

ENVIRONMENTAL SCIENCE

EXTERNAL EXAM INFORMATION SHEET

'COMMAND' WORDS COMMONLY USED IN EXAMINATION QUESTIONS

Analyse	examine data mathematically to gain understanding of the data	Estimate	find an approximate value and always include the units of the number (value)
Calculate	to find the answer using mathematics	Evaluate	assess the limitations and implications
Compare	give an account of similarities and difference between two factors	Explain	give a detailed and clear account including causes and reasons
Construct	represent information in a graphical form	List	give a sequence of names or brief answers
Correlate	describe trends in one variable as another variable changes	Identify	find an answer for a quantity
Deduce	reach a conclusion from the information given	Interpret	provide conclusions that can be drawn from data
Describe	give a detailed account including all relevant information	Measure	use a measuring instrument to find a value for a quantity and always include the units of the number (value)
Design	produce a plan	Outline	give a brief account or summary
Discuss	give an account including a range of arguments, assessment of the importance of various factors or a comparison of alternatives	Predict	give an expected result
Distinguish	give the difference between two or more different items	Name	give the specific scientific term for
Draw	represent by means of pencil lines – include labels (unless told not to) – not to be confused with <i>Draw a Conclusion</i>	State	give a specific term for or definition of

CRITERION 2 – Develop, interpret and analyse experiments and investigations

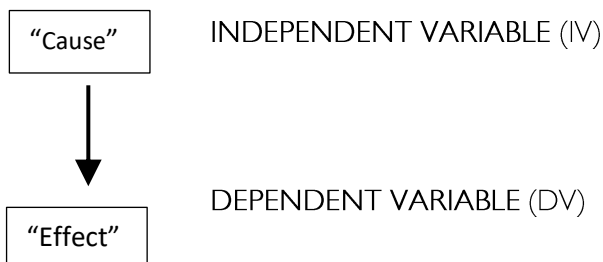
A Hypothesis should:

1. be a **statement** (not a question).
2. involve **one independent** and **one dependent variable** in a **cause-and-effect** relationship.

Experimental Design

State the hypothesis to be tested (unless already stated)

1. State the independent variable and how it is **manipulated**.
2. State the dependent variable and how it is **measured**.
3. Describe the procedure clearly in a step-by-step fashion which could be easily followed in a laboratory or the field.
 - Indicate **sample sizes**, quantities of materials and time involved. Indicate how many replicas there are (if needed).
 - Describe which variables are **controlled** and how. Say **why fixed variables are needed**. Include factors relevant for the organism – biotic, and those abiotic relevant in the environment.
 - What is the **control group** in the experiment and **why** is it needed.
4. How are the results analysed.
5. Indicate any repetitions of the experiment.
6. State what results would support the hypothesis and what results would not support the hypothesis.
7. Discuss any foreseeable problems in conducting the experiment.
 - Variables difficult to control, sample size issues, animal vs human experimentation/environmental impacts etc.



Also **ethical aspects** need to be considered.

Trial experiments conducted in a confined situation (laboratory/greenhouse) need to precede **field investigations**. If the results of these are positive, **small scale field investigations** are then carried out.

Distinction between a replica and a repeat

- A **replica** is multiple identical groups within the one experiment.
- A **repeat** is doing the experiment again in a future time.

Testing abiotic factors

Temperature: how hot or cold a substance is.

The temperature of a water body directly affects many physical, biological and chemical characteristics.

Temperature directly affects the metabolic rate of plants and animals. Aquatic species have evolved to live in water of specific temperatures.

Turbidity: opacity or muddiness caused by particles of extraneous matter; not clear or transparent.

Suspended material can be particles of clay, silt, sand, algae, plankton, micro-organisms and other substances. Turbidity affects how far light can penetrate into the water. It is not related to water colour: tannin-rich waters that flow through peaty areas are highly coloured but are usually clear, with very low turbidity.

Electrical conductivity: the property of a substance which enables it to conduct (carry) electricity. Salty water conducts electricity more readily than purer water. Therefore, electrical conductivity is routinely used to measure salinity. The types of salts (ions) causing the salinity usually are chlorides, sulphates, carbonates, sodium, magnesium, calcium and potassium.

pH: a measure of acidity (or alkalinity).

Dissolved oxygen: a measure of the quantity of oxygen present in water. Oxygen is essential for almost all forms of life.

Phosphorus a mineral nutrient that is essential for all forms of life. The phosphorus found in a form called **phosphate** (chemical formula, PO_4^{3-}). It is naturally derived from the weathering of rocks and the decomposition of organic material, but it can also enter waterbodies in runoff or discharges - soil and fertiliser particles can carry phosphorus, and sewage is also rich in phosphorus.

Nitrogen an element that is essential for all forms of life. The most common nitrogen compounds are ammonia (NH_3), nitrate (NO_3^-) and nitrite (NO_2^-). They occur in dissolved, particulate and gaseous forms. Present in freshwaters at higher concentrations than phosphate.

Although both nitrate and phosphate are required for plant growth, phosphate is considered to be the limiting factor in freshwater. In saltwater ecosystems, however, nitrate is much less abundant, and it becomes the nutrient that limits algal growth.

Other abiotic factors affecting the environment

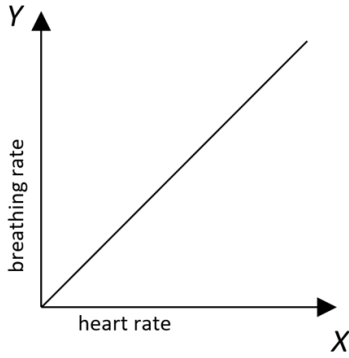
Consist of non-living components of the environment such as:

Light – intensity, direction and day length.

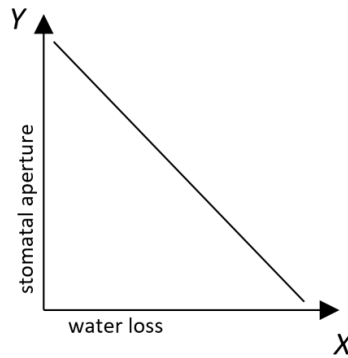
Wind – speed, direction and exposure levels.

Pressure – altitudinal effects and oxygen levels.

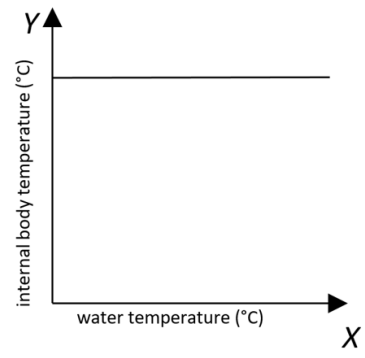
Analysing trends in graphs



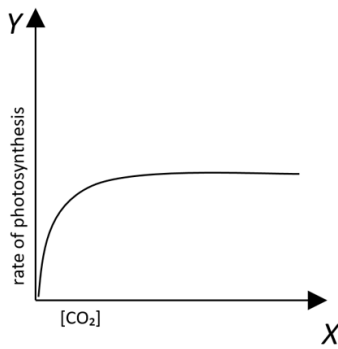
- a) Slope: constantly rising
 Interpretation: variable X causes variable Y to increase regularly



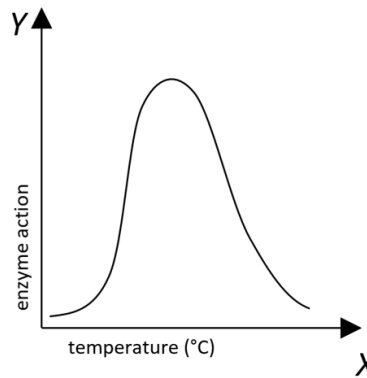
- b) Slope: constantly declining
 Interpretation: variable X causes variable Y to decrease



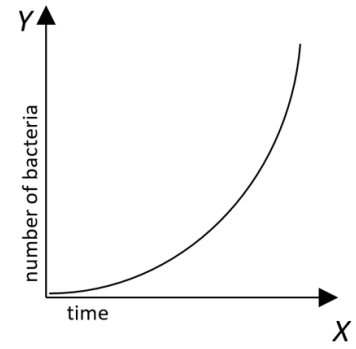
- c) Slope: constantly level
 Interpretation: variable X causes no change in variable Y



- d) Slope: rising then plateaus out
 Interpretation: variable X causes variable Y to increase initially, then has no effect



- e) Slope: rises, peaks, then declines
 Interpretation: variable X causes variable Y to increase, then to decrease

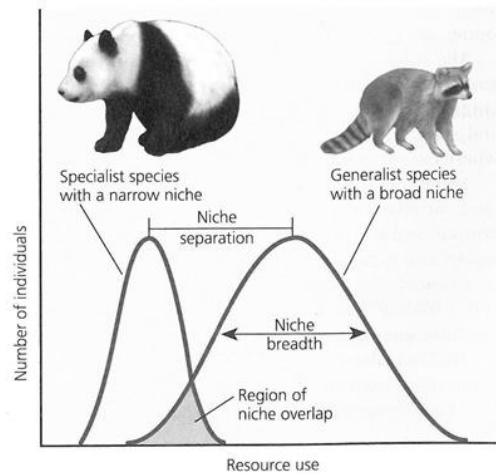


- f) Slope: becomes steeper and steeper
 Interpretation: variable X causes variable Y to rise exponentially

CRITERION 5 – Apply ecological concepts and processes

Ecology	The study of living organisms in the natural environment. How they interact with one another and how they interact with their nonliving environment.
Ecosystem	Community + Abiotic environment interacting.
Community	All the populations of the different species living and interacting in the same ecosystem.
Species	A group of organisms that can breed to produce fully fertile offspring.
Populations	A group of organisms of the same species which live in the same habitat at the same time where they can freely interbreed.
Biodiversity	The total number of different species in an ecosystem and their relative abundance.
Habitat	The characteristics of the type environment where an organism normally lives. (e.g. a stony stream, a temperate woodland).
Niche	Habitat + role + tolerance limits to all limiting factors.

