Topic 4: Ecology

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| **4.1** | **Species, communities and ecosystems** |
| U1 | Species are groups of organisms that can potentially interbreed to produce fertile offspring |
| U2 | Members of a species may be reproductively isolated in separate populations |
| U3 | Species have either an autotrophic or heterotrophic method of nutrition (a few species have both methods) |
| U4 | Consumers are heterotrophs that feed on living organisms by ingestion |
| U5 | Detritivores are heterotrophs that obtain organic nutrients from detritus by internal digestion |
| U6 | Saprotrophs are heterotrophs that obtain organic nutrients from dead organisms by external digestion |
| U7 | A community is formed by populations of different species living together and interacting with each other |
| U8 | A community forms an ecosystem by its interactions with the abiotic environment |
| U9 | Autotrophs obtain inorganic nutrients from the abiotic environment |
| U10 | The supply of inorganic nutrients is maintained by nutrient cycling |
| U11 | Ecosystems have the potential to be sustainable over long periods of time |
| S1 | Classifying species as autotrophs, consumers, detritivores or saprotrophs from a knowledge of their mode of nutrition |
| S2 | Setting up sealed mesocosms to try to establish sustainability |
| S3 | Testing for association between two species using the chi-squared test with data obtained by quadrat sampling |
| S4 | Recognizing and interpreting statistical significance |

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| Definitions |
| **Ecology** – The study of the relationships between living organisms and their environment  **Species** –A group of organisms that can potentially interbreed to produce fertile offspring  **Population** –A group of the same species, living in the same area at the same time  **Communities** –A group of populations living together and interacting with each other within a given area  **Habitat** – The environment in which a species normally lives, or the location of a living organism  **Ecosystems** – A community and its abiotic environment |

* A community is formed by populations of different species living together and interacting with each other
* An ecosystem is formed from community interactions with the abiotic environment

# Species

* Members of a species:
  + Have similar physical characteristics
  + Can interbreed and produce fertile offspring
  + Share common phylogeny (family tree)
  + Has different gene pools compared to other organisms
* However, some species don’t a follow the species definition as:
  + Just because organisms are separated by long distances (speciation) doesn’t mean they can’t interbreed and aren’t a part of the same species
  + Some organisms reproduce asexually (like bacteria) so we can’t use the “interbreeding” definition
  + Some members of different species can interbreed
    - Hybrids are the offspring of two similar but different species
    - A horse and a zebra can interbreed and produce offspring (a mule) as they are closely related
    - **However, the offspring is usually infertile as there will be an odd number of chromosome**
    - Most hybrids are infertile, meaning a second generation of hybrids isn’t possible

# Mode of Nutrition

* Species can be classified according to their mode of nutrition

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| Autotrophs | Heterotrophs |
| Synthesizes their own organic molecules from inorganic molecules (usually through the process of photosynthesis) | Obtains organic molecules from other organisms (via different feeding mechanisms and food sources) |
| Commonly referred to as producers since they synthesize their own organic molecules | Commonly referred to as consumers since they only consumer organic materials |
| Example: Plants, algae, some bacteria | Examples: Animals, fungi, some bacteria |

* Autotrophs obtain inorganic nutrients from the abiotic environment
* Heterotrophs can be classified even further according to their feeding pattern
  + **Consumers**: Heterotrophs that feed on living organisms by ingestion
    - Herbivores are consumers that feed principally on **plant matter**
    - Carnivores are consumers that feed principally on **animal matter**
    - Omnivores are consumers that have a principle diet composed of **both plant and animal matter**
    - Scavengers are consumers that principally feed on dead and decaying carcasses rather than hunting live prey. Examples include hyenas, vultures and carrion birds (such as crows)
  + **Saprotrophs**: Heterotrophs that obtain organic nutrients from dead organisms by external digestion
    - They live on (or in) non-living organic matter, secrete digestive enzymes into it and absorbing the products
    - Unlike other types of heterotrophs, saprotrophs do not ingest food but use enzymatic secretion to facilitate external digestion
  + **Detritivores**: Heterotrophs that obtain nutrients from detritus by internal digestion
    - Detritus is dead, particulate organic matter – such as decaying organic material and fecal matter
    - Humus is the term given specifically to the decaying leaf litter intermixed within the topsoil
    - Detritivores include dung beetles, earthworms, woodlice, snails and crabs

