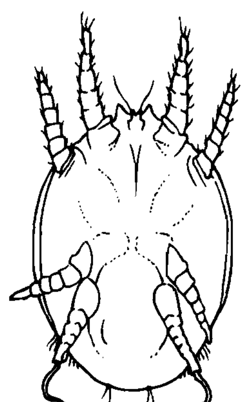
Constructing a key



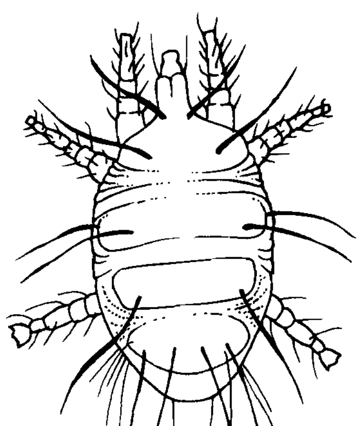
Galleria mellonella



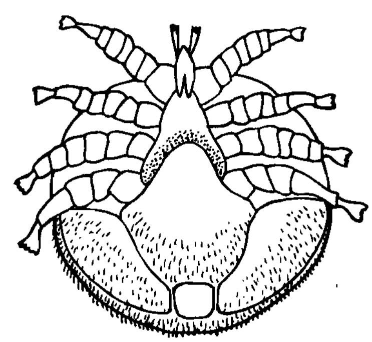
Braula coeca



Acarus siro



Acarapis woodi



Varroa jacobsonii

The five animals shown above are found in beehives. It would be useful to construct a key to allow a beekeeper to identify them, as some of them are very harmful and others are harmless to honey bees.

Measuring populations

POPULATIONS

A human population is the people who live in a town, a country or some other defined area. In biology, populations can be of humans, animals, plants or any living organism. *A population is a group of organisms of the same species living in the same area at the same time.* It is usually impossible to count every individual in a population. Instead, an accurate estimate is made. Ecologists often need to measure the size of a population. There are many methods for making estimates of population size. The **capture–mark–release–recapture method** is suitable for animals that move around and are difficult to find (see below left).

Random sampling is suitable for plants that do not move around and are easy to find (below right).

RANDOM SAMPLES

A sample is a part of a population, part of an area or part of some other whole thing, chosen to illustrate what the whole population, area or other thing is like. For example, a sample of a population is some individuals in the population but not all of them. *In a random sample, every individual in a population has an equal chance of being selected.* Random sampling of plant populations involves counting numbers in small, randomly located parts of the total area. The sample areas are usually square and are marked out using frames called **quadrats**.

CALCULATING THE MEAN OF A SET OF VALUES

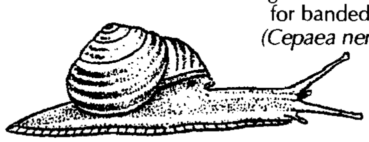
To calculate a mean of a set of values, all of the values must be added together to give a total (Σx). Divide this total by the number of values (n):

$$\text{Mean} = \frac{(\Sigma x)}{n}$$

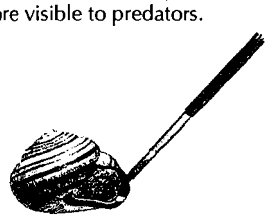
CAPTURE–MARK–RELEASE–RECAPTURE METHOD

1. Capture as many individuals as possible in the area occupied by the animal population, using netting, trapping or careful searching

e.g. careful searching for banded snails *(Cepaea nemoralis)*

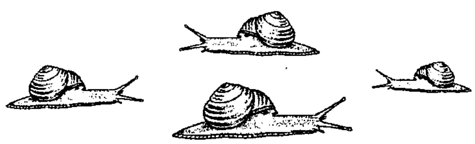


2. Mark each individual, without making them more visible to predators.

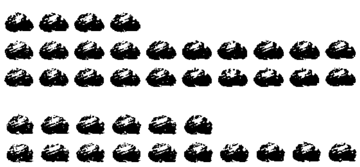


e.g. marking the inside of the snail shell with a dot of non-toxic paint.

3. Release all the marked individuals and allow them to settle back into their habitat.



4. Recapture as many individuals as possible and count how many are marked and how many unmarked.



24 marked

16 unmarked

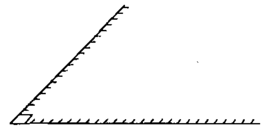
5. Calculate the estimated population size by using the Lincoln index:

$$\text{population size} = \frac{n_1 \times n_2}{n_3}$$

n_1 = number caught and marked initially
n_2 = total number caught on the second occasion
n_3 = number of marked individuals recaptured

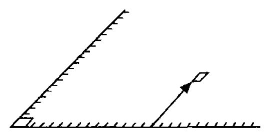
RANDOM SAMPLING USING QUADRATS

1. Mark out gridlines along two edges of the area.



2. Use a calculator or tables to generate two random numbers, to use as co-ordinates and place a quadrat on the ground with its corner at these co-ordinates.

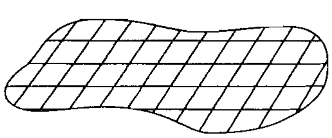
e.g. 14 and 7



3. Count how many individuals there are inside the quadrat of the plant population being studied. Repeat stages 2 and 3 as many times as possible.

= 5 individuals

4. Measure the total size of the area occupied by the population, in square metres.



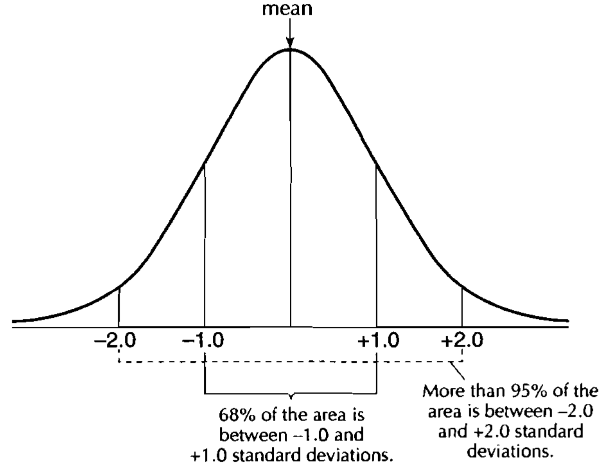
5. Calculate the mean number of plants per quadrat. Then calculate the estimated population size using this equation:

$$\text{population size} = \frac{\text{mean number per quadrat} \times \text{total area}}{\text{area of each quadrat}}$$

Variation in populations

Although members of a population show similarities because they are members of the same species, they also show differences – **variation**. For example, humans vary in height and in skin colour.
The range of variation can be shown using a graph called a frequency distribution. Most variation gives a bell-shaped frequency distribution called the **normal distribution**.
The mean value is in the middle of the distribution. Another statistic called the **standard deviation** is used to assess how far the values are spread above and below the mean. A high standard deviation shows that the data is widely spread and a low standard deviation shows that the data are clustered closely around the mean. A useful rule is that 68% of the values lie between one standard deviation above and below the mean in a normal distribution (right).
The standard deviation can be used to help decide whether the difference between two means is likely to be significant. Two examples are described below.

