Topic 4: Ecology (12 hours)

4.1 Species, communities and ecosystems: The continued survival of living organisms including humans depends on sustainable communities.

Nature of science: Looking for patterns, trends and discrepancies—plants and algae are mostly autotrophic but some are not.

- The majority of plants and algae are autotrophic, meaning they produce their own food through photosynthesis; however, a small percentage of plants and animals obtain these carbon compounds from other organisms, either by growing on them and stealing the nutrients from the plant they are growing on or by consuming dead organic material. Since they obtain these carbon compounds from other species and cause them harm, they are considered parasitic.
- Only approximately 1% of all plants and algae are considered parasitic

*****Do the data based question on 204*****

∑- Understandings:

∑ - Species are groups of organisms that can potentially interbreed to produce fertile offspring.

- Species: a group of organisms that share a common ancestry, can interbreed and produce fertile offspring and is reproductively isolated from other such groups.

∑ - Members of a species may be reproductively isolated in separate populations.

- A population is a group of organisms of the same species who live in the same area at the same time
- Two populations of the same species can live in two different areas and are unlikely to interbreed; however, they are still part of the same species if they could potentially interbreed

Lions of the Serengeti - Tanzania

Tsavo Lions – Kenya/Uganda

∑ - Species have either an *autotrophic* or *heterotrophic* method of nutrition (a few species have both methods).

<u>Autotroph:</u>

- An organism that synthesizes its own organic molecules (makes their own food) from simple inorganic substances.
- Usually autotrophs convert light energy to chemical energy through photosynthesis.
- Chemoautotrophs obtain their energy through the oxidation of inorganic molecules in their environments.

Heterotroph:

- An organism that obtains organic molecules from other living organisms or their dead remains.
- Heterotrophs consume other organisms because they cannot make their own food.

Mixotrophic -

- Some unicellular organisms use both methods of nutrition such as *Euglena gracilis* which have chloroplasts to carry out photosynthesis when there is enough sunlight; however, they can also feed on detritus (dead or decaying material) or other smaller organisms.

∑ - Consumers are heterotrophs that feed on living organisms by ingestion.

- A consumer is an organism that ingests other organic material that is living or has been recently killed.

- Consumer feed of other organisms by ingesting their food, then digesting it and absorbing these products of digestion
- Primary consumers feed off autotrophs (example: Eastern Grey Squirrel feeds of mostly nuts/acorns)

- Secondary consumers feed on primary consumers (example: Red Fox feeds on Eastern Grey Squirrels)

- Tertiary consumers would feed on secondary consumers (example: Black Bear can feed on a Red Fox)

∑ **- *Detritivores* are heterotrophs that obtain organic nutrients from detritus by internal digestion.**

- Detritivore: an organism that obtains food by ingesting non-living organic matter i.e. Vultures and earthworms.

∑ **- *Saprotrophs* are heterotrophs that obtain organic nutrients from dead organisms by external digestion.**

- Saprotroph: an organism that lives on or within nonliving organic matter, secreting digestive enzymes into it and absorbing the nutrients produced by digestion. Saprotrophs help with the decaying or break down of dead organic materials.

<u>β - Skill</u>: Classifying species as *autotrophs, consumers, detritivores or saprotrophs* from a knowledge of their mode of nutrition.

Classify organisms using the dichotomous key on page 206

∑ - A community is formed by populations of different species living together and interacting with each other.

- Community: a group of populations living and interacting with each other in a particular area. Basically it means all living things in a habitat

All the coral, fish and living organisms on this coral reef in Australia make up a community

∑ - A community forms an ecosystem by its interactions with the abiotic environment.

- Ecosystem: a community which consists of all the biotic factors such as plants and animals in an area, functioning together with all of the physical or abiotic factors of the environment.
- So the above example of the coral reef with all the abiotic factors including water temperature, currents, available nutrients etc. is an ecosystem

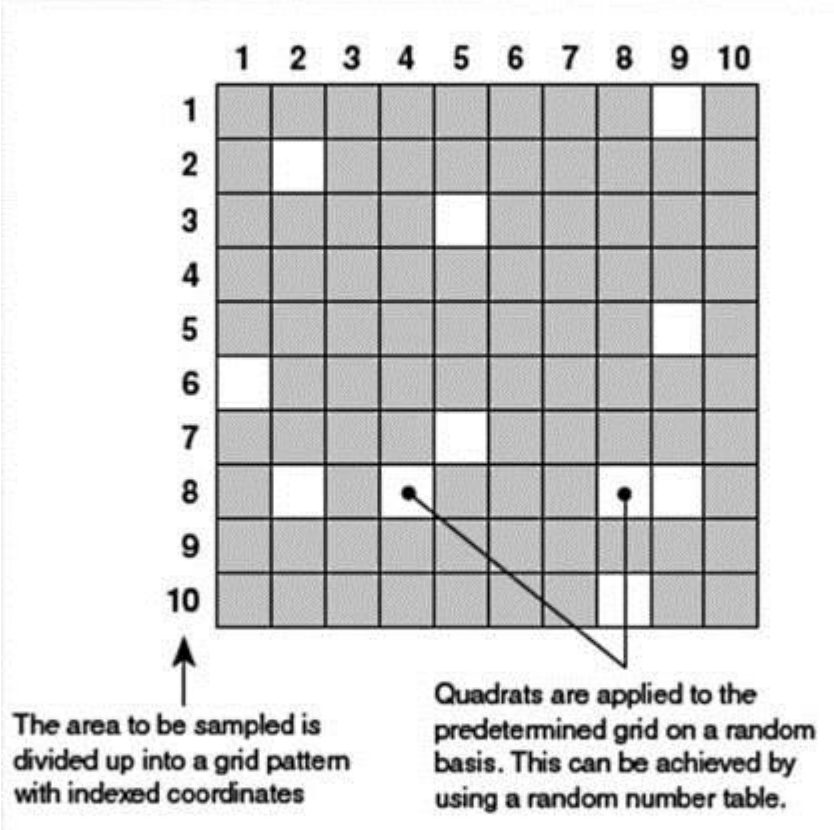
Applications and skills:

<u>β - Skill</u>: Testing for association between two species using the chi-squared test with data obtained by quadrat sampling. To obtain data for the chi-squared test, an ecosystem should be chosen in which one or more factors affecting the distribution of the chosen species varies. Sampling should be based on random numbers. In each quadrat the presence or absence of the chosen species should be recorded. The collection of raw data through quadrat sampling will be done in the North Forest

<u>Example of Quadrat Sampling</u>

- Plot-based (quadrat) methods are often used to study populations of different species within a certain area.
- Quadrats are generally square sample areas marked out using a framed structure.

- Quadrats are placed in a marked out habitat according to random numbers obtained using a random number table or a random number generator on a calculator



- The baseline of this habitat can be marked out using a measuring tape
- A first number is determined for the distance along the measuring tape on one side (along the y-axis) and the second distance is randomly determined along the x-axis
- The quadrat is placed at the point where the two numbers meet
- Within each quadrat, the individual species are identified and the density, frequency, % coverage or abundance of each species is counted or estimated.
- This will be repeated with enough replicate squares to calculate a reliableestimates of the populations of these species in the area.
- If the presence or absence of more than one species is recorded in every quadrat during the sampling of a habitat, one can test for an associationbetween the species
- If two different species are found in the same habitat and within the same quadrat, they are **positively associated**. This basically means that one species is more likely to be found, when the other species is also present
- A **negative association** is when two species tend not to occur together
- If there is no association between the two species, negative or positive, the species are said to be independent. Basically this means that the location of species A has no effect on species B and vice versa.
- One can test these associations using a **chi-squared test** (called Chi Square Test for Independence)

β - Skill: **Recognizing** and **interpreting statistical significance**.