# *Mixotrophs*

* Certain unicellular organisms may on occasion use both modes of nutrition, depending on resource availability
* *Euglena gracilis* possess chlorophyll for photosynthesis (autotrophic) but may also feed on detritus (heterotrophic)

# Ecosystem sustainability

* Ecosystems have the potential to be sustainable over long periods of time
* There are three main components required for sustainability in an ecosystem
  + Energy availability: Light form the sun provides the initial energy source for almost all communities
  + Nutrient availability: Saprotrophs decomposers ensure the constant recycling of inorganic nutrients
  + Recycling of wastes: Certain bacteria can detoxify harmful waste by-products (E.g. denitrifying bacteria such as *Nitrosomnas*)

# Nutrient cycling

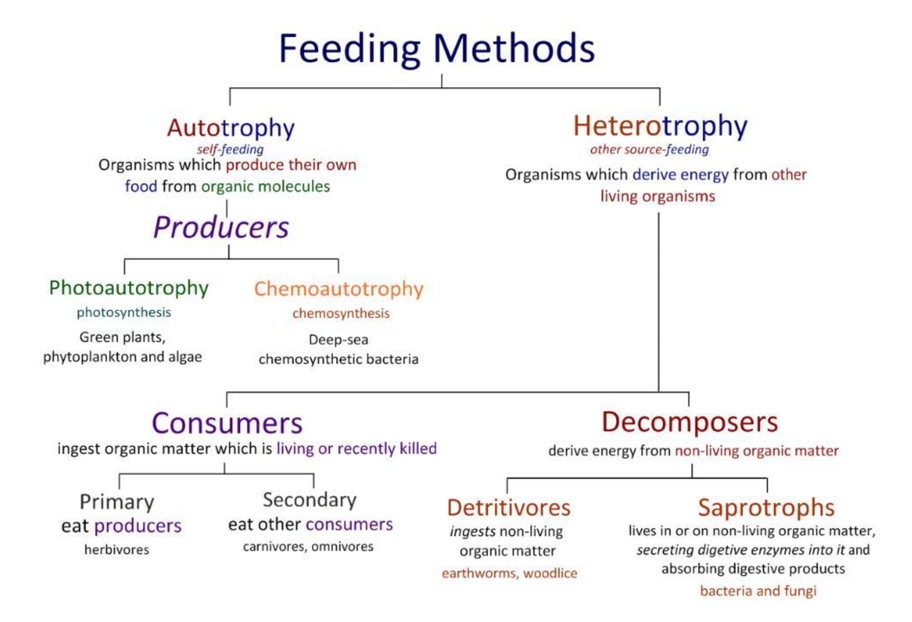
* The supply of nutrients is limited so it is maintained by nutrient cycling to ensure the continuing availability of nutrients.

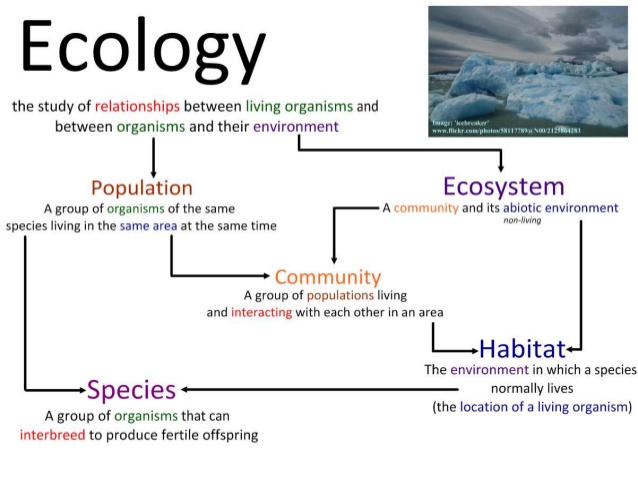
1. **Autotrophs produce organic molecules** as they transform inorganic molecules into organic molecules
2. **Consumers will then obtain the organic molecules** as they will eat the produces and obtain the organic molecules
3. When those consumers die, their cells are broken down by the digestive enzymes of **decomposers** and the nutrients are returned to the soil