Generalist and specialist species



Limiting factor

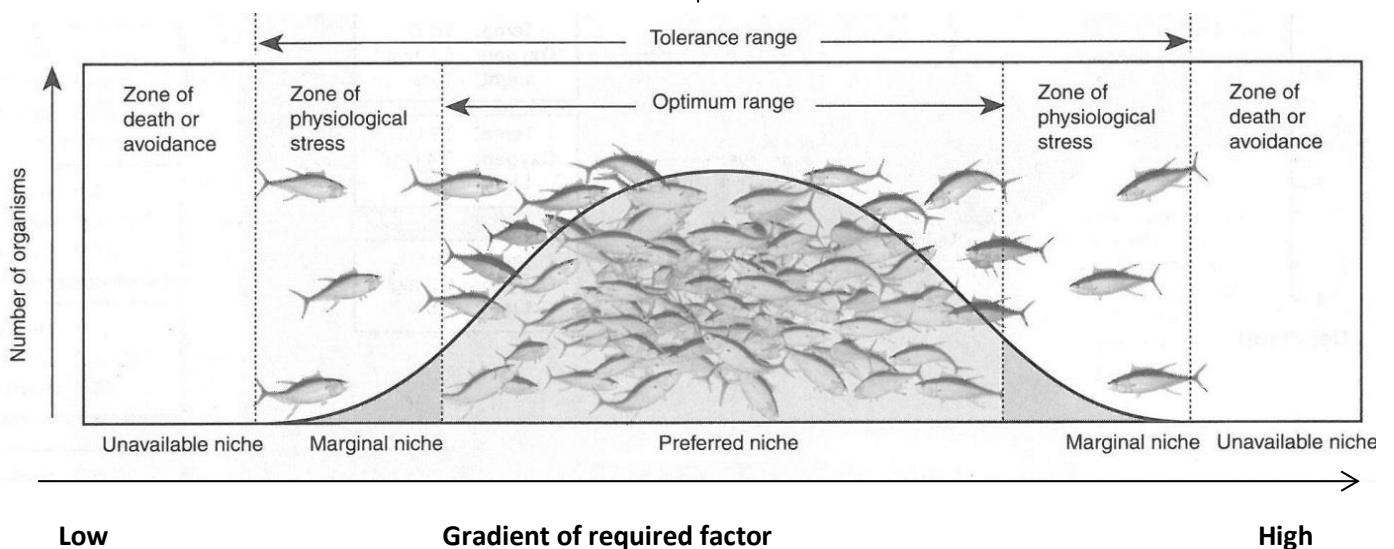
Too much or too little of any abiotic factor can limit or prevent growth of a population, even if all other factors are at or near the optimal range of tolerance.

Biotic factors

Consists of living and once living biological components – plants, animals and microbes. Also include dead organisms, dead parts of organisms, and the waste products of organisms.

Zone of tolerance

Each population in an ecosystem has a range of tolerance to variations in its physical and chemical environment. Individuals within a population may also have slightly different tolerance ranges for a factor due to genetic variation, health and age.



Systems

A system is defined as "an assemblage of parts and their forming a functioning whole". A system can be living or nonliving.

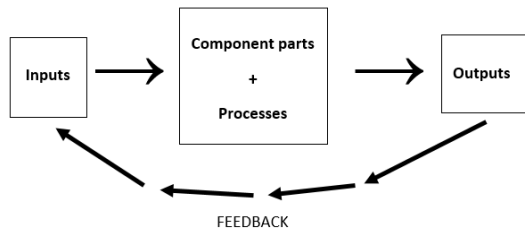
Components of systems

Inputs – matter or energy entering system.

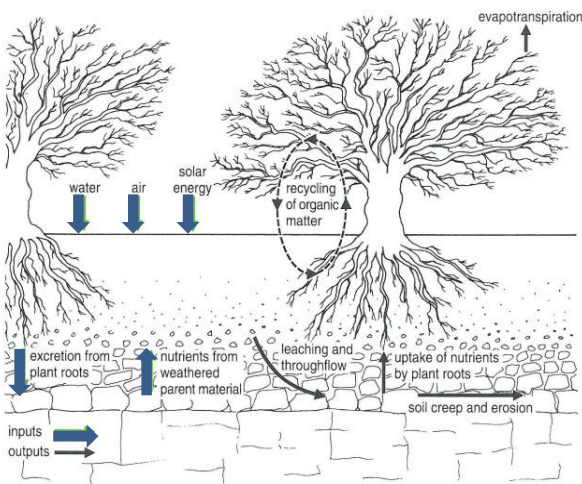
Outputs – matter or energy leaving system.

Component part – where processes take place.

Processes – which transfer or transform energy or matter from one form to another.



Example of a system - soil

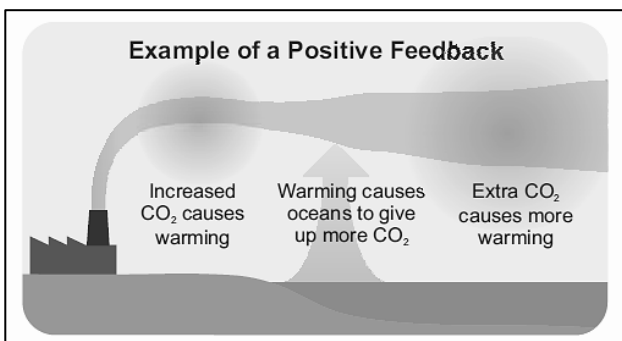


Feedback systems

Any process that increases or decreases a change to a system.

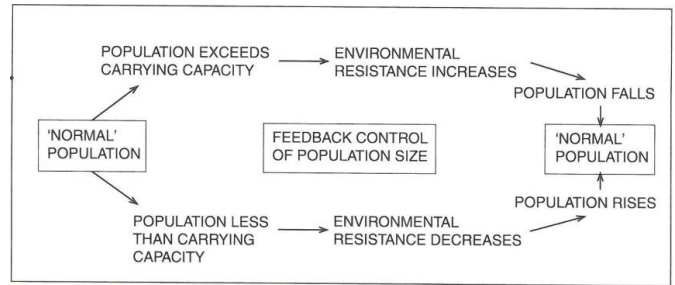
Positive feedback

Feedback loop that causes a system to change further in the same direction.



Negative feedback

Feedback loop that causes a system to change in the opposite direction from which it is moving e.g. population regulation around the carrying capacity.



Energy and organisms

Autotrophs / Producers Organisms which can synthesise their own complex, energy rich, organic molecules from simple inorganic molecules (e.g. green plants synthesise sugars from CO_2 and H_2O).

Heterotrophs / Consumers Organisms who must obtain complex, energy rich, organic compounds from the bodies of other organisms (dead or alive).

Detritivores Heterotrophic organisms who ingest dead organic matter (e.g. earthworms, woodlice, millipedes) **but do not decompose it into inorganic matter.**

Decomposers Heterotrophic organisms who secrete digestive enzymes onto dead organism matter and absorb the digested material (e.g. fungi, bacteria). Completely breaking down the organic molecules into inorganic molecules → make matter available to producers. Decomposers are responsible for the recycling of matter in the ecosystem.

Relationships among organisms in ecosystems

Type of interaction	Species A	Species B
Predator Prey	+	-
Herbivory	+	-
Mutualism	+	+
Commensalism	+	0
Competition	-	-
Parasitism	+	-

Key

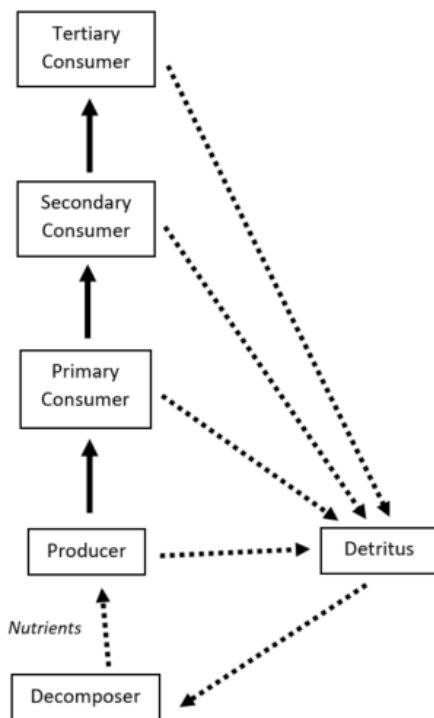
+ benefits
 - harmed (may not mean death)
 0 not affected

Food webs

Important conventions for drawing food webs:

- Sun (source of all energy) is NOT included.
- Autotrophs/Producers are on the bottom of the page.
- Species of the same trophic level are on the same row.
- Arrows show matter and energy flow; UP the trophic levels (UP the page).
- Next trophic or feeding level is one row 'higher' on the page.
- Top consumer is at the top of the page.
- If possible show a species only once, to avoid confusion and place that organism in the highest position.
- Always avoid sideways arrows.
- Dotted lines in food webs are used to show movement of energy through detritus and decomposers.

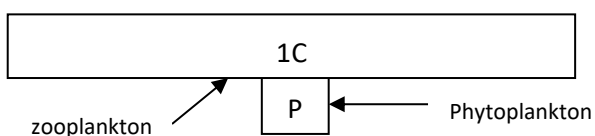
Food webs can be based off producers (grazing web) or detritus (detrital web) or both.



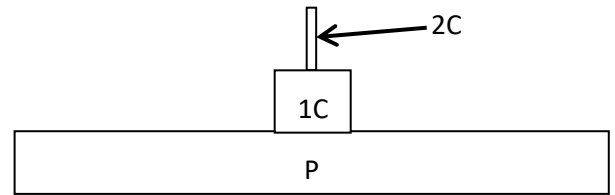
Ecological pyramids

Pyramid of biomass use total weight (dry mass) of organisms at each level - takes into account both numbers and mass).

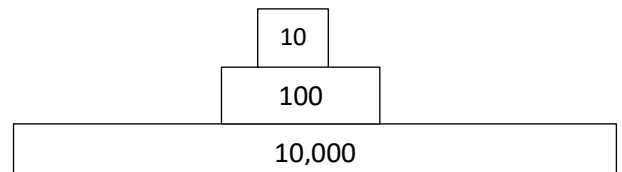
Both pyramids of numbers and biomass can be inverted.



Pyramid of energy - total energy at each level. Each level must be no more than 10% of previous.



Pyramid of numbers shows the number of organisms in a food chain. Such pyramids can be almost any shape depending on the biomass of the organisms at any trophic level



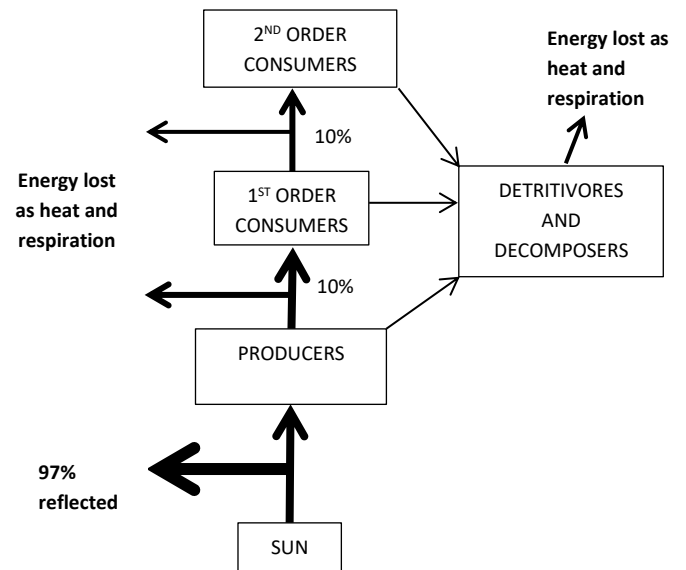
Energy flow

First law of thermodynamics

Energy is neither created nor destroyed. Energy is transformed from one form to another through the food chain.