Complete the following example below for two species of plants found in the Northwest

So you will be testing to see if there is a statistically significant association between these two species of trees. The first step is to create a hypothesis H_A and a null hypothesis H_O. The null hypothesis is basically that there is NO statistically significant association between Douglas Fir and the Dwarf Mistletoe. Write out a H_A and H_O below.

H_A =

H_O =

The presence of two different species Dwarf Mistletoe and Douglas Fir was recorded in 200 different quadrats, 1000 m x 1000m. The quadrats were randomly chosen. Here are the results from the raw data collection

	Douglas Fir present	Douglas Fir absent	Total
Dwarf Mistletoe present	90	45	
Dwarf Mistletoe absent	30	35	
Total			

Add the two columns and the two rows together. This should give you the same total number in the bottom right hand corner of the table

Calculations

Expected results: This is assuming that both of the species are randomly distributed with respect to each other.

The probability of Dwarf Mistletoe (DM) being present in each quadrat is the total of row 1 where DM is present no matter if Douglas Fir (DF) is present or not, divided by the total number of quadrats

135/200 = 0.675

The probability of DF being present is the same calculation but using column one.

120/200 = 0.600

The probability of BOTH species being found together is **0.675 x 0.600 = .405**

Therefore, the expected number of quadrats that both species should occur in is

0.405 x 200 = 81

Now we can make a table with the expected results. 81 will be in the cell where both species are present. The totals remain the same, so just subtract 81 from all the previous totals and fill in the chart.

	Douglas Fir present	Douglas Fir absent	Total
Dwarf Mistletoe present	81	54	135
Dwarf Mistletoe absent	39	26	65
Total	120	80	200

Now one can calculate the remaining ratios, the same way you did the first one for DM and DF present, if you want to check to make sure the expected results are correct.

Now the **statistical test**:

		Douglas Fir present	Douglas Fir absent	Total
Dwarf Mistletoe present	O	90	45	135
	E	81	54	
Dwarf Mistletoe absent	O	30	35	65
	E	39	26	
Total		120	80	200

Then you calculate the chi-squared value using the following formula (same as with genetics)

$$\chi^2 = \sum \frac{(Observed - Expected)^2}{Expected}$$

= $(90 – 81)^2/81$ + ____________ + ________________ + _____________

= 1.00 + 1.50 + 2.08 + 3.12 = **<u>7.70</u>**

To find out if the result is statistically significant or not, the value must be compared to a **<u>critical value</u>** from the chi-squared table.

The degrees of freedom = (number of columns – 1) x (number of rows – 1) = (2-1) x (2-1) = 1

TABLE IV

Chi-Square (χ^2) Distribution

Degrees of Freedom	Area to the Right of Critical Value							
p	0.99	0.975	0.95	0.90	0.10	0.05	0.025	0.01
1	—	0.001	0.004	0.016	2.706	3.841	5.024	6.635
2	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210
3	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345
4	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277
5	0.554	0.831	1.145	1.610	9.236	11.071	12.833	15.086

The critical value for degrees of freedom 1 is 3.841 with a p value or probability value of 0.05.

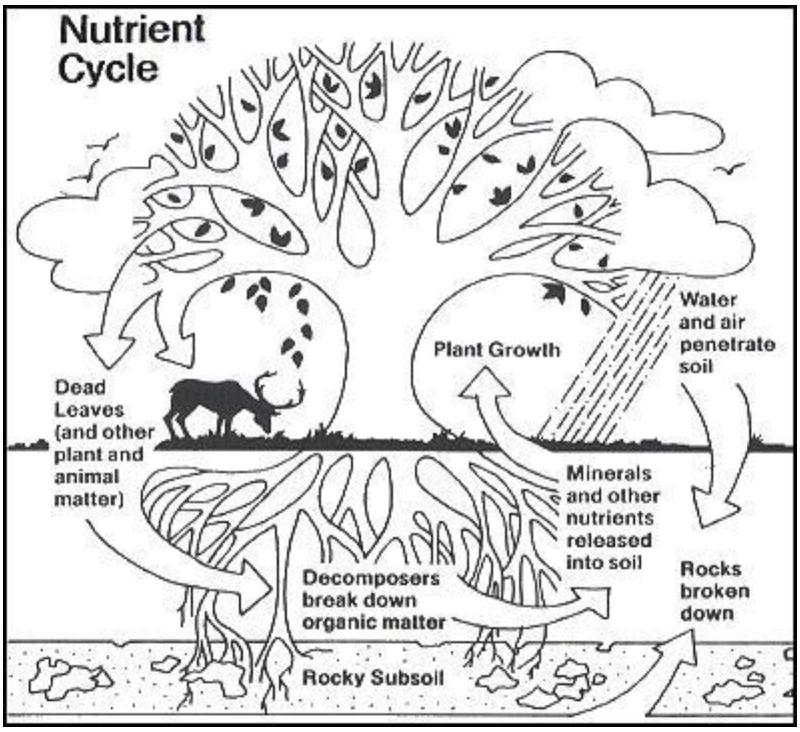
Since our <u>calculated value is 7.70</u> then we can **reject the null hypothesis** and **the alternative hypothesis is accepted**. Basically, the means that there is a<u>statistically significant</u> <u>association between Douglas Fir and Dwarf Mistletoe</u>, and the distributions of the two species are <u>not independent</u> of each other.

∑ - Autotrophs obtain inorganic nutrients from the abiotic environment.

- Autotrophs acquire their nutrients such as carbon, hydrogen, oxygen, nitrogen and phosphorus from inorganic sources in the abiotic environment
- Heterotrophs do obtain nutrients such as sodium, potassium and calcium from inorganic sources, but obtain carbon and nitrogen through organic sources in the food they eat

∑ - The supply of inorganic nutrients is maintained by nutrient cycling.

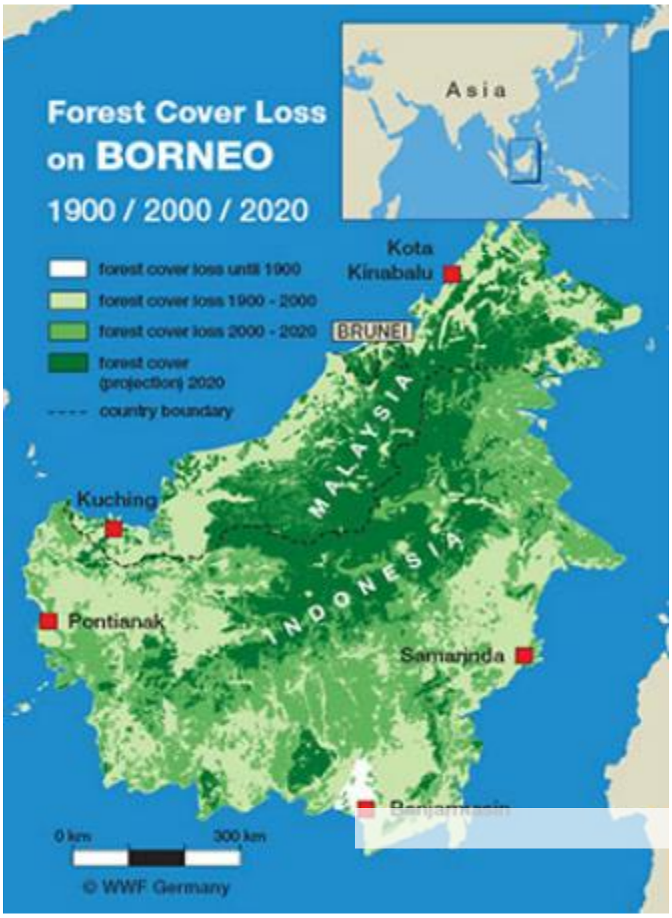
- Since there is a limited supply of nutrients on earth, chemical elements are constantly recycled after they are used.



