4 Ecology

Introduction

- ecosystems require continuous supply of energy
- continued availability depends on cycles
- survival depends on sustainable ecological communities
- concentrations of gases in the atmosphere have significant effects on climates

4.1 Species, communities and ecosystems

Species

- group of organisms that can potentially interbreed to produce fertile offspring
- distinctive courtship dances: show that they are fit, suitable partner, same type of bird
- each type remains distinct; hybrids between types (species) rarely produced
- most species have method ensuring that they reproduce with other members of their species
- interbreeding: two members of same species mating and producing offspring
- cross-breeding: members of different species mating, almost always infertile
- reproductive separation is reason for each species being a recognizable type of organism

Populations

- population: group of same species who lives in same area at the same time
- if two populations live in different areas they are unlikely to interbreed
- if two populations never interbreed they may gradually develop differences: are same species until they cannot interbreed and produce fertile offspring

Autotrophic and heterotrophic nutrition

- organisms need supply of organic nutrients: growth, reproduction
- autotrophic: self-feeding: organisms make own carbon compounds from simple substances
- heterotrophic: feeding on others: obtaining carbon compounds from other organisms
- mixotrophic: some unicellular organisms use both methods: *euglena gracilis* has chloroplast when sufficient light but can feed by endocytosis

Consumers

- heterotrophs that feed off other organisms which are still alive or shortly dead
- ingest their food: absorb the products of digestion
- trophic groups: primary consumers feed on autotrophs, secondary consumers feed on primary consumers; does not always fit

Detritivores

- dead organic matter rarely accumulates in ecosystems: nutrition for two groups of heterotrophs
- detritivores ingest dead organic matter, then digest it internally, absorb products of digestion

Saprotrophs

- secrete digestive enzymes into dead organic matter and digest it externally
- also known as decomposers
- many bacteria and fungi are saprotrophic

Communities

- relationship between organisms are complex and varied: interaction between two species is of benefit to one species and harms the other; in other cases both benefit
- all species are dependent on relationships with others for long-time survival: population of one species can never live in isolation
- community: group of populations living together in an area and interacting with each other

Ecosystems

- abiotic environment: community depends on its non-living surrounding of air, water, soil or rock

- some cases abiotic environment exerts powerful influence over organisms: wave action on rocky shore creates very specialized habitat
- many cases where organisms influence abiotic environment: plants growing in sand, roots stabilize and encourage more dunes
- many interactions between organisms and the abiotic environment
- ecosystem: community and its abiotic environment are highly complex interacting system

Inorganic nutrients
- living organisms need supply of carbon, hydrogen, oxygen, other carbon compounds, nitrogen, phosphorus and 15 other elements
- autotrophs obtain all elements as inorganic nutrients from abiotic environment
- heterotrophs obtain some of the elements in their food, others still from abiotic environment

Nutrient cycles
- limited supplies of chemical elements on Earth: they can be endlessly recycled
- cycles for different elements vary

Sustainability of ecosystems
- concept of sustainability due to current human unsustainable uses of resources
- it is sustainable if it can continue indefinitely
- natural ecosystems can teach us: three requirements for sustainability: nutrient availability, detoxification of waste products, energy availability
- nutrients can be recycled indefinitely; usually waste products of one species are exploited as resource by another species
- energy cannot be recycled: sustainability depends on continued supply (mostly light by sun)

4.2 Energy flow
Sunlight and ecosystems
- initial source of energy is sunlight by photosynthesis
- three groups of autotroph carry out photosynthesis: plants, eukaryotic algae, cyanobacteria: are called producers
- heterotrophs don’t use light energy directly, depend on it: consumers, saprotrophs, detritivores
- in most ecosystems almost all energy in carbon compounds will have been harvested by photosynthesis by producers
- percentage of energy that is harvested by producers and is available to other organisms varies

Energy conversion
- producers convert light energy to chemical energy using chlorophyll: create carbon compounds
- producers can release energy from carbon compounds by cell respiration and is lost as heat
- largest part of energy remains in cell and tissues of producers which is available to heterotrophs

Energy in food chains
- food chain: sequence of organisms each of which feeds on the previous one
- usually between two and five organisms in a food chain
- producers are always the first organism; subsequent organisms are consumers
- no consumers feed on the last organism of a food chain
- consumers obtain energy from the carbon compounds in the organisms on which they feed