The normal distribution

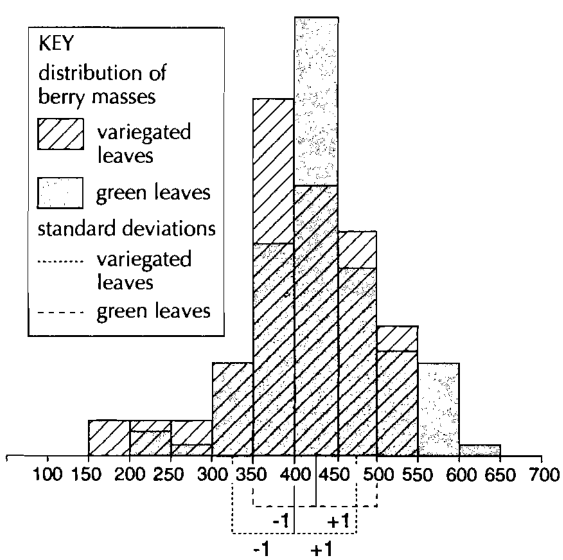


Variation in Holly berries

A group of students collected holly berries from two *Ilex aquifolium* trees. One tree had green leaves and the other variegated leaves (leaves that were partly green and partly yellow).
Hypothesis: the berries from the tree with variegated leaves will be smaller than the berries from the tree with all-green leaves.
The mass of some berries from each tree was found. The mean mass and the standard deviation were calculated for each tree.

Tree	Mean berry mass	Standard deviation
Green leaves	427 mg	73 mg
Variegated leaves	399 mg	80 mg

The berries from the tree with green leaves had a 28 mg larger mean mass than those from the tree with variegated leaves. However the standard deviations (73 mg and 80 mg) are much larger than the difference between the means. The difference in the mean mass of the berries is therefore unlikely to be significant.

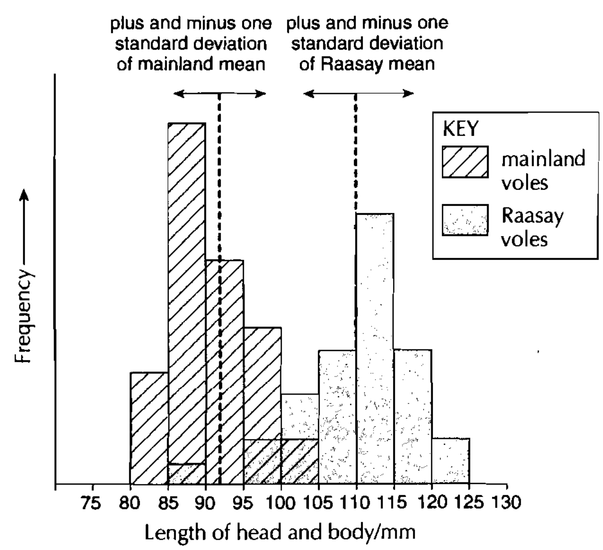


Variation in Bank voles

Ecologists noticed that bank voles (*Clethrionomys glareolus*) seemed to grow to a larger size on Raasay, a small Scottish island than on the mainland.
Hypothesis: adult bank voles are larger on Raasay than on mainland Britain.
Adult voles were caught using small mammal traps on Raasay and on the mainland. The length of each vole was measured and the mean lengths and standard deviations were calculated.

Vole population	Mean length	Standard deviation
Mainland Britain	92 mm	5.2 mm
Raasay	110 mm	7.1 mm

The mean length of the bank voles on Raasay is 18 mm greater than mean length of those on the mainland. The standard deviations (5.2 and 7.1) are much smaller than the difference in the means. The difference in the length of the bank voles was therefore almost certainly significant – the population on Raasay grew to a larger size.



CHANGES TO THE SIZE OF A POPULATION

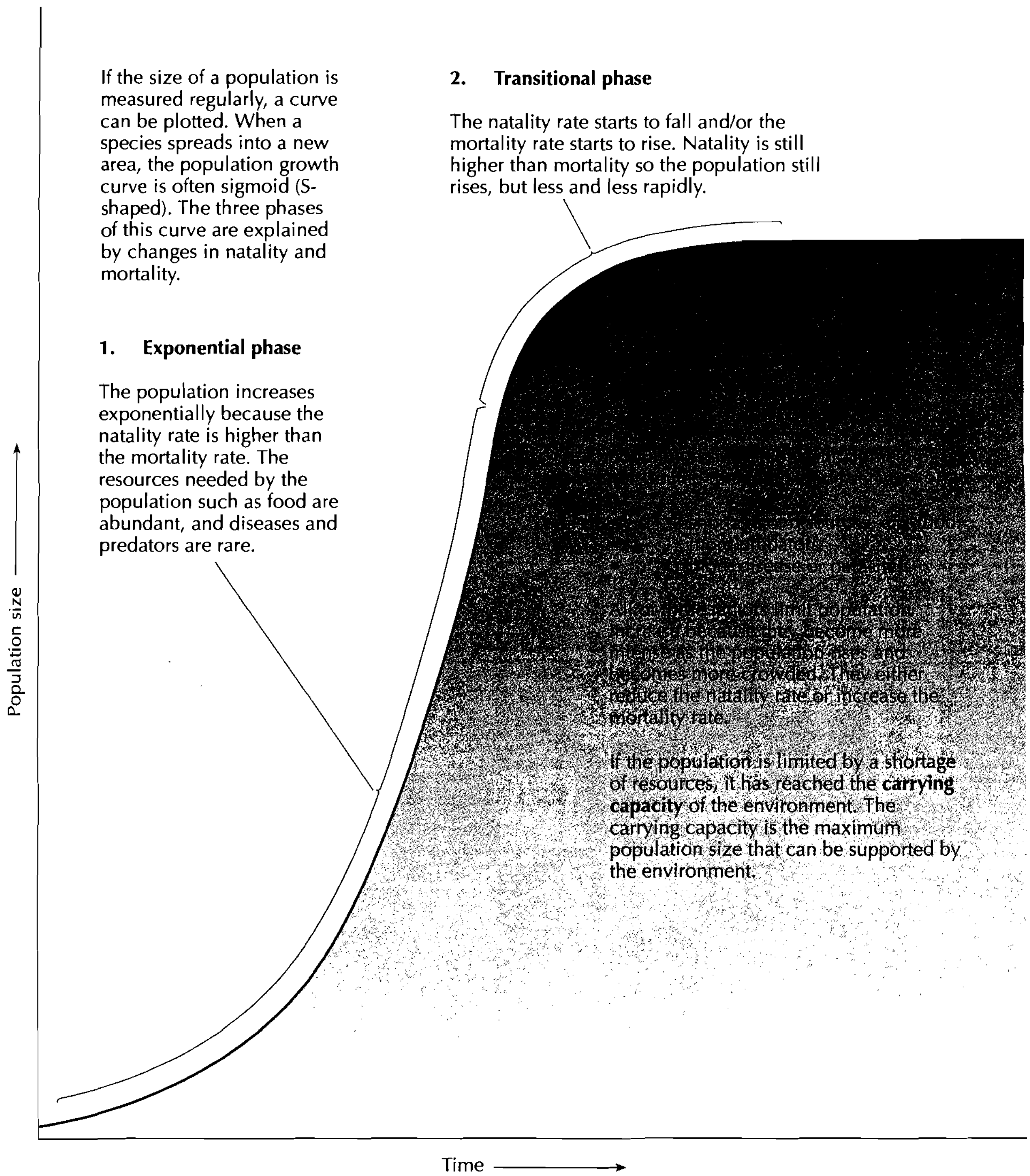
There are four ways in which the size of a population can change:

- Offspring are produced and are added to the population – **natality**.
- Individuals die and are lost from the population – **mortality**.
- Individuals move into the area from elsewhere and are added to the population – **immigration**.
- Individuals move out of the area to live elsewhere – **emigration**.

Populations are often affected by all four of these things and the overall change can be calculated using an equation:

Population change = (natality + immigration) – (mortality + emigration)

POPULATION GROWTH CURVES



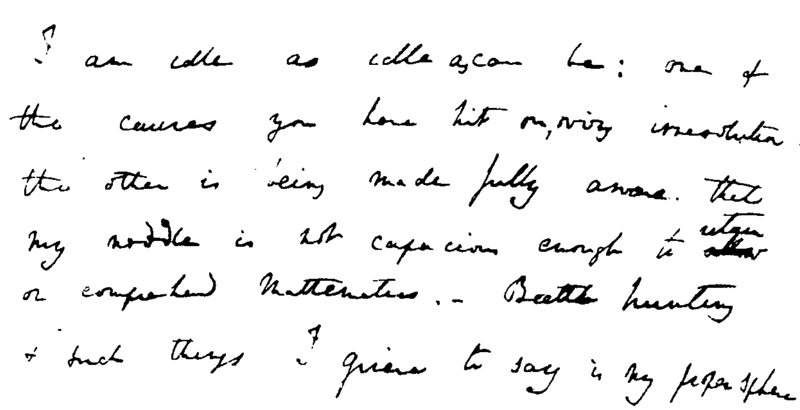
Natural selection

DARWIN, WALLACE AND EVOLUTION BY NATURAL SELECTION

Evolution is the accumulation of changes in the heritable characteristics of a population.
Charles Darwin developed the theory that evolution occurs as a result of natural selection. He explained his theory in *The Origin of Species*, published in 1859. He had done many years of research and had collected much evidence for the theory before then.
Darwin delayed publication of his ideas for many years, fearing a hostile reaction. He might never have published them if another biologist, Alfred Wallace, had not written a letter to him in 1858 suggesting very similar ideas.
The theory of evolution by natural selection can be explained in a series of observations and deductions.
The photograph on the right shows a statue of Charles Darwin at Shrewsbury School, where he was a pupil from 1818–1825.

Observations		Deductions
* Populations of living organisms tend to increase exponentially * Yet, on the whole, the number of individuals in populations remains nearly constant	→	* More offspring are produced than the environment can support * There is a struggle for existence in which some individuals survive and some die
* Living organisms vary. The members of a species are different from each other in many ways * Some individuals have characteristics that make them well adapted to their environment and other individuals have characteristics that make them less well adapted to their environment	→	* The better adapted individuals tend to survive and reproduce more than the less well-adapted individuals This is **natural selection**
* Much variation is heritable – it can be passed on to offspring	→	* The better-adapted individuals pass on their characteristics to more offspring than the less well adapted individuals. The results of natural selection therefore accumulate * As one generation follows another, the characteristics of the species gradually change – the species evolves

In 1828 Darwin, as a young man was struggling to learn enough mathematics to pass a university exam.
The extract below is from a letter that he wrote to Charles Whitley, a friend and eminent mathematician.
' I am as idle as idle can be: one of the causes you have hit on, viz irresolution the other being made fully aware that my noddle is not capacious enough to retain or comprehend Mathematics. – Beetle hunting & such things I grieve to say is my proper sphere...'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the causes you have hit on, viz irresolution
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& such things I grieve to say is my proper sphere

SEXUAL REPRODUCTION AND EVOLUTION

Variation is essential for natural selection and therefore for evolution. Although mutation is the original source of new genes or alleles, sexual reproduction promotes variation by allowing the formation of new combinations of alleles. Two stages in sexual reproduction promote variation.

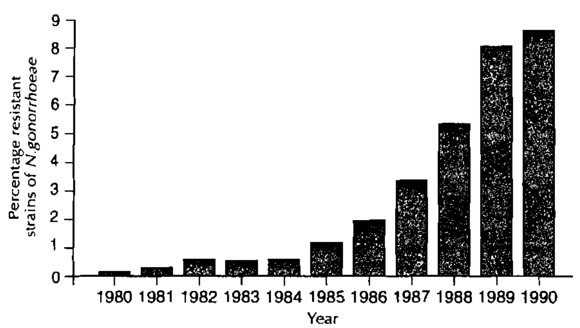
1. Meiosis allows a huge variety of genetically different gametes to be produced by each individual.
2. Fertilization allows alleles from two different individuals to be brought together in one new individual.

Prokaryotes do not reproduce sexually but have other ways to promote variation by exchanging genes.

Some species of organisms only reproduce asexually. Mutations still produce some variation in these species, but without sexual reproduction the variation and the capacity for evolution is less.

MULTIPLE ANTIBIOTIC RESISTANCE IN BACTERIA

Antibiotics are used to control diseases caused by bacteria in humans. There have been increasing problems with disease-causing bacteria being resistant to antibiotics. The figure below shows the percentage of cases of gonorrhea (a sexually transmitted disease) in the United States that were caused by antibiotic-resistant strains of *Neisseria gonorrhoeae* between 1980 and 1990. The trend with many other diseases has been similar.



Genes that give resistance to an antibiotic can be found in the micro-organisms that naturally make that antibiotic.

The evolution of multiple antibiotic resistance involves the following steps.