The carbon cycle will be discussed later in this unit.

∑ - Ecosystems have the potential to be sustainable over long periods of time.

- Ecosystems are largely self-contained and self-sustaining units that can exist over long periods of time; however, human activity has had a negative impact in the sustainability of certain ecosystems
- An example of how humans have drastically impacted an ecosystem is the rainforest being lost in Borneo for the production of Palm Oil



- There are three main requirements for sustainability in an ecosystem: nutrient availability, detoxification and recycling of waste products and energy availability
- Nutrients such as carbon and nitrogen can be recycled indefinitely as long as the proper conditions exist i.e. Nitrosomonas bacteria in the soil convert ammonia into nitrites

- There also must a constant supply of energy, as it cannot be recycled
- Today conservation attempts to manage and sustain the environment so that a balance is maintained, despite human activities. This may include limiting consumption and effective population control in certain areas of the world

β - Lab Skills

You will set up sealed mesocosms in order to create a self-sustaining ecosystem on a small scale according to the handout given in class

4.2 Energy flow:

Ecosystems require a continuous supply of energy to fuel life processes and to replace energy lost as heat.

Nature of science: Use theories to explain natural phenomena—the concept of energy flow explains the limited length of food chains.

∑ - Understandings:

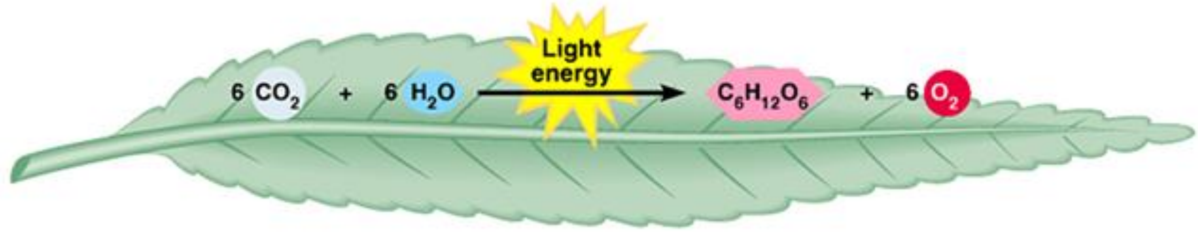
∑ - Most ecosystems rely on a supply of energy from sunlight. There is a continuous but variable supply of energy in the form of sunlight but that the supply of nutrients in an ecosystem is finite and limited and must be cycled.

- In food webs and communities all interactions between the organisms requires energy.
- Sunlight provides the initial energy source for almost all communities.
- Sunlight energy is converted to useable chemical energy throughphotosynthesis.
- Autotrophs that harvest the light energy and produce chemical energy through photosynthesis are called producers. These include plants, eukaryotic algae, and cyanobacteria.
- Heterotrophs feed on other organisms in order to obtain their energy
- The amount of energy supplied and available in ecosystems varies around the world depending upon the amount of sunlight and the number of producers to convert light energy into chemical energy

***** Do the data-based question on page 214*****

∑ - Light energy is converted to chemical energy in carbon compounds by photosynthesis.

- Producers absorb light energy using chlorophyll and other photosynthetic pigments



- Producers release energy using cellular respiration and use it for cellular activities; some energy lost as heat. The energy remaining in the cells and tissues is available for consumers

∑ - Chemical energy in carbon compounds flows through food chains by means of feeding.

- **1° consumers** feed on **the producers**. Only around **10%-20%** of the energy from the producer is passed on to the 1° consumers. The rest of the energy is**lost as heat** through **cell respiration, death and waste**.
- **2° consumers** feed on the **1° consumers**. Again only 10%-20% of the energy is passed on to the next level, with the rest lost as **heat through respiration, death, and waste.**
- **3° consumers** feed on **2° consumers**. 10%-20% is passed on to the tertiary consumer and the rest is lost as heat, death and waste.

Examples of Food Chains:

1. Bent grass --> grasshoppers --> mouse --> Bull snake --> Red-Tailed Hawk
2. Bent grass --> Thomson's gazelle --> Cheetah --> Hyenas
3. Phytoplankton ---> Zooplankton --> Herring --> Salmon -->Harbor Seals --> Killer Whales

∑ - Energy released from carbon compounds by respiration is used in living organisms and converted to heat.

- Organisms need energy for cellular activities, such as **protein synthesis**,**pumping ions or molecules** across membranes and **moving things** such as chromosomes and vesicles around the cell
- **ATP** provides **the energy** needed for these cellular activities
- ATP is produced through cellular respiration, which involves the oxidation of carbohydrates and lipids. These reactions are exothermic and the energy released is used in endothermic phosphorylation reactions to create ATP.
- ATP can be used quickly for the cellular activities listed above.
- These reactions are **not 100% efficient**, therefore some of the energy produced in these oxidation reactions is lost as heat. Some heat can also be produced during cellular activities

*****Do the data based questions on page 216*****

∑ - Living organisms cannot convert heat to other forms of energy.

- Organisms can perform a variety of energy conversions, such as light to chemical energy during photosynthesis, chemical energy to KE during muscle contractions, chemical energy to electrical energy in nerve impulses and chemical energy to heat energy in heat-generating adipose tissue
- Organisms **cannot turn heat energy** into any **other forms of energy**

∑ - Heat is lost from ecosystems.

- Heat resulting from cellular respiration makes an organism warmer. Cold-blooded organisms can become more active, while warm blooded animals can increase their ate of heat generation in order to maintain their in internal body temperature
- Eventually though, since heat passes from warmer to colder bodies (thermodynamics), all heat is lost from the ecosystem

∑ - Energy losses between trophic levels restrict the *length of food chains* and the *biomass of higher trophic levels*. Biomass in terrestrial ecosystems diminishes with energy along food chains due to *loss of carbon dioxide*, *water*and *other waste products*, such as *urea*.

- Biomass is the total mass of a group of organisms, consisting of the cells and tissues of the organisms and the carbohydrates and other carbon compounds they contain
- Since carbon compounds have chemical energy, scientists can measure the amount of energy added per year by groups of organisms to their biomass. Results are calculated per square metre of the ecosystem and the trophic levels can be compared. The energy added to the biomass by each successive trophic level is always less
- Food chain length is **limited** by the amount of energy available as we move up the different trophic levels.
- **Most energy** in food that is consumed, digested and absorbed by organismsfor a certain trophic level is released by them during cellular respiration used in cellular activities and is therefore **lost as heat**
- At each level, when an organism is consumed some parts might not be eaten or consumed
- Not all food is digested or absorbed fully. Indigestible food is egested in feces.
- Also some organism might die before they are eaten or consumed. This waste and dead organic material forms detritus which is non-living particulate organic material.
- The detritus is then broken down and the stored energy is used by decomposers or consumed by detritivores.
- Some energy can be trapped as fossil fuels or peat.