Second law of thermodynamics

Energy conversions are never 100% efficient *i.e.* energy is lost as energy is passed from one trophic level to the next. Energy flow in food chains is one-way.



Photosynthesis

Complex process that takes place in cells of green plants (including algae).

Carbon dioxide + water + sunlight energy → Glucose + oxygen

Respiration

Aerobic respiration – produces a lot of energy in cells by using oxygen

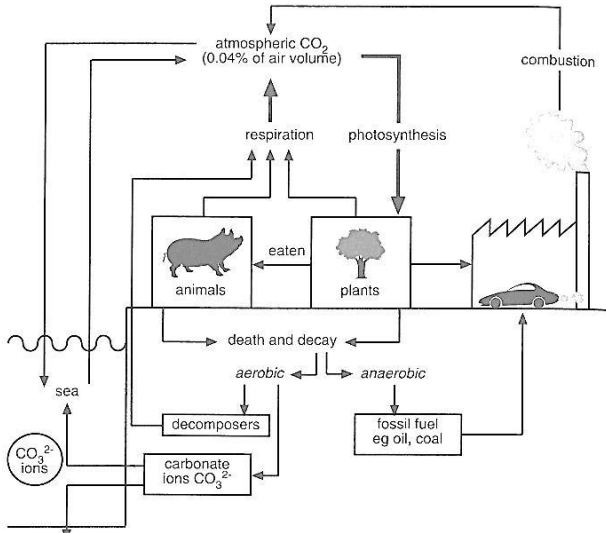
Glucose + oxygen → Carbon dioxide + water + energy

Anaerobic respiration – produces very little energy due to lack of oxygen. Used by some decomposers.

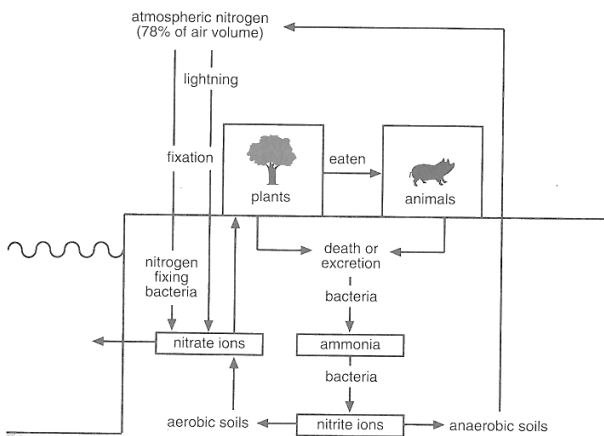
Biogeochemical cycles

- Cannot create/destroy atoms → there is a **finite** (fixed) amount of matter in our biosphere. Assume the earth is a closed system with no losses/gains of matter.
- **Recycling** of nutrients by decomposers.

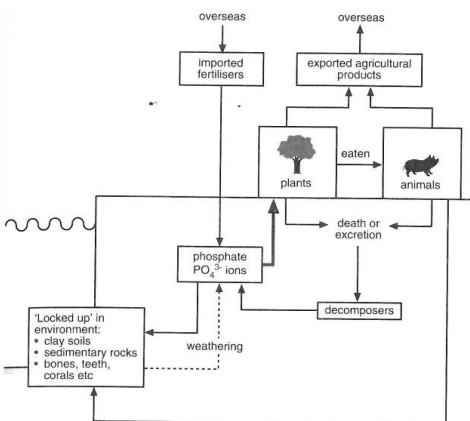
Carbon cycle



Nitrogen cycle



Phosphorus cycle

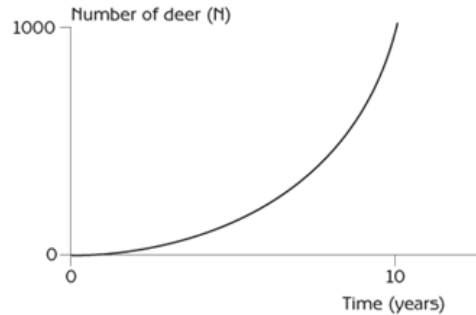


Populations

$$r = (b - d) + (i - e)$$

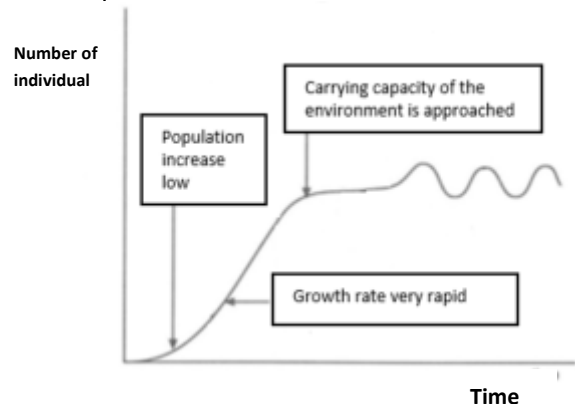
\downarrow \downarrow \downarrow \downarrow \downarrow
 growth birth death immigration emigration
 rate rate rate rate rate

In Ideal conditions – J curve



Growth is exponential and not sustainable in the long term as population either "crashes" or external factors regulate the growth rate.

In reality – S curve



Environmental resistance

Abiotic & biotic factors acting to limit population growth.

If a population overshoots its carrying capacity, negative feedback occurs (in the form of more deaths and fewer births due to lack of food) to reduce the population.

Factors which affect carrying capacity/population size

Abiotic factors – Density independent

e.g. temperature, humidity, rainfall, light intensity, sunlight hours, size of area, presence of trace elements, soil type may have a **direct** effect on the population – e.g. sunlight hours effects amount of photosynthesis and therefore plant growth OR an **indirect** effect – e.g. sunlight hours → photosynthesis → plant growth → kangaroo population.

Biotic factors – Density dependent

Population related factors that influence population size – e.g. competition, disease and predation.

Tasmanian forests

Four major types of forest groups in Tasmania

Dry Sclerophyll

- open canopy
- little understorey
- many grasses
- short sharp prickles

Wet Sclerophyll

- open canopy
- dense understorey
- fewer mosses and ferns

Mixed forests

- Open canopy of eucalypt species with an understorey of rainforest species

Rainforest

- closed canopy
- thin understorey
- many mosses, lichens, ferns

Criterion 6 – Apply concepts and processes of ecosystem change

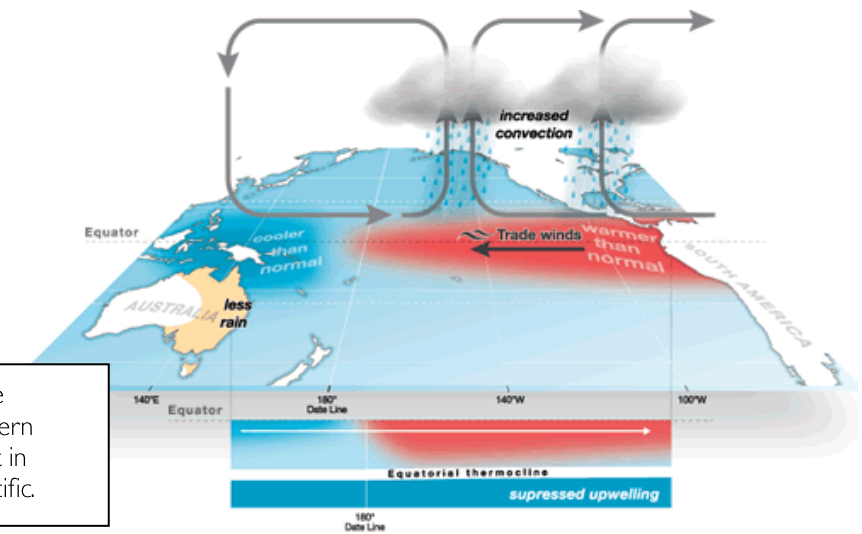
Climate drivers

The climate of any region is largely determined by four geographic aspects: latitude, distance from the sea, direction of the prevailing winds and elevation.

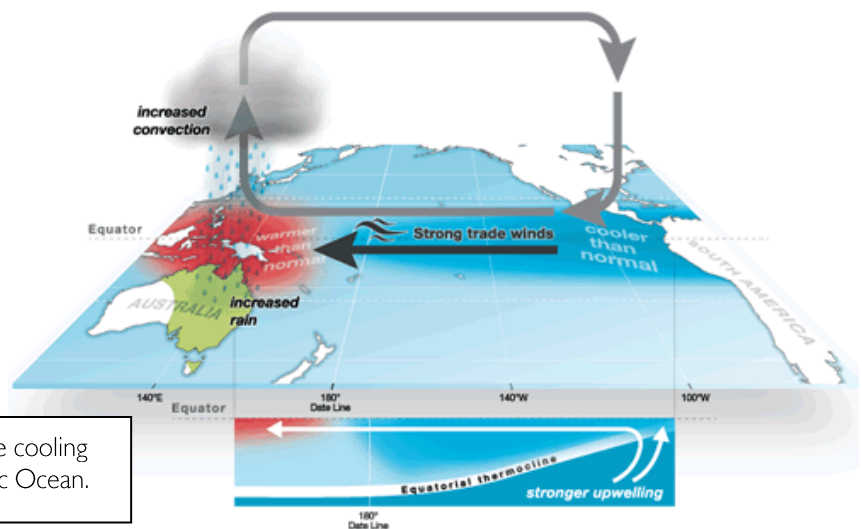
El Niño and La Niña

The seasonal changes in the heating and cooling of sea surface temperatures tend to follow a fairly predictable pattern.