- A gene that gives resistance to an antibiotic is transferred to a bacterium by means of a plasmid or in some other way. There is then variation in this type of bacterium – some of the bacteria are resistant to the antibiotic and some are not.
- Doctors or vets use the antibiotic to control bacteria. Natural selection favours the bacteria that are resistant to it and kills the non-resistant ones.
- The antibiotic-resistant bacteria reproduce and spread, replacing the non-resistant ones. Eventually, most of the bacteria are resistant.
- Doctors or vets change to a different antibiotic to control bacteria. Resistance to this soon develops, so another antibiotic is used, and so on until multiply resistant bacteria have evolved.

The more an antibiotic is used, the more bacteria resistant to it there will be and the fewer non-resistant.

UNCERTAINTIES ABOUT EVOLUTION BY NATURAL SELECTION

There is much evidence for the theory that species evolve by natural selection. For example, there are some well-known cases where species have been observed to change their characteristics in response to changes in their environment. Two examples – the development of antibiotic resistance in bacteria and of metal tolerance in plants are explained below. (Other examples are given in Option D.)

However, recent cases of observed evolution all involve relatively small changes. Despite the strength of the evidence, it is not possible to *prove* that modern species have evolved by natural selection and so evolution remains a theory.

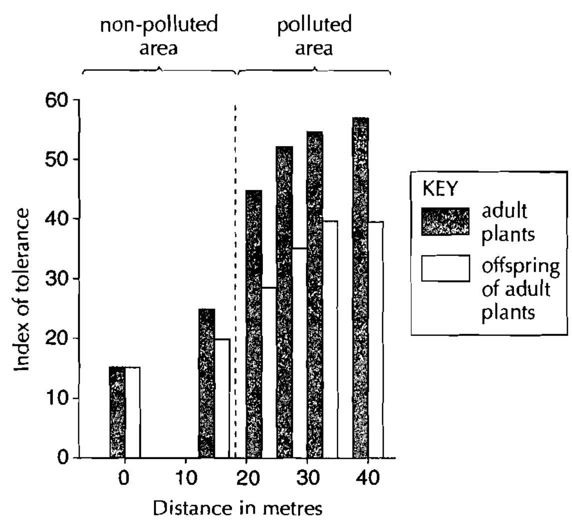
METAL TOLERANCE IN PLANTS

Waste material from the mining of metal ores and smelting often contains high levels of metals such as lead, nickel or copper. These wastes are often dumped and because of the metal pollution, few plants grow on it. Some plants do colonise the waste heaps and when they are tested they are found to have higher tolerance to the metals in the waste than usual for their species.

Evidence for the evolution of metal tolerance in a grass (*Agrostis tenuis*) was obtained in the following way.

- An area of copper pollution around an old copper mine in North Wales was mapped.
- A transect line was marked out, which ran from an unpolluted area to a heavily polluted area.
- Samples of *Agrostis tenuis* plants were collected along the transect line and were tested for copper tolerance.
- Seeds were collected from the same plants. The seeds were germinated and the plants that grew from them were also tested for copper tolerance.

The figure below shows the results.

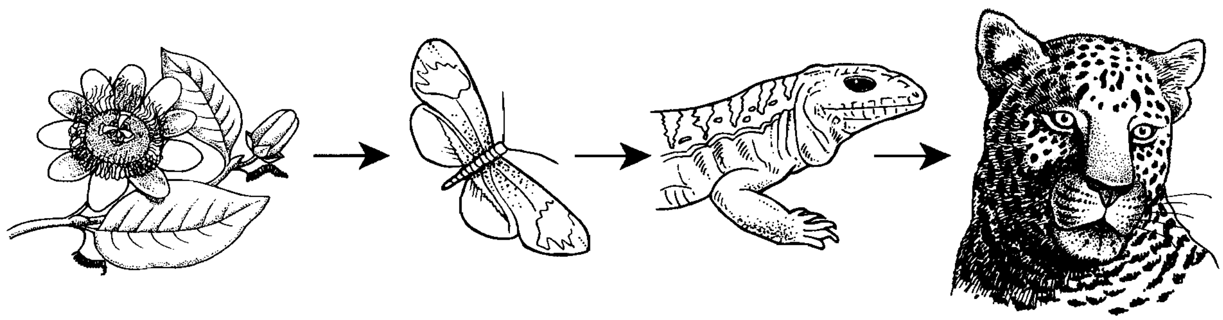


- The plants growing in the polluted area were more copper tolerant than the plants in the unpolluted area.
- The offspring of these plants inherited at least some of the copper tolerance, showing that genes are involved.
- Other experiments showed that, if plants were raised using seed collected from adult plants growing down-wind of the area of copper pollution, these plants also showed copper tolerance. Pollen carrying copper tolerance genes is blown to plants down-wind.

Trophic levels

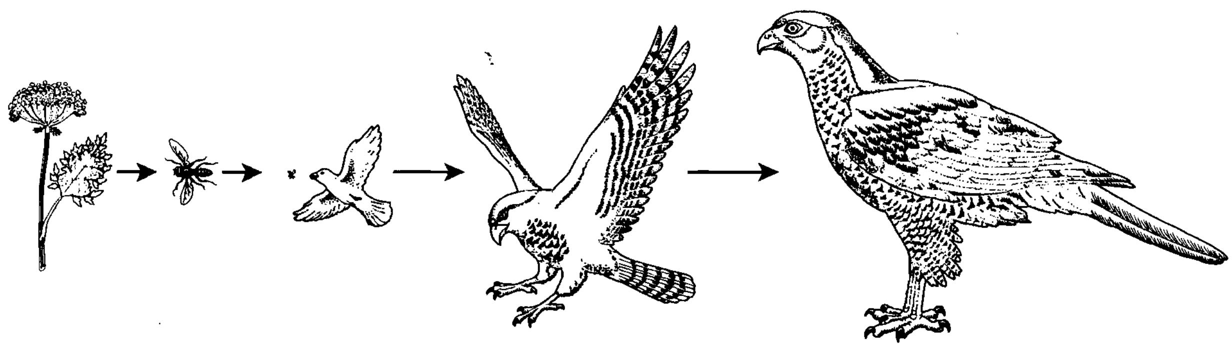
Populations do not live in isolation – they live together with other populations in **communities**. *A community is a group of populations living together and interacting with each other in an area.*
There are many types of interaction between populations in a community. Trophic relationships are very important – where one population of organisms feeds on another population. Sequences of trophic relationships, where each member in the sequence feeds on the previous one, are called **food chains.**

An example from rainforest at Iguazu in north-east Argentina.