∑ - Pyramids of energy should be drawn to scale and should be stepped, not triangular. The terms producer, *first consumer* and *second consumer* and so on should be used, rather than first trophic level, second trophic level and so on.

<table>
<tr><th>Explanation of Energy Pyramid Shape</th><th>Energy Pyramid</th></tr>
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Energy pyramids show the flow from one trophic level to the next in a community
They are shaped like a pyramid because as we move up trophic levels, the majority of energy is lost and only a small amount is passed on to the next trophic level.
The units of measurement for a pyramid of energy is energy per unit area per unit time (KJ $m^{-2}yr^{-1}$), which is kilojoules per square meter per year.
Because so much energy is lost, each level has to be smaller than the next. The second trophic level cannot be larger than the first because organisms cannot create energy. They can only transfer it from one level to the next, rather inefficiently.

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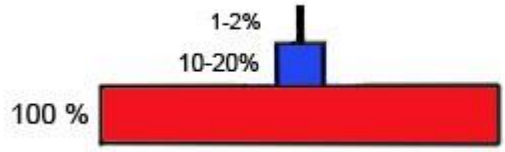

Energy pyramid – Between 80-90% of the energy is lost as you move up from one trophic level to the next trophic level. The amount of energy that is passed from one level to the next depends on how efficiently the organisms can capture and use the energy from the trophic level below.

The first level should be labeledproducers.

The next level is the primary consumers.

The third level is the secondary consumers.

The fourth level is the tertiary consumers
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</table>

Applications and skills:

β - Skill: Quantitative representations of energy flow using pyramids of energy.

Draw a pyramid of energy for an ecological community of your choice

4.3 Carbon cycling:

Continued availability of carbon in ecosystems depends on carbon cycling.

Nature of science: Making accurate, quantitative measurements—it is important to obtain reliable data on the concentration of carbon dioxide and methane in the atmosphere.

Understandings:

∑ - Autotrophs convert carbon dioxide into carbohydrates and other carbon compounds.

- Autotrophs such as plants and algae, convert inorganic carbon dioxide into organic carbohydrates, lipids and all other carbon based compounds through photosynthesis.
- This reduces the carbon dioxide concentration in the atmosphere.

*****Do data-based question on page 221*****

∑ - In aquatic ecosystems carbon is present as dissolved carbon dioxide and hydrogen carbonate ions.

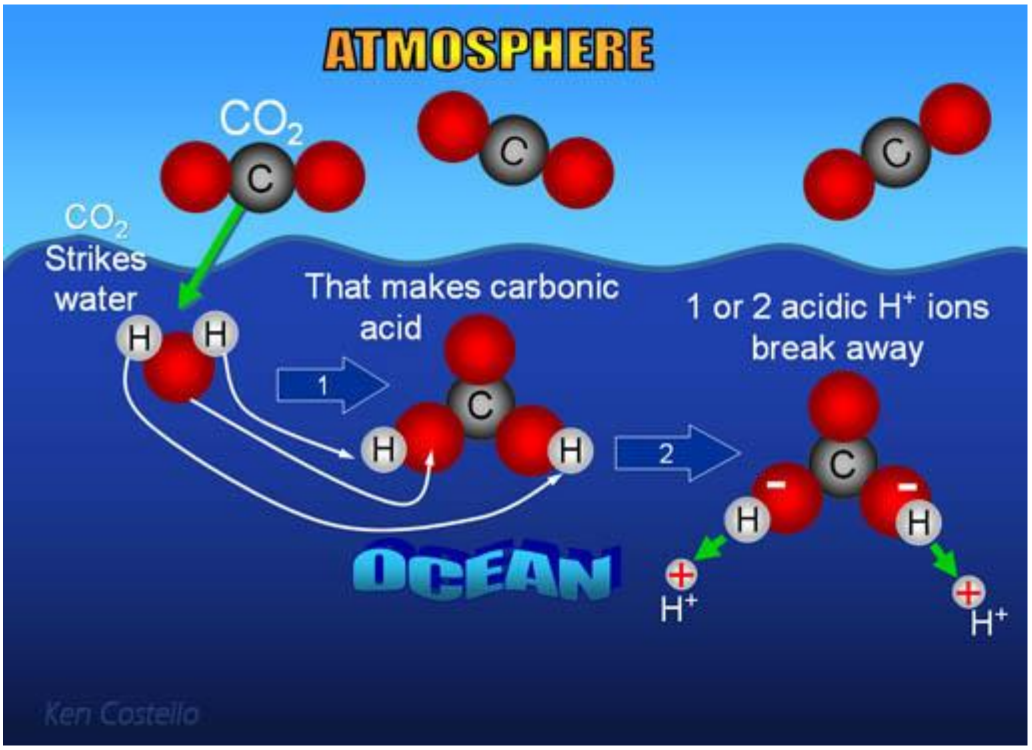
- Carbon dioxide dissolves in water and some of it will remain as a dissolved gas
- Some of the carbon dioxide will combine with water to form carbonic acid

$CO_2 + H_2O \text{<-->} H_2CO_3$.

- Carbonic acid can then disassociate to form H^+ and HCO_3^-

($H_2CO_3 \text{<-->} HCO_3^- + H^+$)

- This is why the pH decreases
- Autotrophs in water absorb both CO_2 and hydrogen carbonate ions, and use them to produce organic compounds



∑ - Carbon dioxide diffuses from the atmosphere or water into autotrophs.

- Since autotrophs use carbon dioxide for photosynthesis, as the CO_2 is depleted by the autotroph, the concentration of CO_2 in the surrounding atmosphere or water is greater than inside the autotroph; therefore a concentration gradient is created
- Carbon dioxide diffuses into the autotroph, following the concentration gradient created
- In aquatic organisms carbon dioxide can diffuse directly into the autotroph as all parts of the plant are usually permeable to CO_2
- For land plants, carbon dioxide diffuses through stomata (openings on the bottom of the leaf)

∑ - Carbon dioxide is produced by respiration and diffuses out of organisms into water or the atmosphere.

- All organisms carry out cellular respiration and produce carbon dioxide as a waste product
- This CO_2 will be released by these organisms through diffusion into the atmosphere or water, depending if they are terrestrial or aquatic organisms
- Examples are animal cells, non-photosynthetic cells in producers, and cells in saprotrophic organisms like fungi

***** Do data based question on page 222*****

∑ - Methane is produced from organic matter in anaerobic conditions by methanogenic archaeans and some diffuses into the atmosphere or accumulates in the ground.