# Mesocosms

* Mesocosms are enclosed environments that allow a small part of a natural environment to be observed under controlled conditions
* They are usually used to test the sustainability of a nutrient cycle

# Chi-Squared test

* The presence of two species within a given environment will be dependent upon potential interactions between them
* *(Be able to do a Chi-Squared Test)*



# Using Quadrat

* A quadrat is a square that generally measures 1m on all sides
* The basic idea of a quadrat is to help count a small percentage of the sample
* The quadrat will be randomly placed around a location and the number of organisms inside of it will be counted
* Then by estimating how many quadrats can be placed in the location by extrapolating the data the total number of that organism can be found

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| **4.2** | **Energy flow** |
| U1 | Most ecosystems rely on a supply of energy from sunlight |
| U2 | Light energy is converted to chemical energy in carbon compounds by photosynthesis |
| U3 | Chemical energy in carbon compounds flow through food chains by means of feeding |
| U4 | Energy released from carbon compounds by respiration is used by living organisms and converted to heat |
| U5 | Living organisms cannot convert heat to other forms of energy |
| U6 | Heat is lost from organisms |
| U7 | Energy losses between trophic levels restrict the length of food chains and the biomass of higher trophic levels |
| S1 | Quantitative representations of energy flow using pyramids of energy |

# Energy sources

* **Energy enters most ecosystems through sunlight** where it is converted into chemical energy by producers (photosynthesis)
* This makes light the initial source of energy for almost all communities
* All green plants and some bacteria are **photoautotrophic**. These organisms use sunlight as a source of energy
* However in a few ecosystems some producers are chemoautotrophic bacteria, which convert their energy from chemical processes

# Light energy

* **Light energy is absorbed by autotrophs and is converted into chemical energy via photosynthesis**
* This light energy is used to make organic compounds (e.g. sugars) from inorganic sources (e.g. CO2)
* Heterotrophs ingest these organic compounds in order to derive their chemical energy (ATP)
* When organic compounds are broken down via cell respiration, ATP is produced to fuel metabolic processes

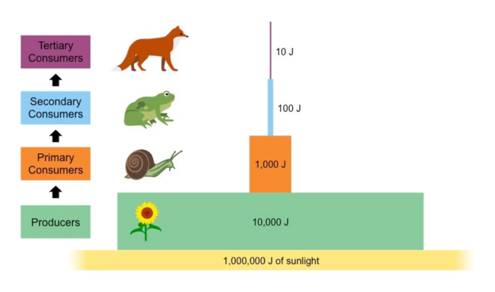
# Energy storage in the form of ATP

* Energy stored in organic molecules (e.g. sugars and lipids can be released by cell respiration to produce ATP)
* This ATP is then used to fuel metabolic reaction required for growth and homeostasis
* A by-product of these chemical reactions is heat (thermal energy) which is released from the organism

# Energy Loss

* **When energy transformations take place in living organisms the process is never 100% efficient**
* Typically, energy transformations are ~10% efficient, with about 90% available energy lost between trophic levels
* Reasons for energy loss:
  + Energy is lost as heat
  + Not all the parts of an organism are swallowed
  + Not all of the parts of an organism can be digested and used
  + Some organisms die before being eaten by an organism in the next trophic level
* **Energy losses between trophic levels restrict the length of food chains and the biomass of higher trophic levels**
* The amount of energy transferred depends on how efficiently organisms can capture and use energy (usually between 5 – 20%). This can be represented using a pyramid of energy

