Organisms and their environment

Energy flow

- The sun is a principal source of energy input into biological systems
- Light energy is absorbed by photosynthetic organisms and made available to all other organisms as chemical energy
- Energy transfer occurs when animals feed on plants and when animals feed on other animals
- Eventually the energy is transferred to the environment as heat and is lost
- Nutrients consist of chemical elements that make up living organisms
- They are taken up by plants, passed on to animals and eventually recycled back inti biological systems
- This is known as nutrient cycling, since they are constantly reused

Communities

- Producers make their own organic nutrients from simple raw materials, such as carbon dioxide and water
- Green plants use light as a source of energy to make sugars from carbon dioxide and water by photosynthesis
- Some bacteria are also producers as they are photosynthetic or obtain their energy from simple chemical reactions
- Some bacteria involved in recycling nitrogen obtain their energy from reactions involving nitrogen
- Producers make energy available for all the other members of the community in the form of energy-rich carbon compounds (carbohydrates, fats and proteins)
- Sunlight is the ultimate source of energy for almost all food chains
- The major exception are the vent communities in the deep ocean that rely on chemical energy rather than sunlight energy
- Consumers obtain their energy by eating other organisms, either plants or animals or both
- They cannot make their own food, so they have to consume it
- Herbivores are primary consumers as they eat the producers
- Carnivores are secondary consumers as they eat herbivores
- Tertiary consumers are carnivores that eat other carnivores, called top carnivores
- Decomposer are fungi and bacteria that gain their energy from waste organic material
- Each of these feeding groups is a trophic level

Food Chains

- Food chains show what living organism feed on in a community
- They show the flow of energy from one organism to the next
- The arrows show the direction in which energy in food is transferred from one organism to the next
- Food chains not only show the flow of food, they also show the flow of energy
- Producers gain their energy from the sun, so an energy chain would look like this:

$$Sun \rightarrow producers \rightarrow primary\ consumers \rightarrow secondary\ consumers$$

- We don't include the sun in food chains as it is not a food
- Food chains start with producers

- Energy flows to decomposers but they are rarely included in these simple food chains

Food Webs

- Animals will eat more than one type of living organism
- A food web gives a more complicated picture of feeding relationships in an ecosystem
- The over-harvesting of food species by humans in an unsustainable manner can result in a decrease in their numbers and extinction
- Also the introduction of foreign species can displace native organisms due to predation and competition for resources
- These disrupt food chains and food webs due to the removal of a species or a decrease in their numbers

Pyramids of numbers and biomass

Pyramids of numbers

- Pyramids of numbers show how many individuals there are at each trophic level but give no indication of their size

Pyramids of biomass

- Pyramids of biomass indicate the mass of living material at each trophic level, but give no indication of the rate of growth
- Biomass is the mass of living material
- A biomass pyramid shows the actual weight or mass of living things at each trophic level
- To draw a biomass pyramid, the data first needs to be collected
- A sample of the organisms from each trophic level is taken and weighed
- The average mass of the sample is calculated
- The average mass is then multiplied by the estimated number of organisms present in the community
- Dry mass tells us how much useful biological material is present as carbohydrates, proteins, and fats as food for the organisms in the community
- The data is usually expressed in grams per square meter
- The dry mass recorded is taken at one instant in time
- Biomass pyramids do not take into account how fast an organism grows
- This means it is better to calculate the biomass produced over a period of time
- Biomass can vary with the seasons

Shortening the food chain

The efficiency of energy transfer

- The efficiency of energy transfer between trophic levels can be seen by using energy pyramids
- These show the energy transferred from one trophic level to the next
- Energy is always lost as it passes from one trophic level to the next
- Since only some of the energy is passed from one trophic level to the next an energy pyramid is never inverted
- Its shape is not affected by the size of the organisms or how many of them there are since it simply looks at the energy has been passed on