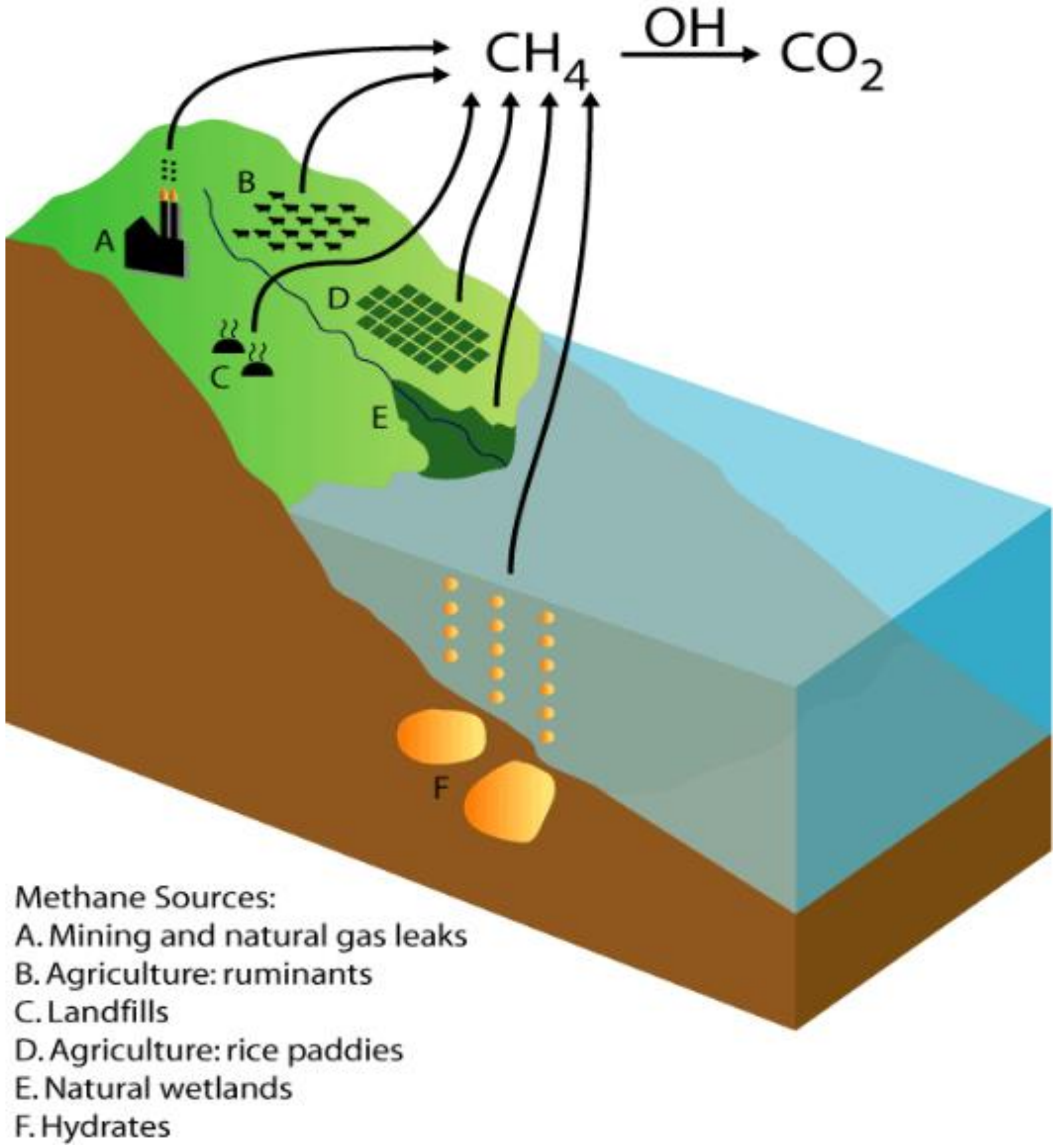
- Methane is widely produced in anaerobic conditions as a waste product of a certain type of anaerobic respiration called methanogenesis
- Some bacteria use organic acids and alcohol to produce acetate, carbon dioxide and hydrogen, which is in turn used by a group of methanogenic archaeans to produce methane as a waste product through two reactions:

1) $CO_2 + 4\ H_2 \rightarrow CH_4 + 2H_2O$ and 2) $CH_3COO^- + H^+ \rightarrow CH_4 + CO_2$

- These reactions occur without oxygen in swamps, wetlands and mangroves, in mud along the banks of rivers and lakes, and in the digestive tracts of mammals and termites.
- With large herds of domestic cattle and sheep being raised worldwide, there is concern that all the methane being produced is contributing to the greenhouse effect

∑ - Methane is oxidized to carbon dioxide and water in the atmosphere.

- Methane is the main ingredient in natural gas. When you burn methane the reaction involves oxygen gas from the atmosphere to produce carbon dioxide and water
- When methane is actually released into the atmosphere through the anaerobic reactions, it can persist in the atmosphere for about 12 years, as it is naturally oxidized by monatomic oxygen (O) and hydroxyl radicals (OH^-)
- This is why methane concentrations are not very great in the atmosphere, even though large amounts are produced



http://www.giss.nasa.gov/research/features/200409_methane/

∑ - Peat forms when organic matter is not fully decomposed because of acidic and/or anaerobic conditions in waterlogged soils.

- Peat, which is partially decomposed plant material, is another organic substance that can be used as a fossil fuel.
- In many soils, saprotrophic bacteria and fungi, digest organic material from dead leaves and plants; however, oxygen (air spaces in the soil) is needed for cellular respiration.
- In muddy, water-logged environments, these air spaces might not be present and therefore anaerobic conditions exist
- Acidic conditions develop, further inhibiting the decomposers
- Since this organic material is not fully decomposed, energy rich molecules that would have been fed upon by saprotrophs and methanogens are left behind and energy rich peat is formed

- The soil that forms peat is called histosol and the layer of peat is usually 10-40 cm thick
- Sphagnum moss is a type of vegetation that often grows on peat

Video on peat development https://www.youtube.com/watch?v=Hu7yCrSzC1A

*****Do data based questions on page 224****

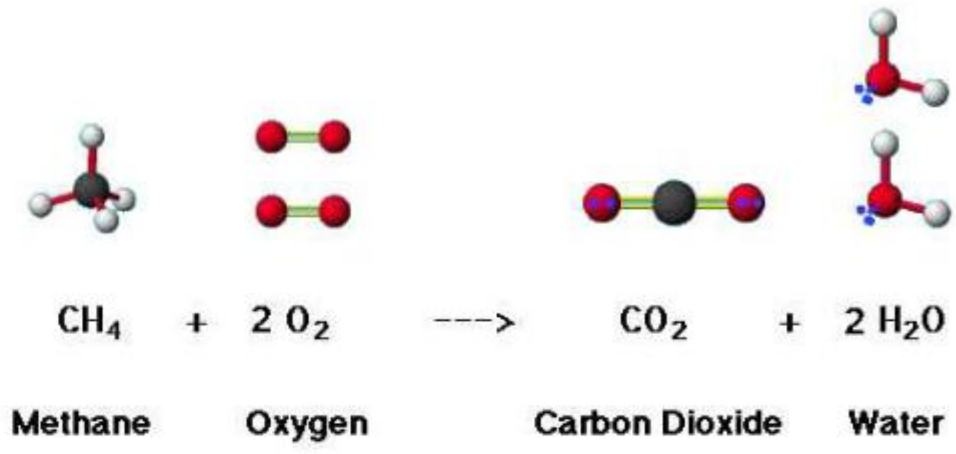
∑ - Partially decomposed organic matter from past geological eras was converted either into coal or into oil and gas that accumulate in porous rocks.