Passionflower *(Passiflora schummaniana)* → Heliconius butterfly *(Heliconius erato)* → tegu lizard *(Tupinambis teguixin)* → jaguar *(Panthera onca)*

An example from chalk grassland and the air above it in Europe.



carrot plant *(Daucus carota)* → carrot fly *(Psila rosea)* → flycatcher *(Muscicapa striata)* → sparrowhawk *(Accipiter nisus)* → goshawk *(Accipiter gentilis)*

The first organism in a food chain does not feed on other organisms so must be a producer – an organism that makes its own food. The other organisms are all consumers and are called primary, secondary, tertiary and so on, depending on their position in the chain.
Producer, primary consumer, secondary consumer and tertiary consumer are examples of **trophic levels**. *The trophic level of an organism is its position in the food chain.*

Example:

Producer	→	**Primary consumer**	→	**Secondary consumer**	→	**Tertiary consumer**
Sea lettuce		Marine iguana		Galapagos snake		Galapagos hawk
(Ulva lactuca)		*(Amblyrhyncus cristatus)*		*(Dromiscus biserialis)*		*(Buteo galapagensis)*

A food chain shows only some of the trophic relationships in a community. Organisms rarely feed on only one other organism and are usually fed on by more than one organism. The complex network of trophic relationships in a community is shown in full in a complex diagram called a food web. An example of a food web is shown on page 42.

OBTAINING ENERGY

The organisms in a community all need a supply of energy. Organisms are divided into two groups according to their source – **autotrophs** and **heterotrophs**.

Autotrophs

Autotrophs are organisms that use an external energy source to produce organic matter from inorganic raw materials

Autotrophs make their own food, so are also called producers

Examples of producers – oak trees, maize plants, algae, blue-green bacteria

All food chains start with a producer. In almost all communities the producers make organic matter by photosynthesis

Light is therefore the **initial energy source** for the whole community

Heterotrophs

Heterotrophs are organisms that use the energy in organic matter, obtained from other organisms

Heterotrophs obtain their food from other organisms. There are three types of heterotroph – **consumers, detritivores** and **saprotrophs**

Consumers feed on other living organisms

Examples of consumers – locusts, sheep, lions,

Detritivores feed on dead organic matter by ingesting it

Examples of detritivores – dung beetles, earthworms

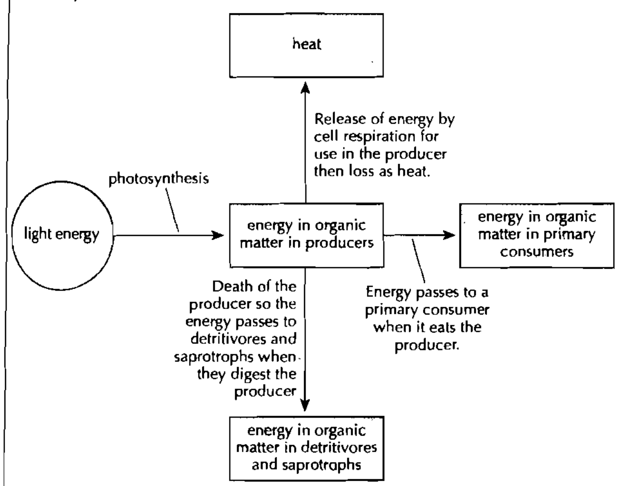
Saprotrophs feed on dead organic matter by secreting digestive enzymes into it and absorbing the products of digestion

Examples of saprotrophs – bread mould, mushrooms

ENERGY FLOW THROUGH COMMUNITIES

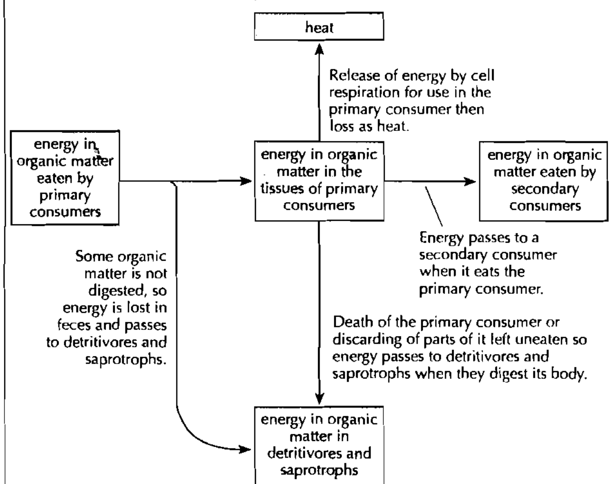
Energy flow through producers

Producers convert light energy into the chemical energy of sugars and other organic compounds. This energy trapped by the producers eventually leaves them in one of three ways.



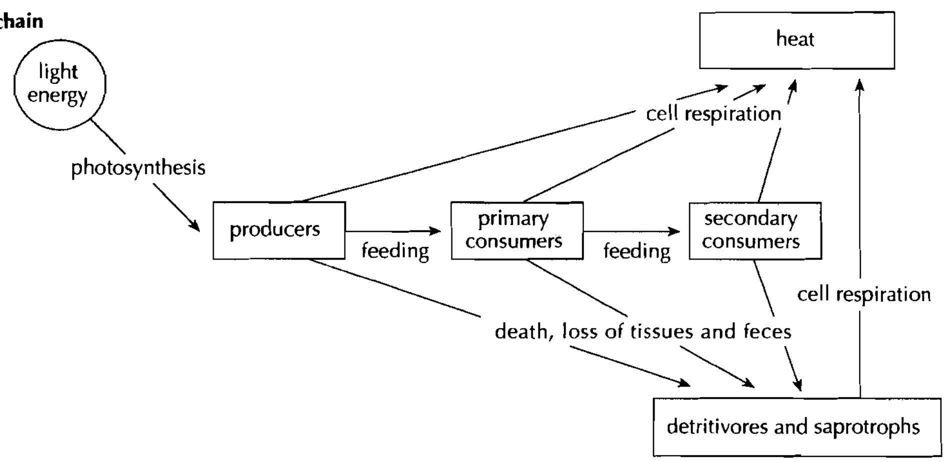
Energy flow through consumers

Primary consumers eat producers and so obtain energy from them. They do not absorb all of the energy in the food that they eat. The energy that they do take into their tissues leaves them in one of three ways.



Energy flow through a food chain

The energy that passes to detritivores and saprotrophs is eventually released by cell respiration and lost as heat. In most communities all the light energy that was trapped by producers is ultimately lost as heat after flowing through the food chain. A summary of energy flow for a three-stage food chain is shown here.

