Chapter 4 —> Ecology

4.1 Species and Ecosystem

Species:

- A group of organisms that can potentially interbreed to produce fertile, viable offsprings
- Members of a single species cannot produce fertile offsprings with members from another specie
- When two different species do produce offspring by cross-breeding, this hybrids are sterile
- Population —> a group of organisms of the same species that live in the same area at same time
- Community —> a group of populations living together and interacting with each other in an area
- Habitat —> the environment or location in which a specie normally lives
- Ecosystem —> a community and its abiotic environment
- Ecology —> the study of the relationship between living organisms and their environment

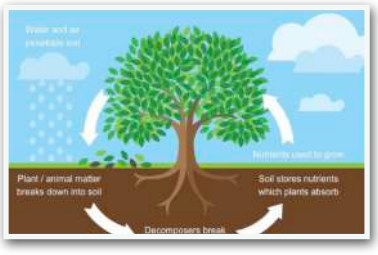
Modes of nutrition:

- Autotrophs —> synthesises its own organic molecules from simple inorganic substances
  —> energy for this process is from sunlight or via oxidation of inorganic molecules
  —> obtain simple inorganic substances needed from the abiotic env. (air, water, soil)
  —> usually producers in the food chain
- Heterotrophs —> obtains organic molecules from other organisms
  —> consumers, they cannot produce own organic molecules from other sources
- Mixotrophs —> unicellular organisms which may use both forms of nutrition based on available
  —> Euglena gracilis —> chlorophyll for photosynthesis and may feed on detritus

Heterotrophs:

- Herbivores —> consumers that feed principally on plant matter
- Carnivores —> consumers that feed principally on animal matter
- Omnivores —> consumers that have a principle diet composed of both plant and animal matter
- Scavengers —> type of consumer that principally feed on dead and decaying carcasses
- Detritivores —> ingest organic molecules found in the non-living remnants of organisms
- Saprotrophs —> release digestive enzymes and then absorb the external products of digestion
  —> decomposers as facilitate the breakdown of dead organic material

Nutrient cycling:



- Nutrients —> material required by an organism, are limited
- Chemical elements are constantly recycled after they are used

Mesocosms:

- Biotic components —> communities …
- Abiotic components —> habitat …
- Sustainability —> energy availability —> light from the sun provides the initial energy source
  —> nutrient availability —> saprotrophic decomposers ensure constant recycling of inorganic nutrients within an environment
  —> recycling of wastes —> bacteria can detoxify harmful waste byproducts
- Mesocosms —> enclosed environments that allows a small part of a natural environment to be observed under controlled conditions (terrarium —> small transparent container)

1) Building a verdant foundation
2) Selecting the right plants
3) Maintaining appropriate conditions

Quadrat sampling:

- A rectangular frame of known dimensions that can be used to establish population densities
- Not effective as a method for counting motile organisms (only plants and sessile animals)

Types of metabolism:

- Carbon source —> organisms can obtain carbon for synthesising organic molecules
- Energy source —> organisms can derive the energy they need for living and growing
  —> phototrophic from light and chemotropic from chemical compounds
- Reducing equivalents —> are chemical species that can transfer electrons needed for energy conversions and biosynthesis

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4.2 Energy flow

Energy source:

- Light is the initial energy for most types of communities
- Photoautotrophic —> use sunlight as source of energy
- Light is absorbed and converted into chemical energy through photosynthesis
- The light energy is used to make organic compound from inorganic sources

Trophic levels and food chains:

- Trophic level —> the position an organisms occupies within a feeding sequence
- Food chain —> the linear feeding relationships between species in a community

Trophic Level 1	Producer
Trophic Level 2	Primary Consumer
Trophic Level 3	Secondary Consumer
Trophic Level 4	Tertiary Consumer

Energy loss:

- Not all energy stored in organic molecules is transferred via heterotrophic feeding
- Some energy loss from —> being excreted as part of the organism's faeces
  —> remaining unconsumed as the uneaten portions of the food
  —> respiration …
- Organisms release heat, which does not pass to the next trophic level of the food chain
- A continuous influx of energy is required (ex. sun) because of heat

Energy transformations:

- Energy transfer is never 100% efficient
- Transformations are ~10% efficient, with 90% of available energy lost between trophic levels
- Higher trophic levels receive less energy / biomass from feeding and so need to eat larger quantities to obtain sufficient amounts

Pyramids of energy:

- Graphical representation of the amount of energy at each trophic level of a food chain
- kJ m^{-2} $year^{-1}$
- Each level should be roughly one tenth of the size of the preceding level
- As the trophic level increases, the biomass and energy available decreases