# Pyramids of Energy

* Pyramid of energy: A diagram that shows how much energy flows from one trophic level to the next in a community
* Units: kJ m-2 year-1
* Pyramids of energy will never appear inverted as so much energy is lost as heat and after many trophic levels, not much energy is left
* Each level should be roughly **one tenth** of the size of the preceding level (as around 90% of the energy is lost between trophic levels)
* The bottom level always represents the producers, with subsequence levels representing consumers (primary, secondary, etc)

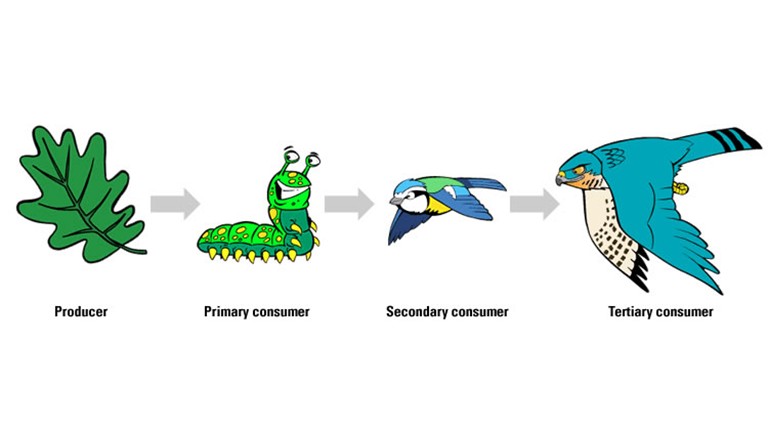
# Energy Conversion

* The chemical energy produced by an organism can be converted into a number of forms, including:
  + Kinetic energy (e.g. during muscular contractions)
  + Electrical energy (e.g. during the transmission of nerve impulses)
  + Light energy (e.g. producing bioluminescence)

# Heat Energy

* All these reactions are exothermic and release thermal energy (heat) as a by-product
* **Heat is lost from ecosystems** as living organisms cannot turn this heat into other forms of usable energy
* Hence ecosystems require a continuous influx of energy from an external source (such as the sun)

# Food Chains

* Energy flow: The process of passing energy from one organism to another through feeding
* **A food chain shows the flow of energy through the trophic levels of a feeding relationship**
* **Arrows represent the transfer of energy** **and matter** as one organism is eaten by another (arrows point in direction of energy flow)
* The first organism in a food chain is always a producer, followed by consumers (primary, secondary, tertiary, etc.)

# Trophic Levels

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

* Trophic level: Feeding position of an organism in a food chain
  + Producers always occupy the first trophic level in a feeding sequence
  + Primary consumers feed on producers and hence occupy the feeding sequence
  + Further consumers (e.g. secondary, tertiary, etc.) may occupy subsequence trophic levels

# Biomass

* As energy is lost between trophic levels, higher trophic levels store less energy as carbon compounds and so have less biomass

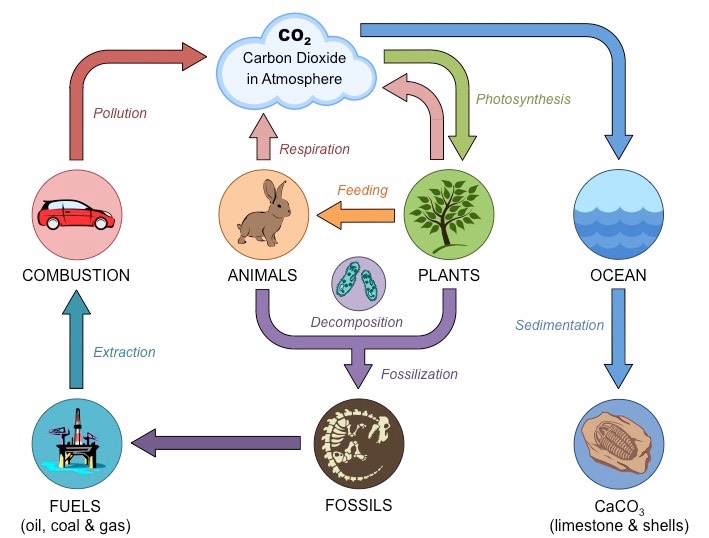
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| Definitions |
| **Biomass –** The total mass of a group of organisms – consisting of the carbon compounds contained in the cells and tissues |