- Partially decomposed peat when put under extreme weight, pressure and heatfrom above sediments can be transformed into coal
- This transformation takes place over millions of years
- The pressure and heat cause lithification (the transformation of sediments into solid rock)
- Large deposits were formed during the Carboniferous era
- Oil and gas are formed at the bottom of oceans, seas and lakes over millions of years
- The dead remains of marine organisms only partial decomposed when they settled at the bottom of the ancient oceans and seas in anaerobic conditions
- As more dead remains and sediment accumulated, intense pressure and heatcaused this sludge to undergo a chemical transformation into a mixture of carbon compounds or gases.
- Lipids which are not easily broken down formed a waxy hydrocarbon called**kerogen**
- Kerogen in porous sedimentary rock becomes crude oil or natural gas; depending on its state

Video on oil and gas formation https://www.youtube.com/watch?v=8YHsxXEVB1M

∑ - Carbon dioxide is produced by the *combustion of biomass* and *fossilized organic matter*.

- When organic compounds rich in hydrocarbons are heated and reach their ignition temperature in the presence of oxygen they undergo combustion(burning). This is an oxidation reaction.
- The products of combustion are carbon dioxide and water



Combustion Reaction

∑ - Animals such as *reef-building corals* and *mollusca* have hard parts that are composed of calcium carbonate and can become fossilized in limestone.

- Animals such as coral and mollusca (clams etc.) contain body parts made out of calcium carbonate ($CaCO_3$)
- Hard corals produce their exoskeletons by secreting calcium carbonate and molluscs have shells that contain calcium carbonate
- The calcium carbonate in alkaline or neutral conditions from a variety of these organisms, settle onto the seafloor when they die
- Through lithification, these sediments form limestone. The hard parts of many of these animals are visible as fossils in the limestone rock

Applications and skills:

β- Application: **Estimation** of **carbon fluxes** (measured in gigatons) due to processes in the **carbon cycle**.

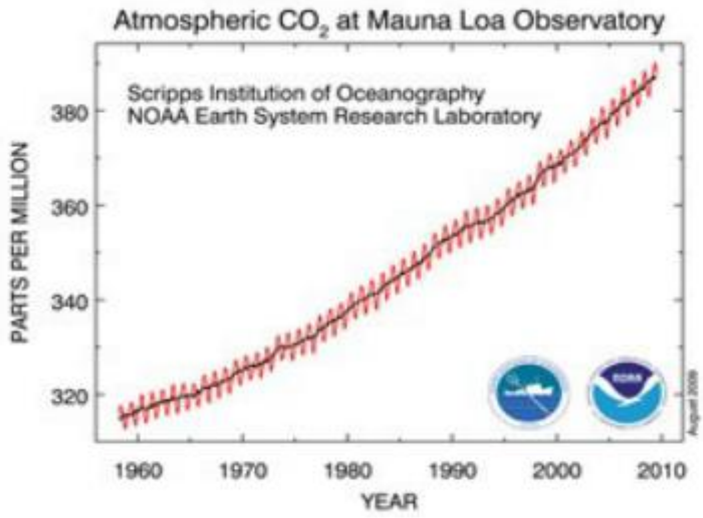
*****Do the data based questions on carbon fluxes on page 227*****

Global carbon fluxes are very large and are therefore measured in gigatons

β - Application: **Analysis of data** from air monitoring stations to **explain annual fluctuation**s.

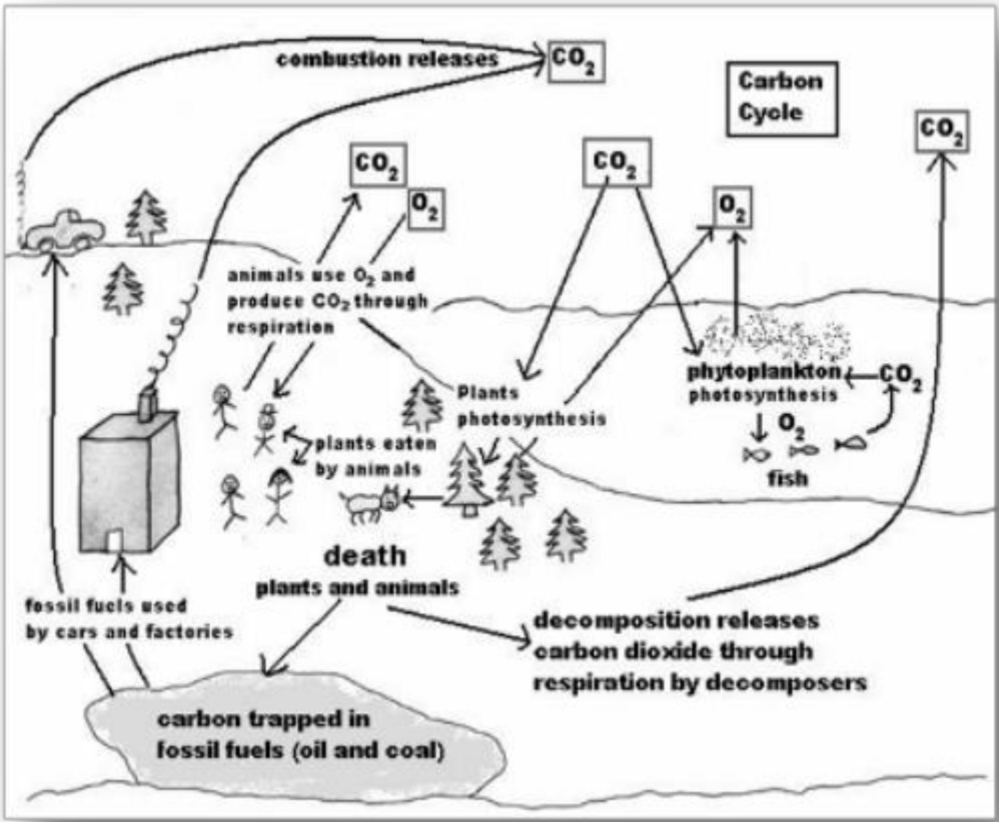
- CO_2 levels have drastically increased since the industrial revolution.
- As seen in the graph below, since 1960 atmospheric CO_2 levels have increased from about 320 ppm to about 390 ppm in the last 50 years.

- The yearly fluctuations indicated by the up and down pattern in the graph are caused by seasonal fluctuations of CO_2, caused by a variety of factors such asphotosynthesis (more photosynthesis, therefore less atmospheric CO_2 in the summer months).
- This upward trend of CO_2 shows a **correlation** with possible climate change (global warming).
- Different monitoring stations might have slightly different graphs because of the distribution of vegetation throughout the world, contributing to slightly different atmospheric CO_2 levels.
- CO_2 levels are the highest they have ever been.



Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends)

β - Skill: **Construct** a **diagram** of the **carbon cycle**.



You must be able to draw your own version of the carbon cycle.

4.4 Climate change:

Concentrations of gases in the atmosphere affect climates experienced at the Earth's surface.

Nature of science: Assessing claims—assessment of the claims that human activities are producing climate change.

Understandings:

∑- *Carbon dioxide* and *water vapour* are the most significant greenhouse gases.