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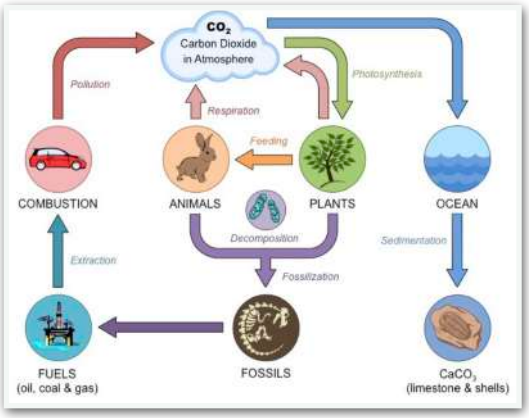
4.3 Carbon cycling

Carbon cycling:

- A biogeochemical cycle whereby carbon is exchanged between the different spheres of the Earth
- Atmosphere (air), lithosphere (ground), hydrosphere (water) and biosphere (living things)
- Atmospheric gases —> CO_2 / CH_4
- Oceanic carbonates —> dissolved in H_2O, corals and shells
- Organic materials —> carbohydrates, lipids, proteins …
- Non-living remains —> fossil fuels and detritus
- Compensation point —> the uptake of CO_2 by plants is balanced by the production of CO_2 by respiration



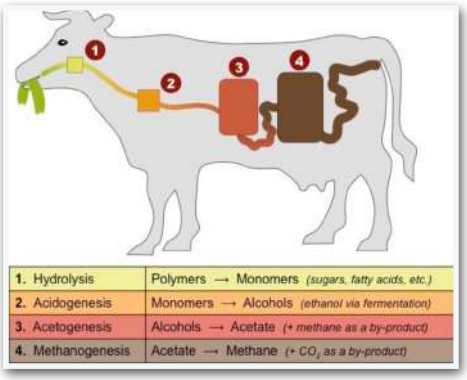
Aquatic conversion:

Oceanic Carbon Conversions
Step 1: CO_2 (atmospheric) ⇌ CO_2 (dissolved)
Step 2: CO_2 (dissolved) + H_2O ⇌ H_2CO_3 (carbonic acid)
Step 3: H_2CO_3 ⇌ HCO_3^- (bicarbonate ion) + H^+
Step 4: HCO_3^- ⇌ CO_3^{2-} (carbonate ion) + H^+
Step 5: CO_3^{2-} + Ca^{2+} ⇌ $CaCO_3$ (calcium carbonate)

-Limestone creation —> When the hydrogen carbonate ions come into contact with the rocks and sediments on the ocean floor and acquire metal ions creating calcium carbonate
-When the organism dies and settles to the sea floor, the hard components may become fossilised in the limestone

Methane:

- Methanogens —> archaean microorganisms that produce methane (CH_4) as a metabolic by-product in anaerobic conditions
- Found in —> Wetlands
  —> Marine sediments
  —> Digestive tract of ruminant animals
- Acetic acid → Methane and Carbon Dioxide
- Carbon Dioxide and Hydrogen → Methane and Water



- When organic matter is buried in anoxic conditions (e.g. sea beds), deposits of methane (natural gas) form underground
- Rising global numbers of domesticated cattle —> increasing the levels of methane
- When methane is released into the atmosphere as a result of anaerobic reactions, it only persists for ~12 years —> will be naturally oxidised to form carbon dioxide and water

Fossil fuels:

Partial decomposition:

- Saprotrophic bacteria and fungi will decompose dead organisms and return nutrients to the soil for cycling —> requires oxygen
- Waterlogged regions may lack oxygenated air spaces within the soil (so anaerobic conditions)
- Anaerobic respiration by organisms in these regions produces organic acids (acidic conditions)
- Saprotrophic bacteria and fungi cannot function in these conditions —> no decomposition

Coal formation:
- Carbon-rich molecules remain in the soil and form peat from non-decomposed organisms
- The heat and pressure force out impurities and remove moisture from peat
- Remaining material has a high carbon concentration and chemical transformation produces coal

Oil/natural gas formation:
- Form as the result of the decay of marine organisms on the ocean floor
- Sediments deposit on top of the organic matter, creating anoxic conditions
- Burial and compaction —> the organic material becomes heated and hydrocarbons are formed
- Hydrocarbons form oils and gases —>forced out of source rock and accumulate in porous rocks
- Takes place over millions of years, making them a non-renewable energy source

Combustion:

- When organic compounds rich in hydrocarbons are heated in the presence of oxygen
- Exergonic —> produces energy + releases CO_2 and H_2O as by-products
- Two main sources are fossil fuels and biomasses

Fossil fuels:
- Organic compounds become rich in hydrocarbons if compacted underground millions of years
- Coal / Oil / Natural gases

Biomass:
- manufacture fuels from biological processes
- Living organisms produce hydrocarbons as part of their total biomass —> hydrocarbons can be extracted and purified to produce an alternative fuel source
- New raw materials are provided and waste products are removed
- Renewable

Carbon fluxes:

- The rate of exchange of carbon between the various carbon sinks / reservoirs (4 spheres of earth)
- Factors influencing the rate of carbon exchange are:
    —> Photosynthesis
    —> Respiration
    —> Decomposition
    —> Gaseous dissolution —> exchange of carbon gases between the ocean and atmosphere
    —> Lithification —> compaction of carbon sediments into fossils and rocks in the crust
    —> Combustion
- Estimates can be made to directly measure the size of the carbon sinks or the fluxes (gigattones)
- Main causes of change in carbon flux —> climate, human activity, natural events

Climate:
- Rates of photosynthesis —> higher in summer (more light)
- Oceanic temperatures —> determine how much carbon is dissolved CO_2
- Melting of polar caps —> frozen detritus will decompose and start uncovering

Natural events:
- Forest fires —> release high levels of carbon dioxide when plants burn
- Volcanic eruptions —> release carbon compounds from the Earth's crust into the atmosphere

Human activity:
- Deforestation —> will reduce removal of atmospheric CO_2 via photosynthesis
- Increased number of ruminant livestock —> higher levels of methane
- Combustion —> release of CO_2 in the atmosphere

CO_2 levels:
- Fluctuate annually
- CO_2 levels are steadily increasing year on year since the industrial revolution
- Atmospheric CO_2 levels are currently at the highest levels recorded since measurements began
- Efforts to reduce fossil fuel combustion by using alternative energy sources (e.g. solar power)

4.4 Climate change

Greenhouse gases:

- Absorb and emit long-wave (infrared) radiation —> traps and holds heat within the atmosphere
- Collectively make up less than 1% of the Earth's atmosphere
- Water vapour and carbon dioxide are the largest warming gases
- Water vapour —> created through evaporation of water bodies and is removed by precipitation
- Carbon dioxide —> made by cell respiration and combustion —> photosynthesis and absorption
- Methane and nitrogen oxides

Factors affecting impact of greenhouse effect:

- Ability to absorb long-wave radiation —> greater capacity to absorb long-wave radiation —> greater warming impact
- Concentration within the atmosphere —> the greater the concentration the greater the impact
  —> rate of release and persistence in the atmosphere

	Water	Carbon Dioxide	Methane	Nitrous Oxide
				
Atmospheric Concentration	0.01–4%*	385 ppm	1797 ppb	322 ppb
Rate of Increase	n/a	1.5 ppm/yr	7.0 ppb/yr	0.8 ppb/yr
Atmospheric Lifetime	Very short 1–5 days	Variable 5–200 yr	12 yr	120 yr
Global Warming Potential (GWP)	n/a†	1	21	310

Greenhouse effect:

- A natural process whereby the atmosphere behaves like a greenhouse to trap and retain heat —> the Earth has moderate temperatures for organisms to maintain life processes (homeostasis)
- Without, Earth's temperatures would drop significantly at night in the absence of direct sunlight

1) Sun radiates short wave radiation
2) Earth absorbs short wave radiation and re-emits it in a long wave radiation
3) Green-house gases absorb and re-radiate this longer wave radiation keeping the heat trapped

Climate changes:

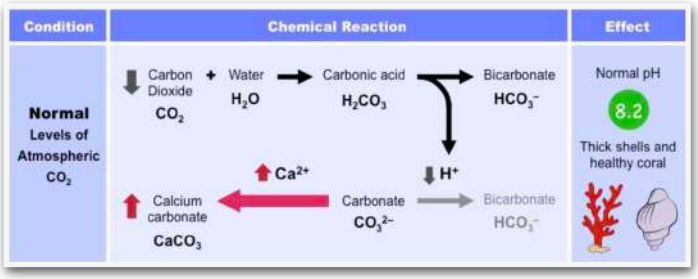
- Greenhouse gases play a pivotal role in determining global temperatures and climate patterns
- Increases in greenhouse gas concentrations will lead to an enhanced greenhouse effect —> More extreme weather conditions, more droughts and rainfalls, changes to circulating ocean currents