* Because carbon compounds store energy, scientists can measure the amount of energy added to organisms as biomass
* Biomass diminished along food chains with the loss of carbon dioxide, water and waste products to the environment

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| **4.3** | **Carbon Cycling** |
| U1 | Autotrophs convert carbon dioxide into carbohydrates and other carbon compounds |
| U2 | In aquatic ecosystems carbon is present as dissolved carbon dioxide and hydrogen carbonate atoms |
| U3 | Carbon dioxide diffuses from the atmosphere or water into autotrophs |
| U4 | Carbon dioxide is produced from organic matter in anaerobic conditions by methanogenic archaea’s and some diffuses into the atmosphere or accumulates in the ground |
| U5 | Methane is oxidized to carbon dioxide and water in the atmosphere |
| U6 | Peat forms when organic matter is not fully decomposed because of acidic and/or anaerobic conditions in waterlogged soils |
| U7 | Partially decomposed organic matter from past geological eras was converted either into coal or into oil and gas that accumulate in porous rocks |
| U8 | Carbon dioxide is produced by the combustion of biomass and fossilized organic matter |
| U9 | Animals such as reef-building corals and Mollusca have hard parts that are composed of calcium carbonate and can become fossilized in limestone |
| A1 | Estimation of carbon fluxes due to processes in the carbon cycle |
| A2 | Analysis of data from air monitoring stations to explain annual fluctuations |
| S1 | Construct a diagram of the carbon cycle |

# Carbon Cycle

* The carbon cycle is a biogeochemical cycle whereby carbon exchanged between the different spheres of the Earth
  + Hydrosphere: Water
  + Biosphere: Living things
  + Lithosphere: Ground
  + Atmosphere: Air
* Carbon is exchanged between a variety of forms including:
  + Atmospheric gases: CO2 and CH4
  + Oceanic carbonates: Calcium carbonate in corals and shells, bicarbonates dissolved in water
  + Organic materials: Carbohydrates, lipids, proteins
  + Non-living remains: Detritus, fossil fuels
* **Autotrophs convert carbon dioxide into carbohydrates and other carbon compounds** via photosynthesis
  + Terrestrial plants obtain carbon dioxide by absorbing it from the air
  + Aquatic producers obtain carbon dioxide by absorbing it from the water
* Heterotrophs cannot synthesize their own organic molecules and instead obtain carbon compounds via **feeding**
* There are many sources that produce CO2 into the environment



* The carbon cycle is also present in aquatic ecosystems
* In aquatic ecosystems, carbon is present as dissolved carbon dioxide and hydrogen carbonate ions
* Carbon dioxide is produced by respiration and diffuses out of organisms into water or the atmosphere
* When carbon dioxide from the air diffuses into water it forms an acid, which lowers the pH
* The consequences of rising atmospheric carbon dioxide levels include:
  + Acidic water can dissolve organism shells, weakening them, making them more prone to predation
* Factors increasing CO2 concentration

# *Methane*

* Methanogens are Archaean microorganisms that produce methane (CH4) as a metabolic by-product in anaerobic conditions
* Anaerobic conditions where methanogens may be found include:
  + Wetlands (swamps and marshes
  + Marine sediments (mud of lake beds)
  + Digestive tract of ruminant animals (Cows, sheep, goats)
* Methanogens produce methane from the by-product of anaerobic digestion, generally with acetic acid and carbon dioxide
* When methane is released into the atmosphere as a result of anaerobic reactions, it only persists for ~12 years
* **Methane is oxidized to carbon dioxide and water in the atmosphere** which is why methane are not very lare