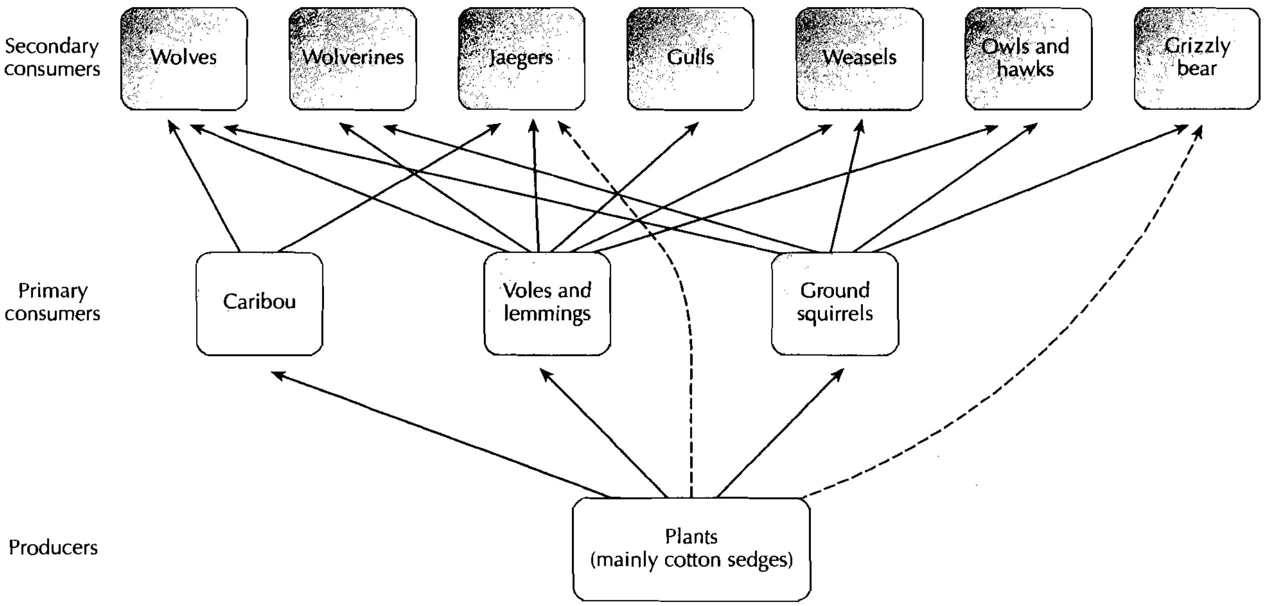


Food webs and energy pyramids

FOOD WEBS

A food web is a diagram that shows all the feeding relationships in a community. The arrows indicate the direction of energy flow. Complete food web diagrams are very complex. The figure (below) shows a simplified food web for a community that lives in an area of Arctic tundra in Ogotoruk Valley.

Food web for Arctic tundra



ENERGY PYRAMIDS

Energy pyramids are diagrams that show how much energy flows through each trophic level in a community. The amounts of energy are shown per square metre of area occupied by the community and per year (kJ m^{-2} year^{-1}).

The figure (right) is a pyramid of energy for Silver Springs, a stream in Florida.

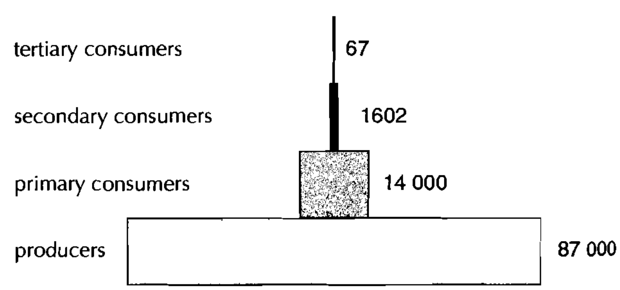
The figure (below right) is a pyramid of energy for a salt marsh in Georgia. Pyramids of energy are always pyramid shaped – each level is smaller than the one below it. This is because less energy flows through each successive trophic level. Energy is lost at each trophic level, so less remains for the next level. Note that mass is lost as well as energy, so the energy content per gram of the tissues of each successive trophic level is *not* lower.

Energy is lost in various ways. In each of the first three ways the energy is not completely lost from the community as it passes to detritivores and saprotrophs.

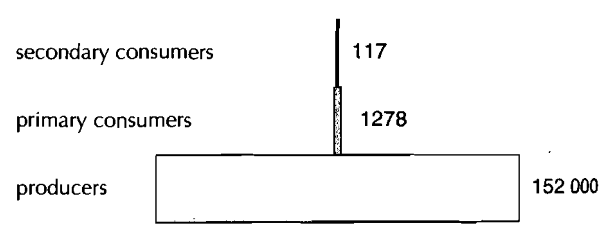
- Some organisms die before an organism in the next trophic level eats them.
- Some parts of organisms such as bones or hair are not eaten.
- Some parts of organisms are indigestible and pass out as feces.
- Much of the energy absorbed by an organism is released in cell respiration. The energy, in the form of ATP, is used in processes such as muscle contraction or active transport that require energy. These processes involve energy transformations, which are never 100% efficient. Some of the energy is converted to heat. 10–20% is a typical efficiency level. Most of the energy released by cell respiration is lost from the organism as heat.

Energy absorbed by living organisms is only available to the next trophic level if it remains as chemical energy in the growth of the organism. This is only a small proportion of the energy absorbed.