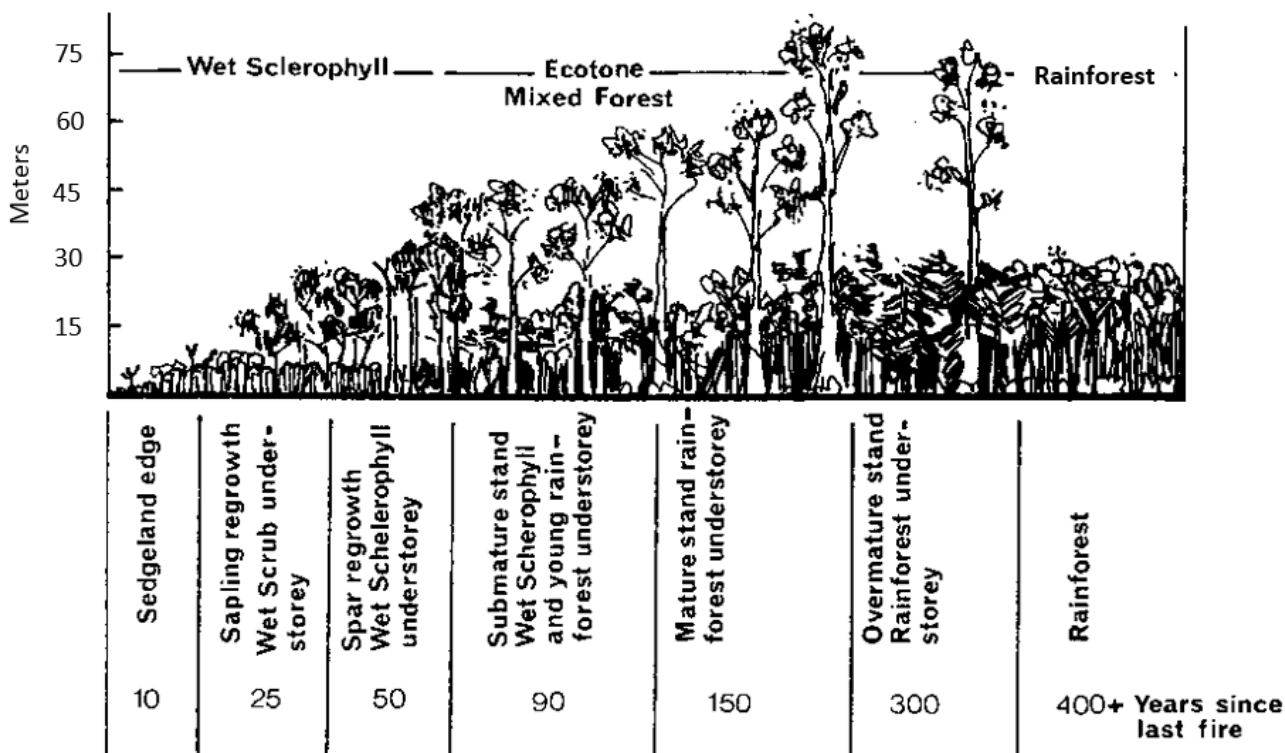
- El Niño refers to the extensive warming of the central and eastern Pacific that leads to a major shift in weather patterns across the Pacific.



- La Niña refers to the extensive cooling of the central and eastern Pacific Ocean.



Changes in a high rainfall area forest type due to absence of fire



Biodiversity

Types of biodiversity

1. Genetic: the variety of genetic information contained in all of the individual plants, animals and microorganisms that inhabit the earth - genetic diversity occurs within and between the populations of organisms that comprise individual species as well as among species.
2. Species: the variety of species on earth.
3. Ecosystem: the variety of habitats, biotic communities and ecological processes.

Processes that threaten biodiversity (HIPPO C)

- Habitat destruction
- Introduced species
- Population growth
- Pollution
- Overconsumption
- Climate change

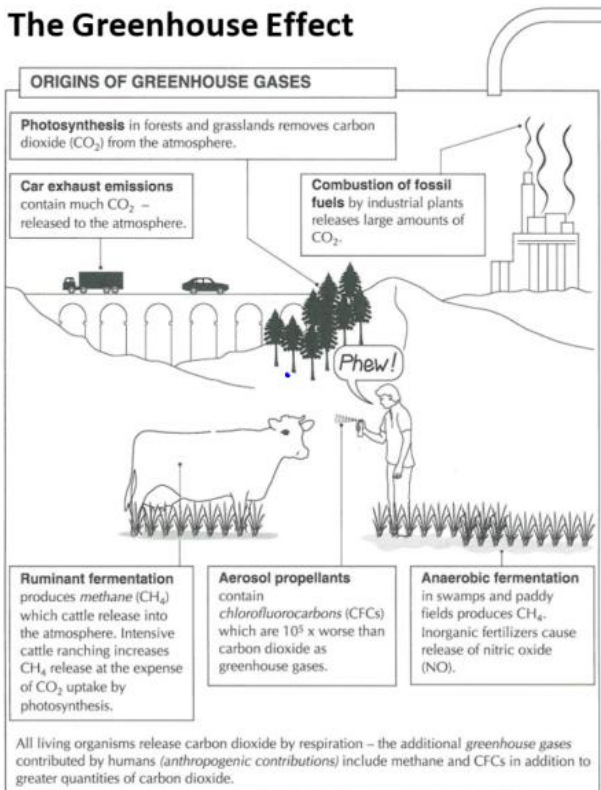
Species least at risk	Species most at risk
Broad range of physiological tolerance to factors such as temperature, water availability and fire	Narrow range of physiological tolerance
High degree of variability in the physical appearance of individuals and genetic variability	Low genetic variability
Short life cycles and high fertility	Long life cycles and low fertility
Good dispersal capacity	Poor dispersers
Broad geographic range	Narrow geographic range

EPBC listing status categories

- Extinct – no individuals alive
- Extinct in the wild – no individuals alive in the wild, but may occur in captivity of some description
- Critically endangered – extremely high risk of extinction in the immediate future
- Endangered - extremely high risk of extinction in the near future
- Vulnerable – not endangered but facing very high risk of Extinction in the medium term future.
- Conservation dependent – not vulnerable but needs a conservation program to survive or will move into one of the other categories.

Climate change

The Greenhouse Effect



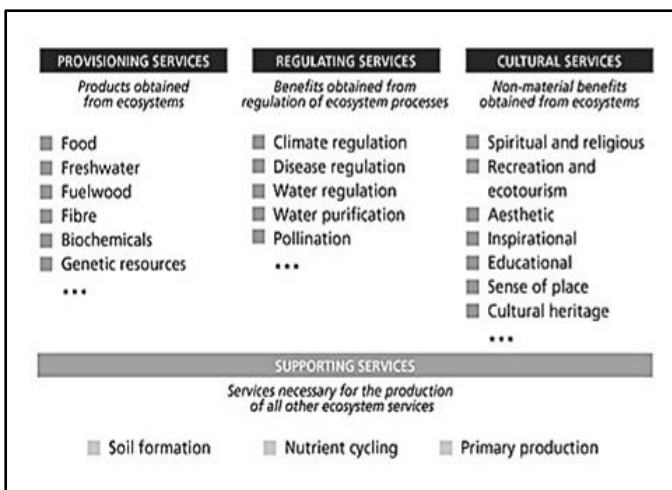
Introduced species

See notes on chemical and biological control of introduced species on page 15.

Criterion 7 - Apply concepts relating to human dependence and impact on ecosystems

Ecosystem services

The role of ecosystems in providing humans with services.



Ecological footprints

Ecological footprint - the amount of productive land appropriated on average by each person (in the world, a country etc.) for food, water, transport, housing, waste management, and other purposes.

Global hectare - (acre) is one hectare (2.47 acres) of biologically productive space with an annual productivity equal to the world average.

Pollution

Contamination occurs when a substance is present in the environment at a level greater than it is naturally found but causes no harm.

Pollution occurs when the presence of a substance in the environment prevents the functioning of natural processes and produces undesirable environmental and health effects *i.e.* any undesirable change in the chemical, physical or biological characteristics of an ecosystem that causes harm.

Primary pollutant - is one that is unchanged since production.

Secondary pollutant is created when a primary pollutant reacts with other forms of pollution or with an environmental component.

Sources of Pollution

- **Point sources**
 - Source of pollution with specific points of discharge.
- **Diffuse sources**
 - Sources of pollution that are harder to identify.

Degradable pollutant – can be broken down by natural processes.

Biodegradable pollutant - can be broken down living organisms.

Persistent pollutant takes a long time to break down.

Biological magnification

Some poisons (those that are not **biodegradable**) are not completely broken down and excreted by organisms, instead they accumulate in tissues and are passed along a food chain.

Atmospheric pollution

Three factors determine level of air pollution

1. Amount of pollutants entering the air.
2. Amount of space into which the pollutants can spread out.
3. Mechanisms that remove pollutants from the air.

Particles - (or suspended particles) are small solid particles of dust (e.g. dust from a dirt road) or organic material (e.g. pollen), they also include liquid droplets such as tiny droplets of oils and tars (e.g. wood-smoke). Larger particles quickly fall out of the air due to gravity (referred to as 'dust fallout') but smaller particles (those less than about 0.1mm diameter, referred to as 'total suspended particles') may remain in the air for many hours.

PM₁₀ - is particulate matter (particles) less than 10 micrometres (µm) in diameter. These are tiny particles that are too small to see individually but if there are millions of them they become visible as smoke or mist.

PM_{2.5} - is particulate matter (particles) less than 2.5 micrometres (µm) in diameter. They are of greatest concern to air pollution professionals because they penetrate deep into our lungs when we breathe and can carry toxic compounds that cause illness.

Primary pollutants

– Pollutants released *directly* into atmosphere mainly as a result of burning fuels and wastes

Secondary pollutants

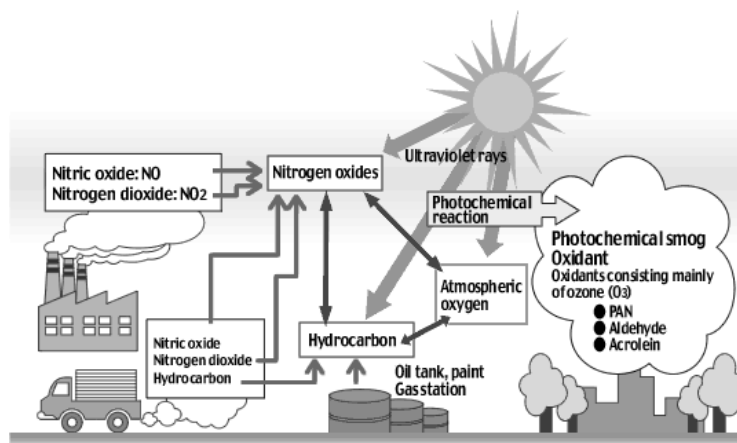
– Pollutants resulting from *reactions* of primary air pollutants in the atmosphere

Smog

- **Industrial smog**

Greyish mixture of moisture, soot, and sulphurous compounds. Occurs in industrial areas and where coal is a primary energy source.
- **Photochemical smog**

Brownish haze that typically forms over large cities with lots of automobile traffic.



Water pollution

Dissolved oxygen (DO): the oxygen dissolved in sewage, water, or other liquid, usually expressed in milligrams per litre or percent of saturation. It is the test used in BOD determination.

Dissolved solids: the total amount of dissolved material, organic and inorganic, contained in water or wastewater. Excessive dissolved solids make water unpalatable for drinking and unsuitable for industrial use. Measurements are expressed as ppm or mg/L.

Effluent: a liquid that has passed through a processing operation.