# *Peat*

* Peat: A type of waterlogged soil that contains large amounts of partially decomposed organic matter
* Peat forms when organic matter is not fully decomposed because of acidic and/or anaerobic conditions in waterlogged soils
* Peat is formed in the following steps:

1. Dead organisms are covered in water
2. The weight of the water forces the air out, creating an anaerobic environment
3. Microorganisms that would normally decompose the dead things die off
4. Energy-rich compounds are compressed and preserved

* **Peat is used as a fossil fuel through burning**
  + Burning peat yields a lot of energy, although to harvest peat the wetland environments must be dug up
  + Burning peat also releases carbon dioxide into the environment
* Factors that favor the production of peat include
  + Presence of organic matter
  + Anaerobic conditions
  + Acidic conditions

# *Fossil Fuels*

* Oil (i.e. petroleum) and natural gas form as the result of the decay of marine organisms on the ocean floor
  + Sediments (e.g. clay and mud) are deposited on top of the organic matter, creating anoxic conditions that prevent decomposition
  + As a result of the burial and compaction the organic material becomes heated and hydrocarbons are formed
  + The hydrocarbon form oil and gas, which are forced out of the source rock and accumulate in porous rocks
* The formation of fossil fuels (coal, oil and gas) takes place over millions of years, making them a non-renewable energy source
* Oil, coal, natural gas and other fossil fuels are energy rich and provide lots of usable energy
* Although **burning them releases carbon dioxide and other containments into the air**

# *Combustion*

* Carbon dioxide is produced by the combustion of biomass and fossilized organic matter
* When organic compounds rich in hydrocarbons are heated in the presence of oxygen, they undergo a combustion reaction
* This reaction produces energy and releases carbon dioxide and water as by-products
* The carbon dioxide is typically released into the atmosphere, increasing the concentration of the gas in the air

# *Biofuels*

* Biofuel: A fuel derived directly from living matter
* Biofuels provide advantages over fossil fuels
  + Habitats don’t have to be disrupted to be mined in
  + The carbon dioxide released are absorbed faster than fossil fuels (a few days vs millions of years), making the cycle time shorter

# *Limestone*

* Limestone is inorganic, the majority of it is made of calcium carbonate or CaCO3
* Animals such as reef-building corals and mollusca have hard parts that are composed of calcium carbonate and can become fossilized in limestone
* Production of limestone:

1. Marine organisms absorb carbon dioxide from their environment
2. Carbon dioxide is transformed into calcium carbonate, which is used to make their shells
3. The animals die and their shells accumulate on the ocean floor
4. Non-porus sedimentary rock layers form on top of the shells
5. Heat and pressure turn the shells into limestone

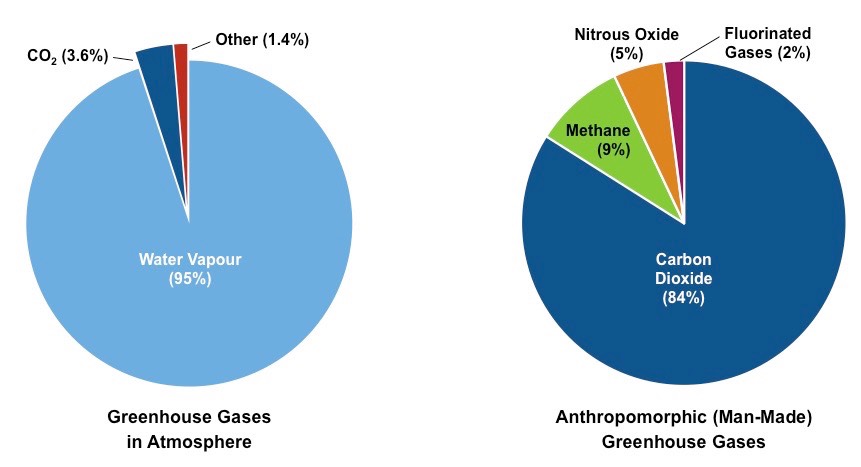
* The formation of limestone is important in biosequestration
  + Biosequestration: The process of removing carbon from the environment and locking it up in a substance for an extended period of time
* **When limestone is mined and crushed up for concrete it can released carbon dioxide back into the air which disrupts the biosequestration of the atmospheric carbon**