Energy pyramid for a stream



Energy pyramid for a salt marsh



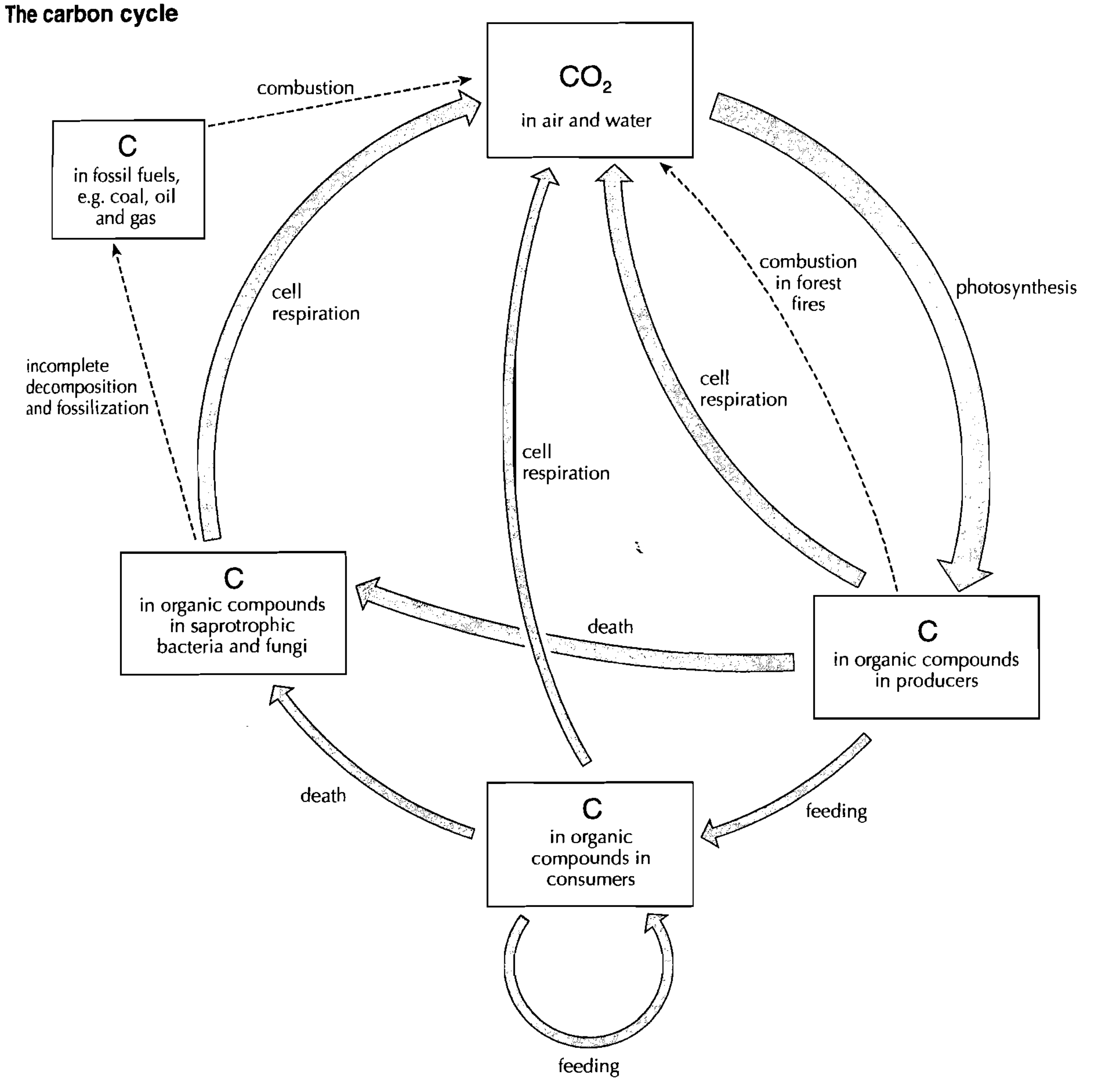
ECOSYSTEMS, ECOLOGISTS AND ECOLOGY

Communities of living organisms interact in many ways with the soil, water and air that surround them. The non-living surroundings of a community are its abiotic environment.
A community and its **abiotic environment** function together as a system called an **ecosystem**. *An ecosystem is a community and its abiotic environment.*
Ecologists study the complex relationships within ecosystems. This area of study is called **ecology**. *Ecology is the study of relationships in ecosystems – both relationships between organisms and between organisms and their environment.*

NUTRIENT RECYCLING IN ECOSYSTEMS

The recycling of nutrients is one example of the interactions between living organisms and the abiotic environment in an ecosystem. Energy is not recycled. It is supplied to ecosystems in the form of light, flows through food chains and is lost as heat. Nutrients are not usually resupplied to ecosystems – they must be used again and again by recycling. Carbon, nitrogen, phosphorus and all the other essential elements must be recycled. They are absorbed from the environment, used by living organisms and then returned to the environment.
The processes involved in the carbon cycle are shown below.

The carbon cycle



THE ROLE OF SAPROTROPHS IN RECYCLING OF NUTRIENTS

Saprotrophic bacteria and fungi have an essential role in nutrient cycles. They feed by secreting digestive enzymes into dead organic matter, including dead plants and animals and feces. The enzymes gradually break down the organic matter and the nutrients that were locked up in complex organic compounds are released. The saprotrophs absorb the substances that they need from the digested organic matter.
Without saprotrophs, nutrients would remain locked up permanently in dead organic matter and organisms that need the nutrients would soon become deficient.

Global impacts

HUMANS AND THE BIOSPHERE

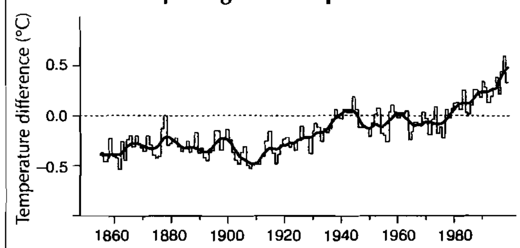
The ecosystems of the world are not isolated. They have effects on each other and sometimes even depend on each other. For example, carbon dioxide produced by one ecosystem can be carried in winds to another ecosystem and there be used in photosynthesis. Ecosystems function together as a system called the **biosphere**. The biosphere is the thin layer of interdependent and interrelated ecosystems that cover the Earth.

Many human activities have affected the biosphere. Even the ice of the Antarctic has been affected – it contains lead from vehicle exhausts and large amounts of it have melted as a result of the increased greenhouse effect. The increased greenhouse effect is an example of human activities having a global impact.

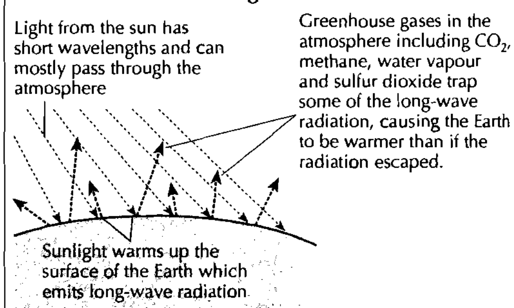
RISING GLOBAL TEMPERATURES

Temperature records have been analysed to find the mean for the whole world in each year from 1856 onwards. The figure (right) shows the difference between the mean temperature for each year and an overall mean temperature for the years 1961 – 1990. The trends are that, from 1856 until about 1910, temperatures were relatively stable, from 1910 until 1940 temperatures rose and were then stable and from 1970 there has been a rapid rise. These changes in temperature could have various causes, but the most likely cause is an increased greenhouse effect. The figure (below right) shows how gases in the atmosphere cause the greenhouse effect on Earth. Carbon dioxide has the greatest overall effect.

Graph of global temperatures



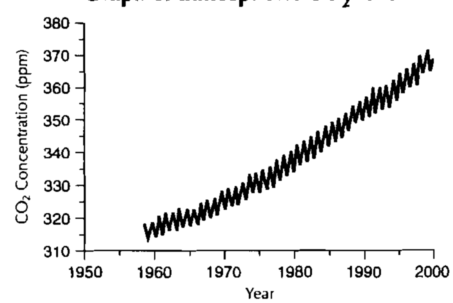
Cause of the greenhouse effect



RISING CARBON DIOXIDE LEVELS

The carbon dioxide concentration of bubbles of air trapped in Antarctic ice at different dates have been measured. These show that for 2000 years before 1880 the carbon dioxide concentration of the atmosphere remained fairly constant at about 270 parts per million (ppm). From 1880 onwards, the concentration rose. Since 1958 the concentration has been monitored continuously at Mauna Loa, Hawaii (below right). There is an annual fluctuation, but the overall trend has been upwards and the concentration is now 100 ppm higher than in 1880. This rise is enough to cause a significant increase in the greenhouse effect.

Graph of atmospheric CO_2 levels



CONSEQUENCES OF THE INCREASED GREENHOUSE EFFECT

The whole biosphere is likely to be affected in many ways:

- Global warming by up to 3 °C over the next 50 years.
- Rising sea levels due mainly to thermal expansion of water.
- Flooding of low-lying land including coral atolls.
- Melting of glaciers and polar ice.
- More frequent storms and hurricanes.
- Changes to weather patterns, with different areas becoming warmer or colder and wetter or drier.