- The greenhouse effect is the earth's ability to use its atmosphere to retain heat and keep warm even when no sun is hitting the surface
- The gases that have the greatest impact on the warming effect on earth are CO2 and water vapour

- Carbon dioxide is released into the atmosphere by cellular respiration by organisms and combustion of organic materials and burning of fossil fuels. It is removed by photosynthesis and absorption by the oceans
- Water vapour is created by evaporation of the water in oceans, seas and lakes and transpiration by plants. It is removed through precipitation.
- The greenhouse effect is a natural phenomenon that keeps the surface of the earth warm due to the presence of an atmosphere containing these gases that absorb and radiate heat.

∑ - Other gases including *methane* and *nitrogen oxides* have less impact.

- Methane has the third greatest impact on the greenhouse effect
- It is emitted from marches, other water-logged habitats and from landfill sites containing organic wastes
- Nitrous oxide, which is another significant greenhouse gas is released naturally by bacteria in some habitats and also by agriculture and vehicle exhaust
- All the greenhouse gases together make up less than 1% of the earth's atmosphere

∑ - The impact of a gas depends on its ability to absorb long wave radiation as well as on its concentration in the atmosphere.

- The two factors that determine how much of an influence a gas will have on the greenhouse effect are

1) The ability of the gas to absorb long-wave radiation (heat)

2) The concentration of the gas in the atmosphere

- Methane actually has the ability to cause much more warming per molecule than carbon dioxide; however, there is a much lower concentration of methane in the atmosphere

∑ - The warmed Earth emits longer wavelength radiation (heat).

- When light (shorter wavelengths) enters the earth's atmosphere, some of the light reflects off the earth's surface back towards outer space.
- Some of the light is converted into heat, which in turn warms the surface of the earth (the air, mountains and water).
- This heat (longer wavelengths) radiates off the earth back towards the atmosphere.
- The peak wavelength for infrared is 10,000 nm, while the peak wavelength of solar radiation is 400 nm

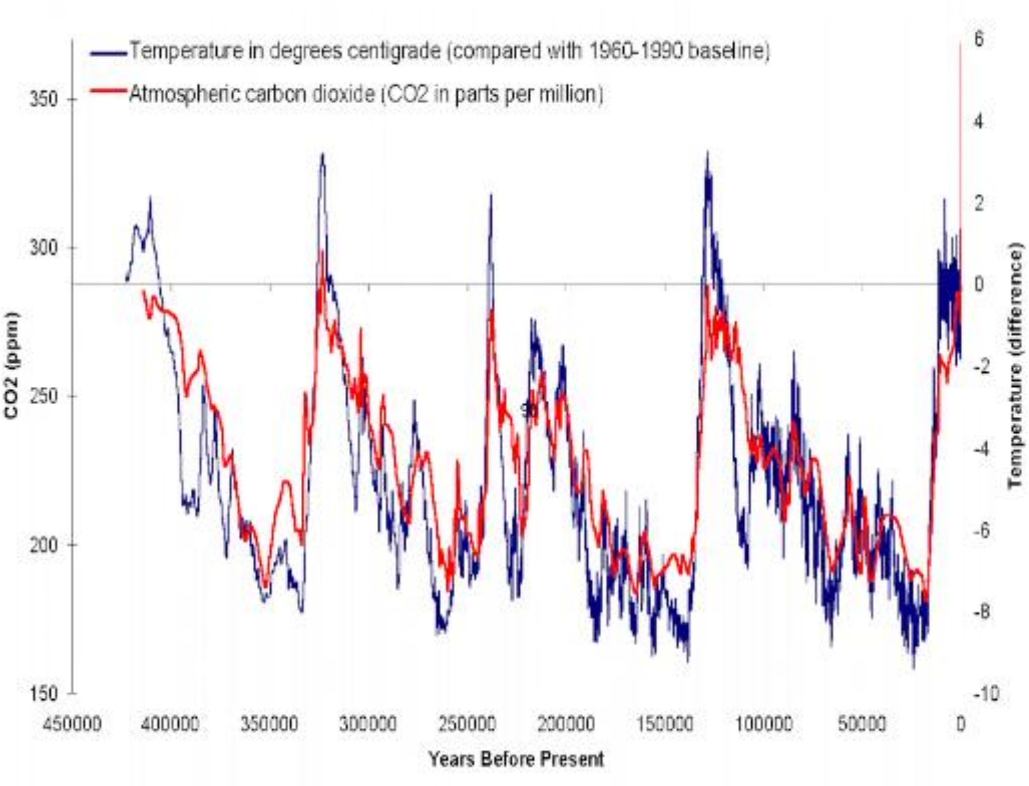
∑ - Longer wave radiation is absorbed by greenhouse gases that retain the heat in the atmosphere.

- Greenhouse gases such CO_2 and water vapour absorb this heat (infrared radiation) trapping it within the atmosphere, further warming the earth.
- 70-75% of the solar radiation reaches the earth's surface, with a high percentage of this radiation being converted into heat
- As the infrared radiation is reflected back off the earth, a large percentage of this heat is captured by the greenhouse gases in the atmosphere. This energy is re-emitted, thus heating up the earth's atmosphere. This effect is called global warming.
- The ability of the earth's surface to reflect light is called the albedo effect. Light coloured and white objects such as snow and ice, have a high albedo and therefore little light is absorbed and less heat is produced. Black and dark coloured objects like asphalt and pavement have a low albedo, and therefore absorb more light and produce more heat.
- With the spread of urban cities and areas, a greater amount of heat is being produced

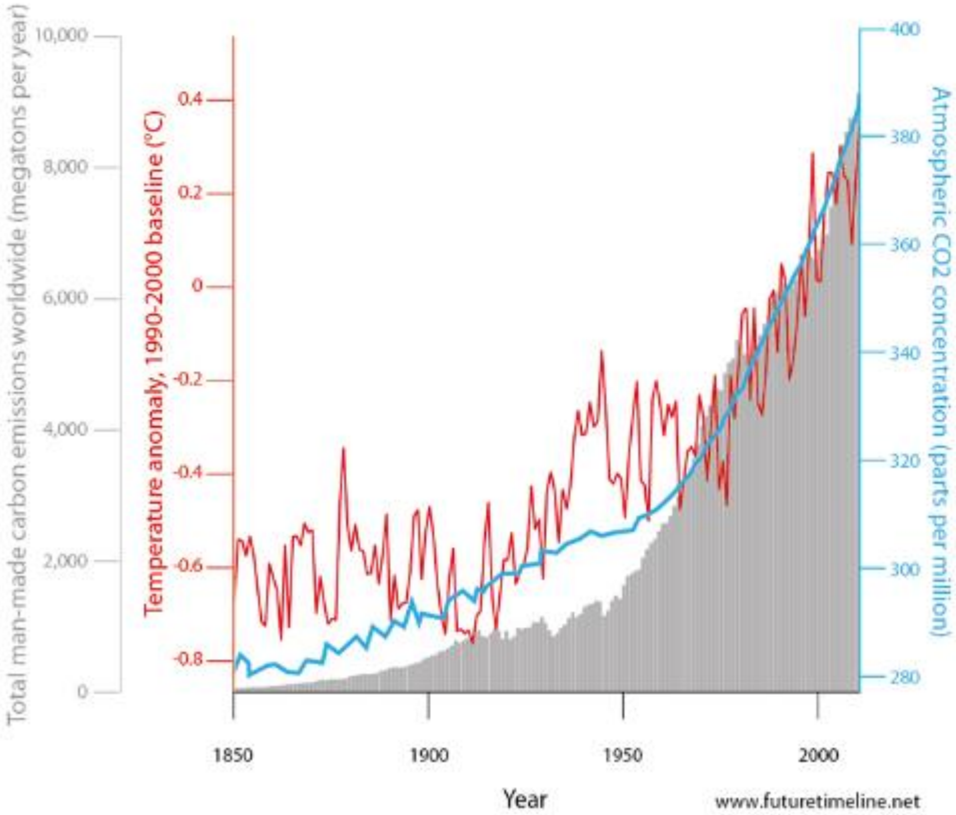
∑ - *Global temperatures* and *climate patterns* are influenced by concentrations of greenhouse gases.