Pollution of the atmosphere

LEAD COMPOUNDS may slow mental development. They are in 'anti-knock' additives in petrol, and are released into the atmosphere from exhaust gases. Now most cars use lead-free petrol.

THE GREENHOUSE EFFECT CAUSES GLOBAL WARMING

Greenhouse gases include:

- Carbon dioxide released by combustion of fossil fuels
- Methane produced by ruminants – released from gut into atmosphere
- CFC's from aerosol propellants
- Nitrous oxide from fossil fuel combustion in transport and power production, and nitrate fertilisers

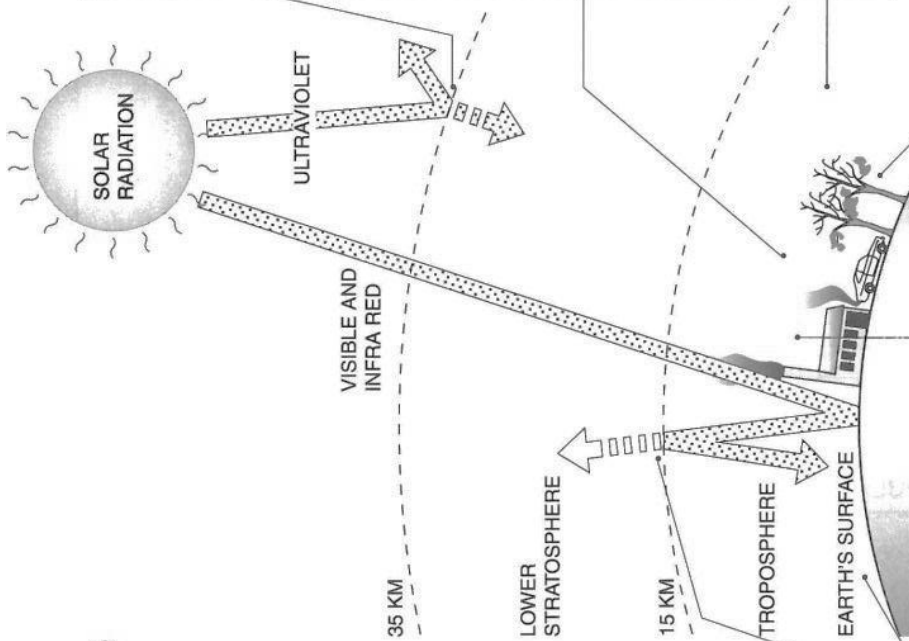
Heat cannot escape if the atmosphere contains high levels of these gases. The infra-red radiation is reflected back towards the Earth's surface.

There are good and bad results

more carbon dioxide and higher temperatures mean **more photosynthesis** and **more food**.

Global warming causes

- greater climatic extremes - high winds and heavier rains
- rising sea levels due to melting of polar ice
- crop losses as water evaporates from fertile areas
- extended range of pests



ATMOSPHERIC OZONE IS ESSENTIAL (but in the wrong place it can be harmful!)

High level ozone offers protection: ozone absorbs solar ultraviolet radiation which would reach the Earth's surface and cause

- sunburn
- skin cancer
- cataracts
- mutations (damage to DNA)



'Holes' in the ozone layer have been detected over Antarctica and are thought to have been caused by chlorine from long-lived CFCs.

Human activities affect ozone levels

CFCs (chlorofluorocarbons) used in aerosols, refrigerator coolants and expanded plastics **decrease amounts of high level ozone.**

Fossil fuel combustion produces oxides of nitrogen which react with oxygen to **increase amounts of low level ozone.**

Low level ozone causes problems

- acts as a **greenhouse gas**
- contributes to trapping of dust and smoke: **smog**
- causes **irritation** of eyes, throat and lungs
- damages mesophyll in leaves: **reduction in crops.**

ACID RAIN

Human activities release acidic gases

- Sulphur and nitrogen in fossil fuels are converted to oxides during combustion.
- More oxidation occurs in the clouds, and is catalysed by ozone and unburnt hydrocarbon fuels.
- The oxides dissolve in water, and fall as **acid rain**.



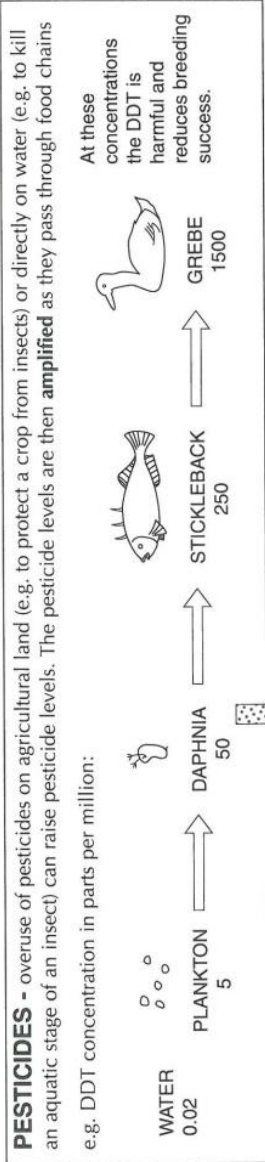
Acid rain causes problems

- Soils become very acidic. This causes **leaching of minerals** and **inhibition of decay.**
- **Water in lakes and rivers** collects excess minerals. This causes **death of fish and invertebrates** so that food chains are disrupted.
- **Forest trees suffer starvation** because of (a) leaching of ions (b) destruction of photosynthetic tissue.

Acid rain can be reduced

- reduce emissions from car exhausts with **catalytic converters.**
- reduce emissions from power stations with **scrubbers.**
- use 'cleaner' power sources e.g. hydro- and nuclear power.

Pollution of water



LEAD POLLUTION - water pipes were traditionally made of lead. Lead dissolves into the water which flows through the pipes. Lead compounds are toxic and accumulate via food chains. Lead weights discarded by anglers also contribute to lead pollution.

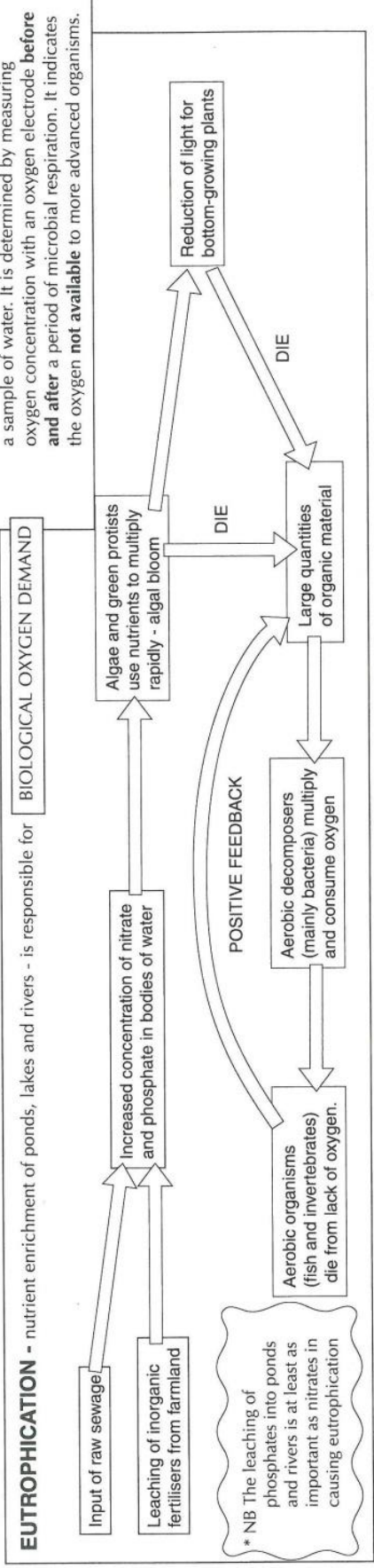
OIL POLLUTION - oil tankers spill their contents, by accident or deliberately (during cleaning), into the sea. The oil floats on the surface, causing

- death of seabirds since feathers lose their ability to insulate when they are coated with oil.
- fish are directly poisoned
- marine mammals are killed by eating poisoned food or by loss of fur's insulating capacity.

THERMAL POLLUTION - industries / power stations use water as a coolant, then discharge the water into rivers.

Now has **lower oxygen concentration** as the capacity of water for dissolved oxygen decreases as temperature rises, and as fish and bacteria become more active and so respire more. May have **new species** e.g. tropical fish, terrapins which may affect food chains.

B.O.D. is the mass of oxygen consumed by micro-organisms in a sample of water. It is determined by measuring oxygen concentration with an oxygen electrode **before and after** a period of microbial respiration. It indicates the oxygen **not available** to more advanced organisms.



Major water pollutants

Pollutant	Major Sources	Effects
Sewage	Various industries, household waste, dumping at sea	Kills aquatic life, dangerous to human health causing a range of gastro-intestinal diseases
Heavy metals, (eg arsenic, cadmium, mercury)	Industry (e.g. chemical, metal), urban run-off, mining	Diseased and contaminated fish, passed through food chain to humans causing lung, heart and nervous disorders
Polychlorinated biphenyls (PCBS)	Industry (e.g. chemical, pulp paper, plastics)	Diseased and contaminated fish and shellfish, damage to vital human organs
Radioactive waste	Nuclear power stations, dumping at sea	Contamination of water, increased risk of cancer
Oil	Oil refineries, flushing of tankers, accidental spills	Kills birds and marine life, poisonous to humans
Biocides (e.g. DDT, dieldrin)	Run-off from farmland	Persistent, pass through food chain to humans, may cause birth defects, cancer and other illnesses
Nutrients	Fertilisers in run-off from farmland, sewage, animal waste	Increased algae in water, causing lack of oxygen, aquatic life destroyed
Sediment	Soil erosion from cleared land	Blocks light needed by aquatic life, pipes and drains become blocked, waterways become too shallow for boats and ships
Plastics	Household waste, litter, dumping	Destroys natural habitats, strangles and mutilates wildlife
Hot water	Power stations, various industries	Harms aquatic life, destroys natural habitats
Acid rain	Power stations, various industries, motor vehicles	Aquatic life killed, pipes corroded, illness in humans

Major air pollutants

Pollutant	Sources	Effect
Carbon monoxide	Motor vehicles, burning of fossil fuels	Blood absorbs carbon monoxide more readily than oxygen, reducing the amount of oxygen being carried through the body. Carbon monoxide can produce tiredness and headaches. People with heart problems are particularly at risk.
Sulfur dioxide	Coal and oil burning power stations, mineral ore processing and chemical manufacture	Attacks the throat and lungs. People with breathing problems can suffer severe illness.
Nitrogen dioxide	Fuel combustion	Affects the throat and lungs
Volatile organic compounds	Motor vehicles, fuel combustion, solvent use	Some VOCs cause eye and skin irritation, headaches or nausea, while some are classed as carcinogens
Ozone	Released by motor vehicles and industry.	Ozone attacks the tissue of the throat and lungs and irritates the eyes
Lead	Exhaust gases from motor vehicles that use leaded petrol, smelters.	Particles containing lead in the air can enter the lungs. The lead can then be absorbed into the blood stream. Over a period lead can affect the nervous system and the body's ability to produce blood.
Particles	Motor vehicles, burning of plant materials, bushfires.	May cause breathing difficulties and worsen respiratory diseases. Some may contain cancer-producing materials

Control of introduced and pest species

Problems with Insecticides: these arise since the principal idea behind chemical control is to kill as many of the pests as possible – the effects on harmless or beneficial organisms were not studied or were ignored. Major problems include:

- **Pest resistance:** genetic variation means that each pest population contains a few resistant individuals. The pesticide eliminates the non-resistant forms and thus a resistant population is selected for and may quickly develop (since many pests reproduce rapidly).
- **Bioaccumulation of toxins:** pesticides or their products may be toxic
 - a. They may seriously affect micro-organisms and thus alter decomposition in soils;
 - b. They may pass along food chains, becoming more concentrated in organisms further up the chain.