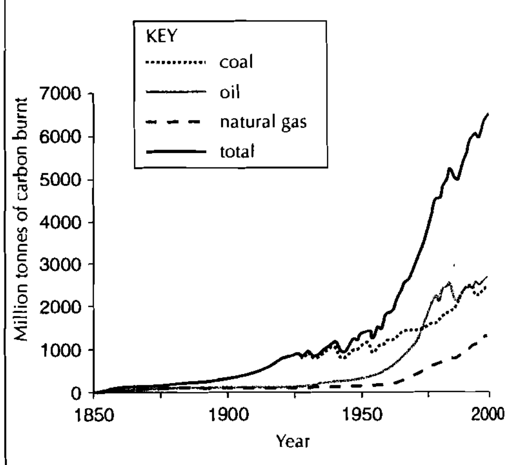
MEASURES NEEDED TO REDUCE THE GREENHOUSE EFFECT

Rising carbon dioxide levels are due to changes in the carbon cycle (page 43) including less photosynthesis and more burning of fossil fuels (right). To reduce the greenhouse effect, carbon dioxide absorption by photosynthesis must be encouraged and emissions from burning of fossil fuels must be reduced.

The following measures would help.

- Restoration of ecosystems where there has been deforestation, desertification or other damage, to encourage the growth of photosynthesizing plants.
- Spreading nutrients such as iron in nutrient-deficient oceans to encourage growth of photosynthesizing algae.
- Reducing energy consumption, for example by thermal insulation of homes, driving smaller vehicles or eating food grown locally rather than food transported great distances.
- Changing from fossil fuels as an energy source to solar, wind or nuclear power.

Graph of global use of fossil fuels



HUMANS AND HABITATS

Every species has its **habitat**. *The habitat of a species is the environment or location where it normally lives.* For example, the habitat of *Pinus aristata* (bristlecone pine) is exposed, dry, rocky slopes and ridges in the sub-alpine zone of mountains in Colorado, New Mexico and California. The habitat of *Hippocampus ramulosus* (seahorse) is among seaweeds and sea-grasses on the seabed in shallow parts of the Mediterranean and the Atlantic as far north as the English Channel.

Many human activities have an impact on a specific habitat – a local impact. Introduction of alien species can have devastating effects on a habitat – for example, the introduction of rats to New Zealand.

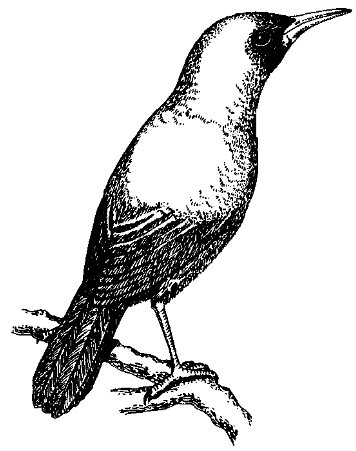
THE INTRODUCTION OF RATS TO BIG SOUTH CAPE ISLAND

Three species of rat that were introduced to the mainland of New Zealand during the nineteenth century eliminated many species of bird from the mainland. On islands that remained free of rats, some of these birds were able to survive. Until the 1950s Big South Cape Island (right) in the far south of New Zealand remained rat free and was a haven for many rare birds. Three types were, by then, found nowhere else: South Island saddleback (right), Stewart Island snipe and Stead's bush wren (bottom right).

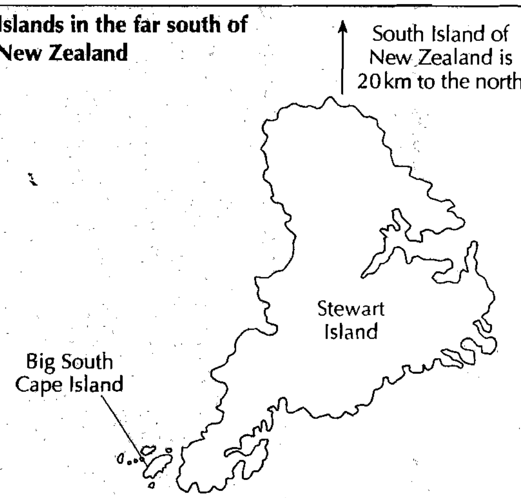
In the mid-1950s black rats (*Rattus rattus*) reached Big South Cape Island. Their numbers rose exponentially and by 1964 there were huge numbers on the island. They attacked eggs, young birds in nests and even adult birds, which were not behaviourally adapted to resist them. It became obvious that human intervention was needed to save the three rarest species of bird. Ecologists from the New Zealand Wildlife Service trapped as many of the remaining individuals as they could. Only two Stewart Island snipe were trapped and they died soon after, so this species became extinct. Nine Stead's bush wrens were trapped and transferred to another island that was still rat free. Unfortunately they failed to breed and gradually died out, so this species also became extinct. Forty-one South Island saddlebacks were caught and transferred to two other rat-free islands. They survived and bred and were eventually distributed to other islands. In the 1980s they were re-introduced to Little Barrier Island after another alien species had been eliminated – wild cats.

The South Island saddleback was the first species of bird to be saved from extinction by human intervention. Its future for the moment seems relatively secure.

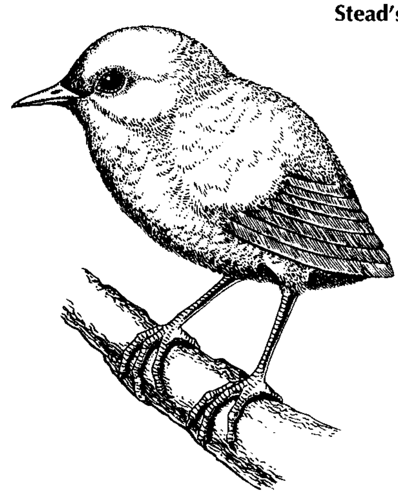
South Island Saddleback



Islands in the far south of New Zealand



Stead's bush wren



REDUCING THE IMPACT OF ALIEN SPECIES

Various lessons can be learned from Big South Cape Island.

- Alien species should never be introduced to habitats containing rare or endangered species.
- Alien species *can* sometimes be eliminated by trapping, poisoning or other methods.
- Human intervention is sometimes essential to save a species, for example moving a population to a safer area.
- Island nature reserves can play a vital role in ensuring the survival of rare and endangered species.

Some methods for controlling alien species that have been tried elsewhere have been found to have serious risks. For example predators have been introduced to try to control alien species, but they have sometimes attacked native species rather than the alien species. Diseases have also been introduced, but again this is a risky policy, as the spread of the disease cannot be predicted with certainty.