Energy Losses

- Energy flows through ecosystems is relatively insufficient
- At best plants absorb only 2-5% of the light energy that strikes their leaves
- Much of this energy is not trapped in photosynthesis because it is reflected from the surface of the leaves, it passes straight through them or is green light which they cannot absorb
- Plants use as much of the energy they trap in photosynthesis in their own respiration
- As an energy process, respiration is about 40% efficient
- Much of the plant's biomass us lost to decomposers
- About 10% of the energy tapped by the plant is available to secondary consumers
- Much of what they eat is not very edible or easy to digest
- So primary consumers make available about 10% of what they have eaten to secondary consumers
- At each trophic level, energy is lost as heat to the environment and consumers loses energy in their faeces to decomposers
- Food chains on land are rarely more than four trophic levels
- When farmers grow crops, all the energy in the grain is available to us primary consumers
- Livestock farmers grow or buy their plant food to feed their animals
- Animals use up most of the energy in their food
- This means that there is not as much energy available to us
- A vegetarian diet can support more people
- This is because we are cutting down the 90% wastage of energy that occurs between each trophic level
- People in many countries tend to have diets that mainly consist of food of plant origin or some meat or fish
- The human population is increasing
- If farmers are to provide enough food for everyone, our diet may change to one that includes more plant matter and less animal matter

Nutrient cycles

Nutrient cycling

- Most living matter (95%) is made up of six elements: carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur
- Living things must have a constant supply of these elements if they are to make proteins, carbohydrates, fats and other organic materials
- There is a finite source of these nutrients
- Bacteria and fungi feed on dead and decaying matter
- They also feed on the waste matter of animals (urine and faeces)
- They feed by breaking down carbohydrates, fats and proteins into small molecules that they can absorb
- Many of these are respired
- To do this they require water and a warm temperature as the process of digestion and respiration are catalysed by enzymes
- They also need oxygen for aerobic respiration
- Decomposers release carbon as carbon diocese when they respire

- They also break down amino acids releasing ammonia into their surroundings
- In thus way they recycle carbon and nitrogen
- Single compounds are absorbed by plants and concerted into complex compounds
- These nutrients are then passed in to animals when they eat the plants
- We say that nutrients are cycled

The carbon cycle

- Carbon is used to make carbohydrates, proteins, fats, DNA and other important biological molecules
- The carbon comes from carbon dioxide in the air
- Plants also absorb carbon dioxide from the atmosphere and use it in photosynthesis to make food
- Animals get the carbon compound by eating plants
- Carbon dioxide gets into the air in the following ways:
    - Plants and animals use some of their food for respiration, releasing carbon dioxide
    - Decomposer use dead plants and animals for food. They also use some of the decaying material for respiration, releasing carbon dioxide
    - Fossil fuels and natural gas contain carbon. Carbon dioxide is one of the gases released in the air during combustion when these fuels are burnt
- These processes release carbon dioxide in the air and balances the uptake from photosynthesis so the concentration of carbon dioxide in the atmosphere remains constant
- Sometimes, dead plants and animals do not decompose
- Their dead bodies become fossilised to form coal and gas-fossil fuels

The water cycle

- The water cycle demonstrates how important water is to life on earth

The nitrogen cycle

- Nitrogen is an element required for many biologically important molecules
- Amino acids, proteins, DNA and chlorophyll contain nitrogen
- Approximately 80% of the air is nitrogen gas
- It is not useful to many organisms in this form
- It has to be made available to them in the form of compounds such as amino acids and proteins, and ions such as nitrate and ammonium ions
- Most of the nitrogen that plants absorb is in the form of nitrate ions
- They use the amino acids in their leaves
- The amino acids are used to form proteins such as enzymes
- Animals eat plants and so obtain their nitrogen in the form of plant protein
- Any excess amino acid are broken down to ammonia by deamination
- Animals that live on land convert the ammonia to urea and excrete it in urine

Decomposers

- Break down dead remains and animal waste releasing ammonium ions
- Bacteria also break down urea in urine to ammonium ions (deamination)

Nitrifying bacteria

- Change ammonium ions to nitrate ions
- Bacteria gain their source of energy from the oxidation reaction

Nitrogen-fixing bacteria

- Convert nitrogen gas from the air into compounds of nitrogen that they use themselves
- When they die this nitrogen ions available to plants
- Nitrogen fixing bacteria is found is some legumes (peas, beans, alfalfa)
- The bacteria are inside swellings on the roots called root nodules
- These bacteria change nitrogen gas into ammonia that the legume plants use to male amino acids
- In return, the legumes provide a stable environment for the bacteria
- Nitrogen fixation requires a lot of energy

Denitrifying bacteria

- Live in water logged soil
- Change nitrate ions to nitrogen gas
- They balance the uptake of nitrogen gas by nitrogen fixing bacteria