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| **4.4** | **Climate Change** |
| U1 | Carbon dioxide and water vapour are the most significant greenhouse gases |
| U2 | Other gases including methane and nitrogen oxides have less impact |
| U3 | The impact of a gas depends on its ability to absorb long wave radiation as well as on its concentration in the atmosphere |
| U4 | The warmed Earth emits longer wavelength radiation (heat) |
| U5 | Longer wave radiation is absorbed by greenhouse gases that retain the heat in the atmosphere |
| U6 | Global temperatures and climate patterns are influenced by concentrations of greenhouse gases |
| U7 | There is a correlation between rising atmospheric concentrations of carbon dioxide since the start of the industrial revolution 200 years ago and average global temperatures |
| U8 | Recent increases in atmospheric carbon dioxide are largely due to increases in the combustion of fossilized organic matter |
| A1 | Threats to coral reefs from increasing concentrations of dissolved carbon dioxide |
| A2 | Correlations between global temperatures and carbon dioxide concentrations on Earth |
| A3 | Evaluating claims that human activities are not causing climate change |

# The Atmosphere

* The atmosphere is the collection of gases above Earth’s surface
* The role of the atmosphere is to retain heat at night and prevent fluctuations in temperatures

# Greenhouse gases

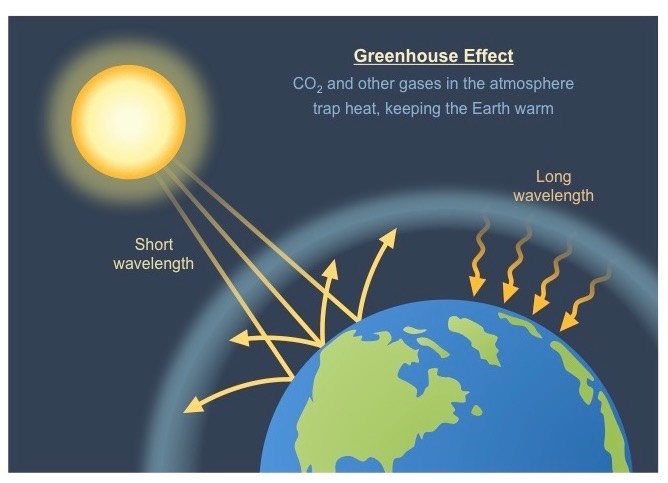
* Greenhouse gases absorb and emit long-wave (infrared) radiation emitted by the Earth’s surface. Therefore trapping and holding heat within the atmosphere
* They collectively make up less than 1% of the Earth’s atmosphere
* The greenhouse gases with the **largest warming** effect within the atmosphere are water vapour (clouds) and carbon dioxide
* Water vapour is created via evaporation of water bodies and transpiration and is removed via precipitation (rain)
* Carbon dioxide is made by cell respiration and burning fossil fuels
* It is removed via photosynthesis and absorption by oceans
* Other greenhouse gases include methane and nitrogen oxides. These have **less impact** on the overall warming effect
* Methane is emitted from waterlogged habitats (like marshes) and landfills). It is also a gaseous waste produced by ruminants
* Nitrogen oxides are released naturally by certain bacteria and also is emitted in the exhaust by certain vehicles

# Impact of greenhouse gases

* There are two factors which determine how much an impact of a greenhouse gas will have