- Climate refers to the patterns of temperature and precipitation that occur over long periods of time. Climate changes over thousands or millions of years
- Climatologists and palaeoclimatologists collect and study data about atmospheric conditions in recent decades and from the distant past in order to infer what the climate was like thousands to millions of years ago
- Since greenhouse gases cause the earth to retain heat, one can infer that the more greenhouse gas there is in the atmosphere, the warmer the earth will be.
- This does not mean that the amount of greenhouse gas is the only reason for the earth warming and cooling; however, there is a correlation between the earth's temperature and the amount of greenhouse gas
- Other factors such as the cycles in the Earth's orbit around the sun, variations in the amount of solar radiation due to sunspot activity, past volcanic activity, and changes or oscillations in ocean currents
- Even if greenhouse gases aren't the only factor in the rise of the Earth's temperature, if the Earth heats up even a few degrees, it will have profound effects on the climate patterns

∑ - 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.



- As evident from the above graph, there has been large fluctuations of temperature and carbon dioxide concentration over the past 400,000 years
- The concentrations of CO_2 varied between about 300 ppm during warmer interglacial periods and about 170 ppm during glacial cooling periods
- However, over the past 200 years the amount of CO_2 has risen to unprecedented highs of about 380-90 ppm as seen in the graph below



- These increases began after the industrial revolution as more and more countries became industrialized and started to burn oil, coal and natural gas in great quantities
- Even though it can't be stated that this is the only cause for the rise in global temperature, there is a strong correlation between CO2 concentration in the atmosphere and the rise in global temperatures

*****Do the data-based questions on page 233*****

∑ - Recent increases in atmospheric carbon dioxide are largely due to increases in the combustion of fossilized organic matter.

- As described above, since the industrial revolution the amount of CO2 has drastically increased, largely due to the increasing quantities of combustion of fossilized organic matter (coal, oil and natural gas)
- The number one source of carbon emissions due to human activities is through combustion of fossil fuels in automobiles, buses and planes.
- Another source of carbon dioxide is the deforestation through burning large tracks of land and heating homes with fossil fuels, such as natural gas
- Humans demand for meat has led to large numbers of cattle, which is responsible for releasing methane into the atmosphere, which is changed into carbon dioxide
- As the human population increases and countries become more industrialized, human production of greenhouse gas, shows no sign of slowing down

*****Do the data-based questions on page 236*****

Applications and skills:

<u>β - Application</u>: **Threats to coral reefs** from **increasing concentrations** of dissolved **carbon dioxide**.

- Ocean acidification is the ongoing <u>decrease</u> in the **pH** of the Earth's oceans, caused by the uptake of <u>carbon dioxide</u> from the earth's atmosphere.
- Over 500 billion tonnes of CO2 released by humans since the start of the industrial revolution have been dissolved in the oceans.
- pH of surface layers of the earth's oceans in the late 18th century ≈ 8.1179 currently ≈ 8.069, which represents about a 30% acidification.

- Reef-building corals that use calcium carbonate in their exoskeletons need to absorb carbonate ions from seawater.
- The concentration of <u>carbonate ions</u> is low in seawater because they are not very soluble.
- Dissolved CO_2 makes the carbonate concentration even lower as a result of some interrelated chemical reactions:

$$CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^- \longleftrightarrow H^+ + CO_3^{2-}$$

- If the carbonate ions concentrations drop it is more difficult for reef-building corals to absorb these ions to make their exoskeletons
- Also, if seawater ceases to be a saturated solution of carbonate ions, existing calcium carbonate tends to dissolve, so existing exoskeletons of reef-building corals are threatened.
- Volcanic vents in the Gulf of Naples have been releasing carbon dioxide into the water for thousands of years, reducing the pH of the seawater. In this area of acidified water there are no corals, sea urchins or other animals that make their exoskeletons from calcium carbonate. In their place other organisms like invasive algae and sea grasses flourish. Unfortunately this could be the disheartening future for coral reefs around the world if carbon dioxide emissions continue to rise…
- Loss of tropical coral reefs to acidification could cost $1 trillion by 2100 in terms of lost shoreline protection and lost revenues for the tourism and food industries.

<u>β - Application</u>: Correlations between *global temperatures* and *carbon dioxide concentrations* on Earth. Databases can be used to analyse concentrations of greenhouse gases.

<u>β - Application</u>: Evaluating claims that human activities are not causing climate change.

Some claims that human activities are not causing climate change	**Possible responses from scientists**
'Global warming stopped in 1998' but CO_2 has continued to rise. How can carbon dioxide be the cause then?	
'Long winters, cold summers – what global warming?' Many point to the winters in recent years in Central Europe as an example.	
Climate change is just a theory, not a fact!	

Many scientists disagree and have published research showing climate change is not due to humans!	
"Antarctica is gaining ice"	
There has been huge fluctuations in climate in the past, and the current changes that we are seeing in recent decades are natural and the sun is currently in a phase of high-energy output.	

International-mindedness: Release of greenhouse gases occurs locally but has a global impact, so international cooperation to reduce emissions is essential.

Theory of knowledge: The precautionary principle is meant to guide decision-making in conditions where a lack of certainty exists. Is certainty ever possible in the natural sciences?

- The precautionary principle is a moral and political principle that states that, if a human-induced change might cause severe or irreversible harm to the public or to the environment, those responsible for the change must prove that it will **not do harm** before proceeding.
- In the absence of a scientific consensus that harm would not ensue, the burden of proof falls on those who want to take the action.
- This is the reverse of the normal situation, where those who are concerned about the change would have to prove that it will **do harm** in order to prevent such changes going ahead.
- The principle implies that there is a responsibility to intervene and protect the public and environment from exposure to harm where scientific investigation discovers a plausible risk.

Discuss if you think certainty is ever possible with regards to natural sciences

Aims: There are interesting parallels between humans that are unwilling to reduce their carbon footprint and cheating in social animals. When the level of cheating rises above a certain level, social behaviour breaks down.

http://www.nytimes.com/2011/04/17/weekinreview/17chump.html

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Topic 1 - Cells
Topic 2 - Molecular Biology
Topic 3 - Genetics
Topic 4 - Ecology
Topic 4.1 - Species, Communities and Ecosystems
Topic 4.2 - Energy Flow

Topic 4.3 - Carbon Cycling
Topic 4.4 - Climate Change
Topic 5 - Evolution & Biodiversity
Topic 6- Human Health and Physiology
Topic 7 - Nucleic Acids (AHL)
Topic 8 - Respiration and Photosynthesis (AHL)
Topic 9 - Plant Biology (AHL)
Topic 10 - Genetics and Evolution (AHL)
Topic 11 - Physiology (AHL)