Respiration and energy release
- living organisms need energy for synthesis of large molecules (DNA, RNA, protein), active transport, moving things in cell: ATP supplies this energy
- every cell produces its own ATP supply by cell respiration
- during cell respiration carbon compounds are oxidized: oxidation reactions are exothermic and the energy released is used in endothermic reactions to make ATP
- cell respiration transfers chemical energy from carbon compounds to ATP
- energy transformations are never 100% efficient: remainder from cell respiration is converted to heat (e.g. muscles warm when hey contract)

Heat energy in ecosystems

- energy conversions: light to chemical (photosynthesis), chemical to kinetic (muscle contraction), chemical to electrical (nerve cells), chemical to heat (heat-generating adipose tissue)
- organisms cannot convert heat energy into any other form of energy

Heat losses from ecosystems

- heat from cell respiration makes living organisms warmer
- heat produced in living organisms is all eventually lost to abiotic environment

Energy losses and ecosystems

- biomass: total mass of a group of organisms, biomass has energy
- the energy added to biomass by each successive trophic level is less
- energy in sec. consumers per year per square meter is always less than in prim. consumers
- loss of energy between trophic levels
- most of energy in food that is digested and absorbed by organisms in trophic level is released by cell respiration, lost as heat: only energy available to organisms in next trophic level is chemical energy
- organisms in a trophic level are usually not entirely consumed; energy in uneaten material passes to saprotrophs or detritivores rather than passing to organisms to next trophic level
- not all parts of food ingested are digested and absorbed; energy in feces does not pass along the food chain and passes to saprotrophs and detritivores
- only small proportion of energy in biomass of one trophic level will ever become part of biomass of organism in next trophic level (ca. 10%)
- less and less energy available to each successive trophic level: after a few stages remaining energy would not support another level: number of trophic levels is restricted
- generally a higher biomass of producers, the lowest rank of all

4.3 Carbon cycling

Carbon fixation

- autotrophs absorb carbon dioxide from atmosphere and convert it into carbon compounds
- they reduce carbon dioxide concentration in atmosphere, mean is at 0.039% or 390 µmol/mol

Carbon dioxide in solution

- carbon dioxide is soluble in water: either dissolved or combines with water to form carbonic acid (H_2CO_3) which dissociates into hydrogen and hydrogen carbonate ions (H^+, HCO_3^-)
- hydrogen and hydrogen carbonate explain how carbon dioxide reduce pH of water
- dissolved carbon dioxide and hydrogen carbonate are absorbed by aquatic plants and other autotrophs which they use for creating carbon compounds

Absorption of carbon dioxide

- autotrophs use carbon dioxide which reduces the concentration of carbon dioxide in the atmosphere and sets up concentration gradient between cells and water/air: carbon dioxide diffuses from atmosphere or water into autotroph
- in land plants it diffuses through stomata under leaf; in water all parts are permeable

Release of carbon dioxide from cell respiration

- carbon dioxide is waste product of aerobic cell respiration and diffuses out of cells
- non-photosynthetic cells in producers (root cells), animal cells, saprotrophs (fungi) are groups which produce carbon dioxide

Methanogenesis

- methane is produced in anaerobic environments; waste product of anaerobic respiration
- three groups of bacteria are involved: bacteria convert organic matter into organic acids, alcohol, hydrogen, carbon dioxide; bacteria use organic acids and alcohol to produce acetate, carbon dioxide, hydrogen; archaeans produce methane from carbon dioxide, hydrogen, acetate ($CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$; $CH_3COOH \rightarrow CH_4 + CO_2$)

- archaeans are methanogenic: they carry out methanogenesis in anaerobic environments: mud along shores, swamps, guts of ruminant mammals, landfill sites
- some methane produced by archaeans diffuses into atmosphere (conc. at 1.7-1.85 μmol/mol)

Oxidation of methane
- molecules of methane persist in atmosphere around 12 years: naturally oxidized in stratosphere

Peat formation
- in soils organic matter is digested by saprotrophic bacteria or fungi: saprotrophs obtain oxygen from air spaces in soil
- some environments water is unable to drain out, so become waterlogged and anaerobic: saprotrophs cannot thrive and dead organic matter is not fully decomposed: acidic conditions
- accumulated partially decomposed matter becomes compressed and forms dark brown acidic material called peat

Fossilized organic matter
- carbon and some carbon compounds are chemically stable and remain unchanged in rock for hundreds of million years: large deposits of carbon from past geological eras
- deposits are results from incomplete decomposition
- coal is formed when peat is compressed and heated
- oil and natural gas are formed in mud at bottom of seas and lakes: conditions are anaerobic so decomposition is often incomplete; when compressed and heated chemical changes occur producing mixtures of liquid carbon compounds or gases: crude oil and natural gas