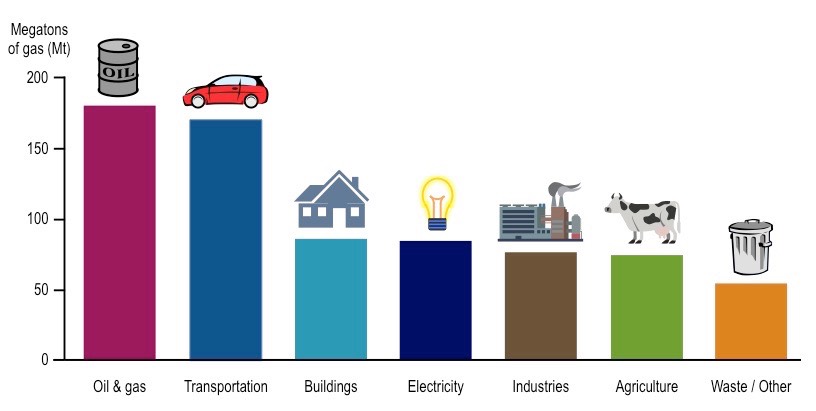
1. The ability to absorb long wave radiation. Gases that have a greater capacity to absorb long-wave radiation will have a greater warming impact (per molecule)
2. Concentration within the atmosphere. The greater the concentration of the gas the greater it’s warming impact will be. The concentration of a gas will be determined by both its rate of release and persistence within the atmosphere

# The Greenhouse Effect

* Greenhouse effect: A planet’s ability to use its atmosphere to retain heat and keep warm even without sunlight
* This ensures the Earth maintains a moderate temperature needed by organisms to maintain life processes
* Without a greenhouse effect, Earth’s temperatures would drop significantly at night in the absence of direct sunlight
* The greenhouse effect works in the following steps:

1. Solar energy (short waves) enters the atmosphere
2. Solar energy is absorbed by objects and is transformed into heat
3. Objects radiate heat back towards the atmosphere
4. Heat (long waves) aren’t able to escape the atmosphere
5. Heat is trapped inside the atmosphere

# CO2 Concentration

* While greenhouse gases occur naturally, man is increasing greenhouse gas emission via a number of activities including:
* Deforestation: The removal of trees means that less carbon dioxide is removed form the atmosphere via photosynthesis
* Increased farming/agriculture: This involves land clearing for cattle grazing, also ruminant cattle produce methane
* Combustion: This is the main cause of increasing CO2 concentrations
  + When fossil fuels (e.g. coal, oil, gas) are combusted to release energy, carbon dioxide gas is released as a by-product
  + The increased reliance on fossil fuels following the industrial revolution has resulted in ~38% increase in CO2 levels
  + There are now efforts to reduce our reliance on fossil fuels by exploiting alternative energy sources (e.g. solar power)

# Climate changes

* Greenhouse gases play a major role in climate change. As these gases trap heat, increases in greenhouse gas concentrations should correlate with an increase in global temperatures
* An increase in greenhouse gas concentrations will lead to an enhanced greenhouse effect resulting in
  + More frequent extreme weather conditions
  + Some areas to become more drought affected, while others will be more prone to heavy rainfall
  + Changes to circulating ocean currents

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| Definitions |
| **Weather** – Current conditions in a small area: can change rapidly  **Climate** –Patterns of temperature and precipitations over large periods of time |

# Ocean Acidification

* The oceans are a major carbon sink and absorb roughly a third of all human produced CO2 emissions
* CO2 solubility is temperature dependent (more soluble when cooler), so less CO2 will be absorbed as temperatures rise
* When oceans absorb atmospheric CO2 some of it will remain dissolved in a gaseous state but most will be chemically modified
  + Carbon dioxide combines with water to form carbonic acid
  + H+ ions will lower ocean pH
  + A decrease in ocean pH is predicted to threaten the survival of marine organisms that require calcium carbonate
  + Shells and coral exoskeletons are also likely to begin to dissolve when ocean conditions are more acidic
  + Experiments have shown that increasing water acidity correlates with the significant thinning of shells over several weeks
  + This could also lead to the disappearance of coral reefs