Other issues include:

- **Direct killing**
- **Non-specificity**
- **Pest replacement**
- **Pest resurgence**

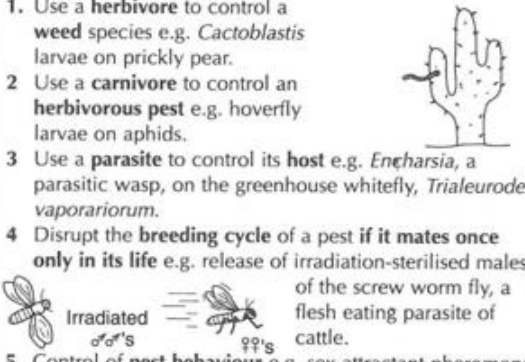
Similar problems exist with the use of **herbicides** for controlling unwanted plants.

Biological pest control

depends on an understanding of the relationship between populations of predators and their prey.

PRINCIPLE
TECHNIQUES IN BIOLOGICAL CONTROL

1. Use a **herbivore** to control a **weed** species e.g. *Cactoblastis* larvae on prickly pear.
2. Use a **carnivore** to control an **herbivorous pest** e.g. hoverfly larvae on aphids.
3. Use a **parasite** to control its **host** e.g. *Encharsia*, a parasitic wasp, on the greenhouse whitefly, *Trialeurodes vaporariorum*.
4. Disrupt the **breeding cycle** of a pest if it **mates once only in its life** e.g. release of irradiation-sterilised males of the screw worm fly, a flesh eating parasite of cattle.
5. Control of **pest behaviour** e.g. sex attractant pheromones are used to attract apple codling moths into lethal traps.



A comparison between biological and chemical control

	BIOLOGICAL CONTROL	CHEMICAL CONTROL
SPECIFICITY	Very high, so little danger to beneficial species or to humans	May be low, but legislation leading to great improvements
'ACCUMULATION' IN ECOSYSTEMS	None	Concentrations may increase along food chains
PERMANENCE OF CONTROL	Good, but small numbers of pests must be tolerated	Requires regular reapplication
DEVELOPMENT OF PEST RESISTANCE	Very rare	Common, requiring ever-increasing 'dose'
COST IN FINANCIAL TERMS	Initially may be high, but very low in the long-term	May be very high, restricting use to wealthy nations

Criterion 8 - Apply principles and processes related to ecologically sustainable management of the environment

Tragedy of the commons

Depletion or degradation of a potentially renewable resource to which people have free and unmanaged access e.g. oceans, atmosphere, fisheries in international oceans.

Ecologically sustainable development

A sustainable society is one in which all human activity takes place and is maintained over time within the limits of the earth to provide the necessary resources for survival (particularly food) and assimilate waste.

A sustainable society allows the human members to meet their own needs without compromising the needs of other species and future generations of humans.

Principles of sustainable development

Ethical considerations

Intergenerational Equity- It is important that future generations of humans have supplies of important resources and that they are not required to clean up the environmental disasters of the past.

Intra-generational Equity – The resources of the planet should meet the needs of all humans and all human should have access to clean water, clean air, and basic food materials, fibres for clothing, building materials and other basic human requirements.

Ecological Integrity - It is important that all the ecosystems be able to continue to function. The biodiversity of ecosystems must be maintained as well as the habitat necessary for them to survive.

Strategies

Precautionary & Anticipatory Principles – These should apply to all new developments. The development should only be allowed if it can be proved beyond doubt by the developer that it will not harm the environment.

Full Cost Pricing - In the use of natural resources all values should be considered in the price not just the financial values. The user pays principle should always apply. The cost of cleaning up pollution should also be included in the price – the polluter pays principle.

Efficient Use of Resources - The use of non-renewable resources should be decreased and the use of renewable resources increased. Reusing and recycling should be encouraged.

Approaches to sustainable development

Education

Establishing community based programs that involve the public in environmental management. Damage already done can be repaired and future problems can be avoided. This approach is less expensive and helps create an environmental ethic in the community. Waterwatch, Coastcare and Landcare are good examples of this approach.

Legislation

In Australia there are three levels of government: Commonwealth/Federal, State and Local (councils).

Governments produce environmental laws that essentially provide a set of rules governing human interactions with the environment. They provide a legal framework to prohibit activities that cause harm (e.g. the Federal Ozone Protection Act regulates the release of ozone depleting gases, and the Tasmanian Environmental Management and Pollution Control Act sets guidelines for sewerage treatment and discharge of effluent). Legislation can be used to assist decision making to ensure only sustainable developments progress (e.g. the Federal EPBC act is used to assess significant projects during the approvals process). Legislation can also be used to support conservation and positive interactions with the environment (e.g. the Tasmanian National Parks and Reserve Management Act sets out the guidelines for allocating and managing land within out state reserves).

Legislation is often tied with economic incentives and disincentives to encourage or discourage certain activities.

International agreements are proposed and adopted through a governing body (in most cases this is the United Nations) and examples include: CITES, Montreal Protocol, IWC, Law of the Sea, World Heritage Convention, Ramsar Convention, CCAMLR.

Economic

This approach uses economics to encourage good environmental practice. Green Economics consists of a group of strategies that would promote this concept.

Green Economic Strategies include:

- The Polluter Pays Principle
- Full-cost Pricing / user pays principle
- Economic incentives
- Economic Disincentives
- Tradable/Marketable Permits
- Market Forces
- Accounting for environmental assets
- Mandatory renewable energy targets (MRETs)

Two economic approaches to improved environmental control

Market based approach	Government control
Examples	
Taxes –fuel / carbon taxes	Environmental standards – usually set by EPA
Improved property rights – transferable water rights in Murray Darling Basin, which increases the value of water and reduces wasteful irrigation practices.	Licences – pollution control permits,
Tradeable emission permits – used to reduce emissions in some places	Regulations – refundable deposits in SA, lead free petrol, emission control on cars
Realistic pricing - user pays	

An **externality** is a cost that can be passed on to someone else and is therefore not considered in the cost/benefit analysis e.g. milk processors are not required to pay for the disposal of the milk cartons, the local council meets this cost. In **full cost pricing** this cost would be included in the price of a carton of milk.

Technology

Includes new innovations resulting from research and development to lessen environmental impact e.g. electric cars, energy efficient LED lighting and dual flushing toilets.

Enhanced technology also allows better environmental monitoring e.g. more sensitive probes capable of detecting lower levels of gases or use of trail cameras for a population census.

Management tools – EIA/EIS

An Environmental Impact Assessment is required for all major projects. It allows us to predict the impact of a development on the environment, manage our resources more effectively and improve our decision making.

An EIA examines the likely impact on the environment of a project and examines the social and economic impacts as well as the impact on the biophysical environment. The biophysical impact must consider the effects on soil, the air and the water as well as the living organisms.

An EIA links together three groups- the developer, the community and the decision makers.

Steps in the EIA process

1. Initiate - the developer initiates the projects and identifies the type of assessment that should be made.
2. Identify the Issues - advice is sought from industry, the community and from governments as to what issues should be addressed in the EIA.
3. Develop Alternatives - including different locations, different designs and always the alternative to 'do nothing'.
4. Predict the likely impact and identify the type of study that should be made.

5. Evaluate the alternatives to make the best decision.
6. EIS - a formal document is completed and presented.
7. Make a decision based on the document. If the answer is "Yes" to the proposal, conditions may be applied.
8. Monitor the projects to see if any conditions have been met, if the predicted impacts occur and to help future decision making.

Management plans

What they are

Management plans are one of several management tool that can be used to promote sustainable development and reduce the impact of human activities on the environment. They are more commonly used for projects and activities that are already in use rather than new projects.

A management plan should include:

- A description of the area and its significance in the region. A map of the area should be included and it should include access points and services available.
- Information about the legal status of the area and any relevant legislation (both State and Federal) should be noted
- The values of the area should be identified and the stakeholders identified. A consultation process with the stakeholders should be established.
- A list of management objectives should be created.
- A baseline study should be designed to document the biotic and abiotic factors relevant to the area. Special note should be made of threatened or endangered species.
- A vision statement should be prepared. Major threats should be identified and a recovery plan should be included if necessary. What human amenities are required should be identified. The vision statement should show how the area should look after a period of time.
- An ongoing plan for monitoring (including specific technology) should be created.
- A timeframe for evaluating and reviewing the current plan.

Managing Biodiversity

- **Conservation reserves** e.g. National Parks, Marine protected areas - Protection of natural and scenic areas of national or international significance for scientific, educational and recreational use.
- The National Reserve System is underpinned by a scientific framework to ensure that Australia progressively extends protection to examples of all our ecosystems.

The scientific framework has a clear objective: to develop a 'comprehensive, adequate and representative' system of protected areas - commonly referred to as the '**CAR**' reserve system.

Specifically **CAR** means:

- **Comprehensive**: the inclusion in the National Reserve System of examples of regional-scale ecosystems in each bioregion.
- **Adequate**: the inclusion of sufficient levels of each ecosystem within the protected area network to provide ecological viability and to maintain the integrity of populations, species and communities.
- **Representative**: the inclusion of areas at a finer scale, to encompass the variability of habitat within ecosystems.

Glossary of Environmental Science terms

Acid deposition: rain or snow that has a lower pH than precipitation from unpolluted skies.

Acid mine drainage: sulphuric acid that drains from mines, especially abandoned underground coal mines. Created by the chemical reaction between oxygen, water, and iron sulphides found in coal and surrounding rocks.