Vostok station, Antartica:

- Link between global temperatures and carbon dioxide concentrations was established by analysing data over a long time period
- Ice cores taken from the Vostok station in Antarctica provide evidence of the environmental conditions at the time of freezing —> 420,000 years and covers the past four glacial cycles
- By analysing the gas bubbles trapped in ice, historical CO_2 levels and air temperatures (via oxygen isotopes) can be deduced

Ocean acidification:

- CO_2 solubility is temperature dependent (more soluble when cooler), so less CO_2 will be absorbed as temperatures rise —> 1/3 of total CO_2 absorbed by oceans
- Rising levels of atmospheric carbon dioxide are causing a decrease in the pH of ocean water
- The decrease in ocean pH is predicted to threaten the survival of marine organisms that require calcium carbonate



- The disappearance of coral reefs could result in a loss of shoreline protection and habitat, altering coastal ecosystems —> 1 trillion $ in loss by 2100
- Increasing the dissolved CO_2 levels in oceans would cause invasive species of algae to flourish

Greenhouse debate:

- **Claim 1:** Climate has changed in the past and current trends merely reflect the Earth's natural climatic cycle

  Climate changes do occur naturally, but usually not as abruptly as what is seen currently

- **Claim 2:** Climate change is being caused by solar activity and the effect of greenhouse gas emissions is negligible

  Over the last 35 years the sun has shown a slight cooling trend, however average global temperatures have increased

- **Claim 3:** Certain changes in climate conditions cannot be linked to greenhouse gas emissions

  Global sea levels began to increase after greenhouse gas emissions significantly increased following the industrial revolution

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Extra:

Species interaction:

- Positive association —> two species interact directly within a shared environment
- Negative association —> interactions with environment are mutually detrimental to both species

Niche:

- Describes the functional position and role of an organism within its environment
- Ecological niches —> includes habitat, activity patterns, resources and interactions
- Fundamental niche —> entire set of conditions under which an organism can survive+reproduce
- Realised niche —> is the set of conditions actually used by a given organism after interactions with other species are taken into account
- Competitive exclusion —> one species will use the resources more efficiently and drive the other species to local extinction
- Resource partitioning —> two species will alter their use of the niche to avoid direct competition, allowing for co-existence

Ecological productivity:

- Refers to the rate of generation of biomass in an ecosystem
- Primary production —> the production of chemical energy in organic compounds by producers
  —> Gross primary production (GPP) is the amount of chemical energy as biomass that a producer creates in a given length of time
  —> Net primary production (NPP) is the amount of chemical energy that is not consumed by respiration (NPP = GPP – respiration)
- Secondary production —> describes the generation of biomass by heterotrophic organisms
  —> can be categorised according to gross (total) and net (usable) amounts of biomass

Biomagnification:

- Biomagnification —> the increase in the concentration of a substance at a particular trophic level
  —> pesticide DDT and mercury
- Bioaccumulation —> the increase of a substance (such as a pollutant) in a particular organism

Biogeochemical cycles:

- Pathway by which a chemical substance moves through the biotic and abiotic spheres of Earth
- Nitrogen cycle —> 79 % of earths atmosphere is composed by nitrogen but it is inert in this form
  —> chemically processed by nitrogen-fixing bacteria to be used by plants
  —> N_2 in the soil converted back into inert nitrogen gas by denitrifying bacteria
- Phosphorus cycle —> primary component of DNA and energy-storing molecules (ATP)
  —> not found as a gas in the atmosphere
  —> is fixed to soil particles but may be released by the weathering of rocks
- Sulphur cycle —> essential component of living organisms (proteins and enzyme cofactors)
  —> sulphur in the air and soil may be oxidised to form sulphates
  —> sulphates are reduced by plants and bacteria
  —> can also be mineralised into inorganic forms and incorporated with metals
  —> burning of fossil fuels releases sulphur dioxide causing acid rain

Precautionary principle:

- States that when a human-induced activity raises a significant threat of harm to the environment or human health, then precautionary measures should be taken even if there is no scientific consensus regarding cause and effect

Carbon footprint:

- The total amount of greenhouse gases produced to directly and indirectly support human activity
- Expressed in equivalent tonnes of carbon dioxide
- Reducing, reusing and recycling are efforts to reduce a carbon footprint

Greenhouse impacts:

- Disease spread
- Ice caps melting —> releasing detritus trapped in ice and rising sea levels
- Extreme weather conditions
- Extinction events
- Temperature increases
- Habitat destruction