Combustion
- if organic matter is heated in presence of oxygen it will set light and burn
- combustion: oxidation reaction that occurs
- products of complete combustion are carbon dioxide and water
- coal, oil, natural gas are different forms of fossilized organic matter: all burned as fuels

Limestone
- some animals have hard body parts from calcium carbonate ($CaCO_3$): mollusk shells, hard corals that build reefs
- when they die, soft parts are decomposed; in acid calcium carbonate dissolves away, in neutral or alkaline condition is stable and hard parts deposit on sea bed
- result of animal hard parts is limestone; hard parts can be seen as fossils

4.4 Climate change
Greenhouse gases
- earth is kept much warmer than without the gases
- greenhouse gases with largest warming effect are carbon dioxide and water vapor
- carbon dioxide is released by cell respiration and combustion of biomass and fossil fuels
- carbon dioxide is removed by photosynthesis and dissolving into oceans
- water vapor is formed by evaporation from oceans and transpiration in plants
- water vapor is removed by rainfall and snow
- water continues to retain heat after condensing to form droplets in clouds
- water absorbs heat energy and radiates it back to Earth’s surface and reflects heat energy

Other greenhouse gases
- other greenhouse gases have a smaller but still significant effect
- methane is the third most significant gas; emitted from waterlogged habitats and released during extraction of fossil fuels and from melting ice polar regions
- nitrous oxide is naturally released by bacteria and by agriculture and vehicle exhausts
- two most abundant gases in atmosphere (oxygen, nitrogen) are not greenhouse gases and do not absorb longer-wave radiation
- all greenhouse gases make up less than 1% of atmosphere

Assessing the impact of greenhouse gases

- two effects determine warming effect: ability to absorb long-wave radiation and concentration
- methane causes much more warming than carbon dioxide but is at much lower concentration
- concentration of gas depends on rate at which it is released and how long on average it remains in the atmosphere
- water vapor enters immensely rapid but only stays for nine days

Long-wavelength emissions from Earth

- warmed surface absorbs short-wave energy from sun; re-emits it at much longer wavelength
- most of re-emitted radiation is infrared (peak at 10'000nm); solar peaks at 400nm

Greenhouse gases

- 25-30% of short-wavelength radiation from sun is absorbed before it reaches surface: most of it is ultraviolet absorbed by ozone
- 70-75% reaches surface and most of it is converted to heat
- 70-85% of longer-wavelength is captured by greenhouse gases: effect is global warming
- greenhouse gases in atmosphere only absorb energy in specific wavebands
- water vapor, carbon dioxide, methane, nitrous oxide absorb some wavelengths and are greenhouse gases

Global temperatures and carbon dioxide concentrations

- if concentration of gas changes we can expect the size of contribution to greenhouse effect to change and global temperature to rise or fall
- ice columns were drilled in Antarctic to deduce past carbon dioxide concentrations
- bubbles of air were trapped in the ice
- global temperatures can be deduced from ratios of hydrogen isotopes in water molecules
- repeating pattern of rapid periods of warming followed by longer period of cooling
- periods of higher carbon dioxide concentration coincide with periods Earth was warmer
- rises in carbon dioxide concentration increases greenhouse effect

Greenhouse gases and climate patterns

- Earth's surface is warmer than without greenhouse gases: if concentration of greenhouse gases rises more heat will be retained and an increase in global average temperature is expected
- global average temperature are not directly proportional to greenhouse gas concentrations
- global temperature influence other aspects of climate: higher temperature increase evaporation of water so rain is more in mass and more frequent
- consequences of rise in average global temperature are unlikely to be evenly spread
- predictions are uncertain, but it is clear that warming would cause profound changes to climate

Industrialization and climate change

- the rise to concentration nearing 400 parts per million is unprecedented (usually to 300ppm)
- concentrations started to rise above natural levels in late 18th century
- much of the rise happened since 1950
- industrial revolution stared in late 18th century but main impact was in second half of 20th
- combustion of coal, oil, natural gases increased rapidly
- since start of industrial revolution, correlation between rising atmospheric carbon dioxide and average global temperatures is very marked

Burning fossil fuels

- increasing quantities of coal were mined and burned causing carbon dioxide emissions after industrial revolution
- energy from combustion provided heat and power; later oil and natural gas were added
- hard to doubt that burning of fossil fuels has been major contributor in rise of atmospheric carbon dioxide concentrations
- steepest rises coincide with increases in burning of fossil fuels