Active solar: capturing and storage of the sun's energy through special collection devices (solar panels) that absorb heat and transfer it to air, water, or some other medium, which is then pumped to a storage site (usually a water tank) for later use. Contrast with *passive solar*.

Adaptation: a genetically determined structural or functional characteristic of an organism that enhances its chances of reproducing and passing on its genes.

Agricultural society: a group of people living in villages or towns and relying on domestic animals and crops grown in nearby fields.

Albedo: a measure of the reflectivity of the earth's surface to light.

Algal bloom: rapid growth of algae in surface waters.

Anthropogenic: created by humans.

Aquaculture: cultivation of fish and other aquatic organisms in freshwater ponds, lakes, or other bodies of water.

Aquifer: underground layer of porous material containing water (ground water).

Atmosphere: layer of air surrounding the earth.

Autotroph: an organism that can produce its own food.

Strategies for managing biodiversity

- **Corridors** – connect fragmented habitats.
- **Translocation** – transfer of plants or animals from one part of their range to another.
- **Reintroduction** – of plants and animals that have been raised in captivity to replace those that have become locally extinct. **Captive breeding** programs are very important.
- **Biodiversity hotspots** –concentrating efforts on protecting significant hotspots where significant biodiversity is under immediate threat.
- **Rehabilitating and restoring** – increases habitat for restricted populations.
- **Quarantine** – aims to reduce major threats by controlling access or removing to a known safer location.

Biological or biochemical oxygen demand (BOD): measure of oxygen depletion of water (largely from bacteria decay) due to presence of biodegradable organic pollutants. Gives scientists an indication of how much organic matter is in water.

Bioaccumulation: ability of an organism to selectively accumulate certain chemicals, elements, or substances within its body or within certain cells.

Biogas: a gas containing methane and carbon dioxide. Produced by anaerobic decay of organic matter, especially manure and crop residues.

Biological control: use of naturally occurring predators, parasites, bacteria, and viruses to control pests.

Biomass: the dried weight of all organic matter in the ecosystem. Any form of organic material (from both plants and animals) from which energy can be derived.

Biomass pyramid: see *pyramid of biomass*

Biome: one of several immense terrestrial regions, each characterised throughout its extent by similar plants, animals, climate and soil type.

Biosphere all the life supporting regions (ecosystems) of the earth and all the interactions that occur between organisms, and between organisms and the environment.

Biotic factor: the biological component of the ecosystem, consisting of population of plants, animals, and micro-organisms in complex communities.

Carcinogen: a chemical or physical agent that causes cancer to develop, often decades after the original exposure.

Catalyst: substance that accelerates chemical reactions but it is not used up in the process. Enzymes are biological catalysts. Also see *catalytic converter*.

Catalytic converter: device attached to the exhaust system of automobiles and trucks to rid the exhaust gases of harmful pollutants.

Chlorofluorocarbons (CFC's): organic molecules consisting of chlorine and fluorine covalently bonded to carbon. Previously thought to be inert, but now known to destroy the stratosphere's ozone layer.

Chlorophyll: pigment of plant cells that absorbs sunlight, thus allowing plants to capture solar energy.

Clear – cutting (also clear-felling): removal of all trees from a forested area.

Coastal wetlands: wet or flooded regions along coastlines, including mangrove swamps, salt marshes, bays, and lagoons.

Coliform bacterium: common bacterium found in the intestinal tracts of humans and other species. Used in water quality analysis to determine the extent of faecal contamination.

Combustion: burning,

Commons: any resource used in common by many people, such as air, water, and grazing land.

Competition: vying for resources between members of the same or different species.

Composting: aerobic decay of organic matter to generate a humus-like substance used to supplement soil.

Conservation: a strategy to reduce the use of resources, especially through increased efficiency, reuse, recycling, and decreased demand.

Consumer (or consumer organism or heterotroph): an organism in the ecosystem that feeds on autotrophs and/or heterotrophs.

Contour farming: soil erosion control technique in which row crops (corn) are planted along the contour lines in sloping or hilly fields rather than up and down the hills.

DDT: dichlorodiphenyltrichloroethane. An insecticide used to control a variety of insect pests, but now banned because of its persistence in the environment and its ability to bioaccumulate.

Debt for Nature: wealthier nations cancel the debts for poorer communities if they will protect their natural ecosystems.

Decibel (dB): a unit to measure the loudness of sound.

Decomposer food chain: a specific nutrient and energy pathway in an ecosystem in which decomposer organisms (bacteria and fungi) consume dead plants and animals as well as animal wastes. Also called detritus food chain.

Deforestation: destruction of forests by removing trees.

Demographic transition: a phenomenon witnessed in populations of industrialising nations. As industrialisation proceeds and wealth accumulates. Crude birth rate and crude death rate decline, resulting in zero or low population growth.

Demography: the science of population.

Denitrification: the breakdown of nitrates by bacteria.

Desert: biome located throughout the world. Often found on the downwind side of mountain ranges. Characterised by low humidity, high summertime temperatures, and plants and animals especially adapted to lack of water.

Desertification: the formation of desert in arid and semiarid regions from overgrazing, deforestation, poor agriculture practices, and climate change.

Detoxification: rendering a substance harmless by reacting it with another chemical, chemically modifying it, or destroying the molecule through combustion or thermal decomposition.

Detritus: any organic waste from plants and animals.

Detritus Feeders: organisms in the decomposer food chain that feed primarily on organic waste (detritus) such as fallen leaves.

Developed Country: a convenient term that describes, industrialised nations, generally characterised by high standard of living, low population growth rate, low infant mortality rate, high per capita income, urban population, and low illiteracy.

Dioxin: a large group of highly toxic, carcinogenic compounds containing some herbicides (2,4-D and 2,4,5-T) and Agent Orange.

DNA (deoxyribonucleic acid): a long-chained organic molecule that is found in chromosomes and carries the genetic information that controls cellular function and is the basis of heredity.

Doubling time: the length of time it takes some measured entity (population) to double in size at a given growth rate.

Ecological niche: see *Niche*

Ecological system: see *Ecosystem*

Economic externality: a cost generally passed on to the general public and tax payers.

Ecosystem stability: dynamic equilibrium of the ecosystem. Also a characteristic of ecosystems causing them to return to their previous state (resilience) and their resistance to change (inertia).

Ecotone: Transition zone between adjacent ecosystems.

Element: a substance, such as oxygen, gold, or carbon, that is distinguished from all other elements by the number of protons in its atomic nucleus.

Emigration: movement of people out of a country to establish residence elsewhere.

Energy: the capacity to do work. Found in many forms, including heat, light, sound, electricity, coal, oil, gasoline.

Energy Pyramid: see *Pyramid of energy*

Environmental control (of pests): methods designed to alter the abiotic and biotic environment making them inhospitable or intolerable. Examples include increasing crop diversity, altering time of planting, and altering soil nutrient levels.

Environmental Resistance: abiotic and biotic factors that can potentially reduce population size.

Estuary: coastal regions such as inlets or mouths of rivers where fresh and salt water mix.

Ethanol: grain alcohol, or ethyl alcohol, produced by fermentation of organic matter.

Eukaryotes: the first aerobic cells complete with nuclei and energy releasing organelles.

Eutrophication: accumulation of nutrients in a lake or pond due to human or natural activities.

Evapotranspiration: see *Transpiration*

Evolution: a long term process of change in organisms caused by random genetic changes that favour the survival and reproduction of the organisms possessing the genetic change. Through evolution, organisms become better adapted to their environment.

Exponential curve: see *J curve*

Extinct species: has completely disappeared.

Feral: a domestic animal or plant that has gone wild.

Fossil Fuels: fuels derived from once living organisms.

Frontier mentality: a mind that views humans as "above" all other forms of life rather than as an integral part of nature and sees the world as unlimited supply or resources for human use regardless of the impacts on other species. Implicit in this view are the notions that bigger is better, continued material wealth will improve life, and nature must be subdued.

Gaia Hypothesis: term coined by James Lovelock to describe the Earth's capacity to maintain the physical and chemical conditions necessary for life.

GDP (Gross Domestic Product): indicates the amount of goods and services used by a society.

Genetic engineering: the transfer of genes from one organism to another.

Geothermal energy: energy derived from the earth's heat that comes from decay of naturally occurring radioactive materials in the earth's crust, magma, and friction caused by movement of tectonic plates.

GNP: See *Gross National Product*

Grasslands: biome found in both temperate and tropical regions and characterised by periodic drought, flat or slightly rolling terrain, and large grazers that feed off the lush grasses.

Grey-air cities: older industrial cities characterised by predominantly sulphur dioxide and particulate pollution.

Grazer food chain: a specific nutrient and energy pathway starting with plants that are consumed by grazers (herbivores).

Greenhouse Effect: mechanism that explains atmospheric heat trapped like the glass in a greenhouse, permitting visible light to penetrate but impeding the escape of infrared radiation, or heat.

Gross National Product (GNP): total national output of goods and services valued at market prices, including net exports and private investment.

Gross Primary Productivity: the total amount of sunlight converted into chemical-bond energy by a plant.

Groundwater: water below the Earth's surface in the saturated zone.

Hazardous waste: any potentially harmful solid, liquid, or gaseous waste product of manufacturing or other human activities.

Herbicide: chemical agent used to control weeds.

Hot-rock zones: most widespread geothermal resource. Regions where bedrock is heated by underlying magma.

Humus: mixture of decaying organic matter and inorganic matter that increases soil fertility, aeration, and water retention.

Hydrocarbons: organic molecules containing hydrogen and carbon. Released during the incomplete combustion of organic fuels.

Hydroelectric power: electricity produced in turbines powered by running water.

Hydrological cycle: the movement of water through the environment from atmosphere to Earth and back again.

Hydrosphere: the watery portion of the planet. Contrast with *atmosphere and lithosphere*.

Hypothesis: tentative explanation for a natural phenomenon, testable by experiment.

Immigration: movement of people into a country to set up residence there.

Industrial society: group of people living in urban or rural environments that are characterised by mechanisation of industrial production and agriculture. Widespread machine labour causes high energy demands and pollution. Increasing control over natural processes leads to feeling that humans are separate from nature and superior to it.

Infrared radiation: heat, an electromagnetic radiation of wavelength outside the red end of the visible spectrum.

Inland wetlands: wet and flooded regions along inland surfaces waters. Includes marshes, bogs, and river outflow lands.

Inorganic fertiliser: synthetic plant nutrient added to the soil to replace lost nutrients. Major components include nitrogen, phosphorus, and potassium.

Insecticide: one form of pesticide used specifically to control insect populations.

Interspecific competition: competition between members of different species.

J curve: a graphical representation of exponential growth.

Joules: the units in which work and heat are measured.

Keystone species: critical species in an ecosystem whose loss profoundly affects several or many others.

KiloWatt: one thousand watts. See Watt.