Lightning

- Causes nitrogen and oxygen to react together at high temperatures
- Nitrogen oxides are formed in these reactions
- Nitrate ions are lost from the soil before plants can absorb them as they are washed out by water (leaching)
- Farmers add fertilisers containing nitrogen to the soil
- This provides material that enters the nitrogen cycle at the point where decomposers act

Populations, communities and ecosystems

Population growth

- A population is a group of individuals of the same species living in the same habitat at the same time
- All the individuals in a population may interbreed
- Sometimes it is difficult to tell the geographical limits of a population
- Some species are widely distributed and it is difficult to divide them into separate populations
- However, there are usually barriers to reproduction such as rivers and mountains that divide them into separate populations
- Some individuals migrate across these barriers, so there in interbreeding between populations
- A community includes all the populations of different species in an ecosystem
- An ecosystem is a unit containing the community of organisms and their environment
- An ecosystem is made up of the biotic component (the community) and the abiotic component (physical factors: light, water, pH and temperature)

Population size

- The number of births adds to the population and the number of deaths decreases it
- Individuals may enter or leave a population from neighbouring populations
- Animals migrate so there is mixing between populations
- Plant use seed dispersal to colonise new areas in this way individuals leave one population of plants to enter another
- The main factors that affect the rate of population growth is food, predation and diseases
- An organism that enter a new habitat may show the lag, exponential and stationary phases if there is plenty food, no predation and diseases
- Competition for resources: plants compete for light, space, water and soil nutrients. Animals compete for food, space and mates
- Predation: predators often take young, sick individuals or less well-adapted individuals. Predators may limit the growth of a population of prey animals. But it more often that the population of prey animals limits the population size of the predator
- Disease: pathogens are transmitted more easily when organisms live close together

The growth of a population: bacteria

- A small number of bacteria are placed into a flask with a warm nutrient solution which is aerated so the bacteria may respire aerobically
- Bacteria grow and divide under these conditions
- Some species of bacteria divide every 20 minutes if conditions are ideal

Phases of bacterial growth

1. The lag phases, when doubling of the numbers has little effect as the numbers are so small. Bacteria take up water and nutrients and make new cytoplasm, DNA and enzymes
2. The exponential or log phase when the population is increasing rapidly. The population increases by doubling and there are no limiting factors. After a while, lack of food and build-up of waste limits the population growth which slows down and stops
3. The stationary phase, when bacteria cells are dying at the same rate at which they are being produced. This may be because of shortage of food or because waste products are building up
4. The death phase, when more cells are dying than being produced so the population declines, causes of death may be lack of food, shortage of oxygen or a build-up of toxic waste products. The curve is known as a sigmoid growth curve

- Some species show this population in the wild
- When resources become available, species that can reproduce rapidly grow exponentially
- When the resources are used up, most of them die
- Most species do not do this, they remain fairly stable over time

Human population

Human population growth

- Lack of food and shelter together with the effects of malnutrition, diseases and wars meant that mortality rates were high and people did not live long
- The human population has increases exponentially over the past 300 years for the following reasons:

- Improved agriculture means that most people are better fed. Better nutrition means they are better defended against diseases, especially those caused by malnutrition
- Public health has improved. There are clean water supplies, drainage of waste and sewage treatment. This has decreased epidemics of waterborne diseases such as cholera
- Medical care has improved. People are also vaccinated against many infectious diseases

- The effects of these improvements have been:
  - Decrease in the infant and child mortality rates
  - Decrease in death rates from starvation and malnutrition
  - Increase in life expectancy
- In spite of these improvements there are huge inequalities in food, housing, water and health services
- Many of the world's human population live in poverty with high infant and child mortality rates

Controlling human population growth

- There are still controls on population increase
- Famine, epidemics, floods, wars, tsunamis and other disasters lead to loss of life
- The earth has limited resources and limited space and the population will have to stabilise and even decrease at some time in the future
- The most obvious way to do this is to reduce the birth rate
- Many groups of people have strongly held religious or moral views on birth control and family size
- This means they often have large families
- The rate of increase in population is most influenced by the proportion of child bearing women in the population
- Increasing the human population size brings greater demands on resources and problems for the environment such as the supply of housing, food, transport and energy needs
- There is also the problem of how to dispose of our rubbish