Kinetic energy: the energy of objects in motion.

Legume: plants (e.g. peas and beans) that have a mutualistic relationship with nitrogen fixing bacteria.

Less developed country: term describing the non-industrialized nations, generally characterised by low standard of living, high population growth rate, high infant mortality, low material consumption, low per capita energy consumption, low per capita income, rural population, and high illiteracy.

Light Year: astronomical unit that measures the distance that light can travel in a year.

Limiting Factor: a chemical or physical factor that determines whether an organism can survive in a given ecosystem.

Lithosphere: the outermost shell of the Earth.

Macronutrient: a chemical substance needed by living organisms in large quantities (e.g. carbon, oxygen, hydrogen and nitrogen).

MegaWatt: measure of electrical power equal to a million watts. See Watt.

Migration: movement of people across state and national boundaries to set up new residence.

Mineral: a chemical element (e.g. gold) or inorganic compound (e.g. iron ore) existing naturally.

Minimum tillage: reduced ploughing and cultivating of cropland between and during growing seasons to help reduce soil erosion and save energy.

Monoculture: cultivation of plant species such as wheat over a large area making it highly susceptible to disease and insects.

Mutation: in general, any damage to the DNA and chromosomes.

Natural Gas: gaseous fuel containing methane and lesser amounts of other burnable organic gases such as propane and butane.

Natural resource: see *resource*

Natural selection: process in which slight variations in organisms (adaptations) are preserved if they are useful and help the organism to better respond to its environment.

Net Primary Productivity: Gross Primary Productivity minus the energy plants use during cellular respiration.

Nitrogen fixation: conversion of atmospheric nitrogen into nitrate and ammonium ions (inorganic form), which can be used by plants.

Nitrogen oxides: nitric oxide (NO) and nitrogen dioxide (NO₂), produced during combustion when atmospheric nitrogen (N₂) combines with oxygen.

Nonpoint source (of pollution): diffuse source of pollution such as an eroding field, urban and suburban lands, and forests.

Non-renewable resource: resource that is not replaced or regenerated naturally within a reasonable period (e.g. fossil fuel, minerals)

Nuclear power (or energy) energy from the fission or fusion of atomic nuclei.

Old growth forest: ancient forests with trees often 150 to 1000 or more years old.

Omnivore: an organism that eats both plants and animals.

Opportunity Cost: money lost when an opportunity is lost e.g. a tree sold for wood chips can't be used to make furniture.

PCBs: see *polychlorinated biphenyls*

Perennial: a plant that grows from the same root structure year after year (e.g. rose bushes).

Permaculture: a method of sustainable agriculture which encourages biodiversity.

Permafrost: permanently frozen ground found in the tundra.

Pesticide: a general term referring to a chemical, physical, or biological agent that kills organisms we classify as pests, such as insects and rodents.

Petroleum: a viscous liquid containing numerous burnable hydrocarbons. Distilled into a variety of useful fuels (fuel oil, gasoline, and diesel) and petrochemicals (chemicals that can be used as a chemical feedstock for the production of drugs, plastics, and other substances).

pH: measure of acidity on a scale from 0 to 14, with pH 7 being neutral, numbers greater than 7 being basic, and numbers less than 7 being acidic.

Photochemical oxidants: ozone and a variety of oxygenated organic compounds produced when sunlight, hydrocarbons, and nitrogen oxides react in the atmosphere.

Photochemical reaction: a chemical reaction that occurs in the atmosphere involving sunlight or heat, pollutants, and sometimes natural atmospheric chemicals.

Photochemical smog: a complex mixture of *photochemical oxidants* and nitrogen oxides. Usually has a brownish-orange colour.

Photosynthesis: a two-part process involving (1) the capture of sunlight and its conversion into cellular energy and (2) the production of organic molecules such as glucose and amino acids from carbon dioxide, water, and energy from the sun.

Photovoltaic cells: thin wafer of silicon or other material that emits electrons when struck by sunlight, thus generating an electrical current. Also solar cell.

Plankton: free floating micro-organisms. May be phytoplankton (plants) or zooplankton (animals).

Point source (of pollution): easily discernible source of pollution such as a factory.

Pollution: any physical, chemical, or biological human alteration of air, water, or land that is harmful to living organisms.

Polychlorinated biphenyls (PCBs): group of at least 50 organic compounds, used for many years as insulation in electrical equipment. Capable of biological magnification. Disrupts reproduction in gulls and possible other organisms high on the food chain.

Population: a group of organisms of the same species living with a specified region.

Population crash: sudden decrease in population that results when an organism exceeds the carrying capacity of its environment.

Population growth rate: rate at which a population increases on a yearly basis, expressed as a percentage.

Positive feedback: control mechanism in ecosystems and organisms in which information influences some process, causing it to enhance the output.

Potential energy: stored energy.

Precipitation: water falling from the sky as rain, snow or ice.

Predator an organism that actively hunts its prey.

Prey: organism (e.g. deer) attacked and killed by predator.

Primary air pollutant: a pollutant that has not undergone any chemical transformation; emitted by either a natural or an anthropogenic source.

Primary consumer: first consuming organism in a given food chain. A herbivore in producer food chains or a decomposer organism or insect in detritus food chains.

Primary treatment (of sewage): first step in sewage treatment to remove large solid objects by screens (filters) and sediment and organic matter in settling chambers.

Producer (autotrophic): one of the organisms that produces the organic matter cycling through the ecosystem. Producers include plants and photosynthetic algae.

Pyramid of biomass: graphical representation of the amount of biomass (organic matter) at each trophic level in an ecosystem.

Pyramid of numbers: graphical representation of the number of organisms of different species at each trophic level in an ecosystem.

Radioactive waste: any solid or liquid waste material containing radioactivity. Produced by research labs, hospitals, nuclear weapons factories, and fusion reactors.

Radioactivity: radiation released from unstable nuclei.

Reclamation: the process of returning land to its prior use. Commonly to convert deserts, wetlands and other areas into habitable, productive land.

Recycling: a strategy to reduce resource use by returning used or waste materials from the consumption phase to the production phase of the economy.

Relative humidity: the amount of moisture in a given quantity of air divided by the amount the air could hold at that temperature. Expressed as a percentage.

Renewable source: a resource replaced by natural ecological cycles (water, plants, animals) or natural chemical or physical processes (sunlight, wind). Does not diminish with use.

Resource (in general): anything used by organisms to meet their needs, including air, water, minerals, plants, fuels, and animals.

Restoration ecology: study of restoring ecosystems to their natural state after human interference. also called conservation biology.

Risk acceptability: a measure of how acceptable a hazard is to a population.

Risk assessment: the science of determining what hazards a society is exposed to from natural and human causes and the probability and severity of those risks.

Salinisation: deposition of salts in irrigated soils, making soil unfit for most crops. May be caused by rising water table.

Saltwater intrusion: movement of saltwater from oceans or saltwater aquifers into freshwater aquifers.

Sclerophyll: plants with hard leathery leaves that contain oils.

Scrubber: pollution control device that removes particulates and sulphur oxides from smokestacks.

Secondary consumer: second consuming organism in food chain. Belongs to the third trophic level.

Secondary pollutant: a chemical pollutant from a natural or anthropogenic sources that undergoes chemical changes as a result of reacting with another pollutant, sunlight, atmospheric moisture, or some other environmental agent.

Secondary treatment (of sewage): after primary treatment, removal of biodegradable organic matter from sewage using bacteria and other microconsumers in activated sludge or trickle filters.

Selective harvesting: restricted removal of trees. Especially useful for mixed hardwood stands. Contrast with clear-cutting and shelter-wood harvesting.

Sewage treatment plant: facility where human solid and liquid wastes from homes, hospitals, and industries are treated, primarily to remove organic matter, nitrates, and phosphates.

Shelterbelts: rows of trees and shrubs planted alongside fields to reduce wind erosion and retain snow to increase soil moisture. May also be used to reduce heat loss from wind on farms.

Slash-and burn agriculture: farming practice in which small plots are cleared of vegetation by cutting and burning. Crops are grown until the soil is depleted; then the land is abandoned. This allows the natural vegetation and soil to recover.

Sludge: solid organic material produced during sewage treatment.

Smelter: a factory where ores are melted to separate impurities from the valuable minerals.

Smog: refers to a greyish haze (combination of smoke and fog) found in industrial cities.

Soil horizon: layers found in most soils.

Solar energy: energy derived from the sun (heat) and natural phenomena driven by the sun (wind, biomass, running water).

Species: a group of plants, animals, or micro-organisms that have a high degree of similarity and generally can interbreed only among themselves.

Species diversity: measure of the number of different species in a biological community.

Synergism: an effect whereby two substances together have a greater impact.

Technological fix: a purely technological answer to a problem.

Temperature inversion: alteration in the normal atmospheric temperature profile so that air temperature increases with altitude rather than decreases.

Terracing: construction of small earthen embankments on hilly or mountainous terrain to reduce the velocity of the water flowing across the soil and thus reduce soil erosion.

Tertiary treatment (of sewerage): removal of nitrates, phosphates, chlorinated compounds, salts, acids, metals and toxic organic after *secondary treatment*.

Thermal pollution: heat added to air or water that adversely affects living organisms and may alter climate.

Toxin: a chemical, physical, or biological agent that causes disease or some alteration of the normal structure and function of an organism. Impairments may be slight or severe. Onset of effects may be immediate or delayed.

Transpiration: escape of water from plants through pores (stomata) in the leaves.

Tree farms: private or public forests devoted to maximum timber growth and relying heavily on herbicides, insecticides and fertilisers.

Trophic level: describes the position of the organism in the food chain.

Tundra (alpine): life zone found on mountain tops. Closely resembles the *arctic tundra* in terms of precipitation, temperature, growing season, plants and animals. Extraordinarily fragile.

Ultraviolet (UV) light or radiation: electromagnetic radiation from sun and special lamps. Causes sunburn and mutations in bacteria and other living cells.

Waste-to-energy plant: incinerator for rubbish that produces small amounts of electricity from heat given off by combustion.

Water-logging: high water table causing saturation of soils due to poor soil drainage and irrigation. Decreases soil oxygen and kills plants.

Watershed: land area drained by a given stream or river. Also known as the catchment.

Water table: top of the zone of saturation in soil or bedrock.

Watt: unit of power indicating rate at which electrical work is being performed.

Wave power: energy derived from sea waves.

Wetlands: land areas along fresh water (*inland wetlands*) and salt water (*coastal wetlands*) that are flooded all or part of the time.

Wilderness: an area where the biological community is relatively undisturbed by humans.

Wind energy: energy captured from the wind to generate electricity or pump water. An indirect form of solar energy.

Wind generators: windmills that produce electrical energy.

Zero population growth: a condition in which population is not increasing; the *population growth rate is zero*.