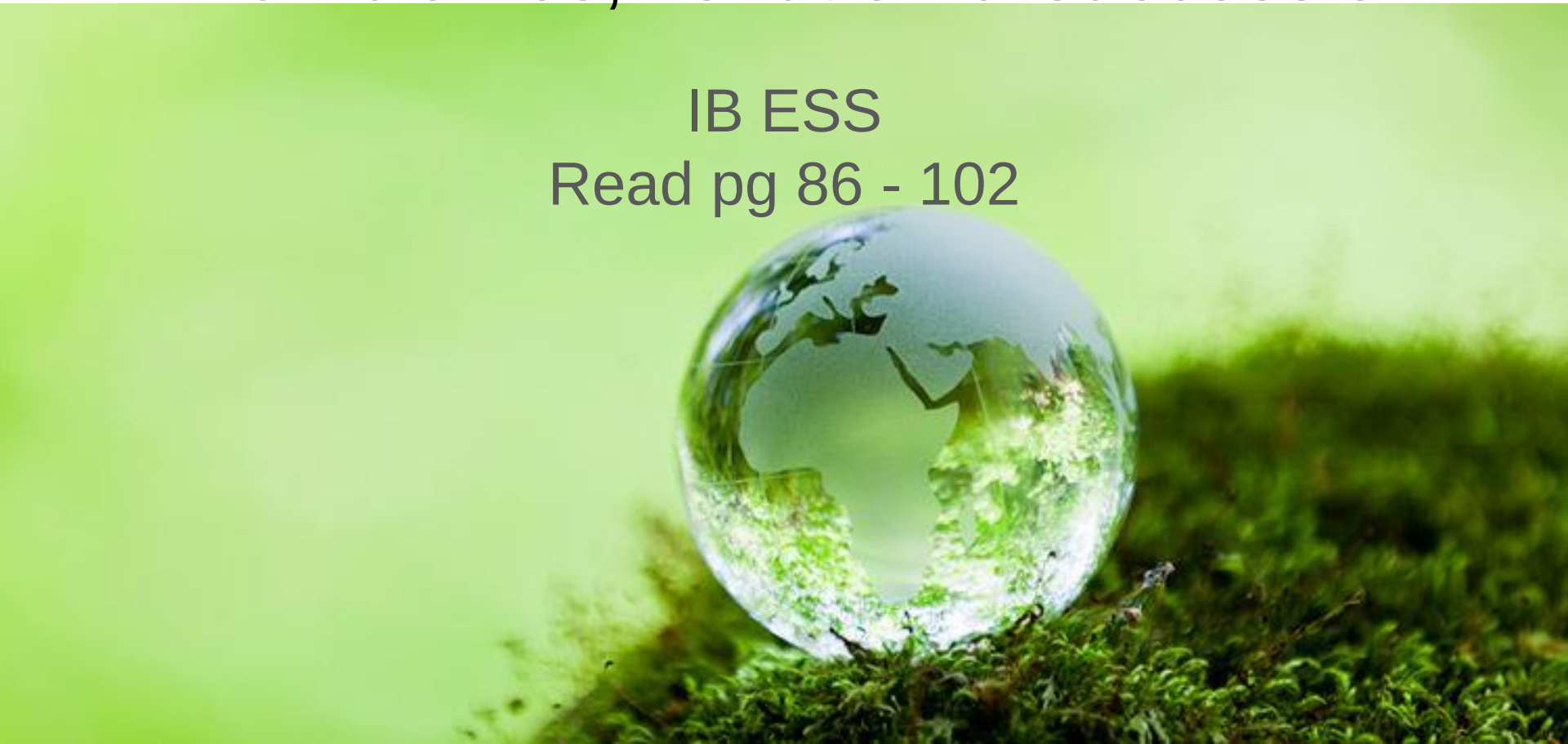
2.04 biomes, zonation & succession

IB ESS

Read pg 86 - 102



Learning Objectives

- Define biome and give examples of five major classes of biome
- Outline the factors that influence the distribution of biomes
- Explain what is meant by zonation along an environmental gradient
- Describe how succession changes the appearance, energy flow and productivity of an ecosystem over time
- Describe the difference between *r* and *K*-strategist species in pioneer and climax communities
- Explain the general patterns of change in communities undergoing succession

Key Questions

1. What are the factors that determine the type of biome in a given area?
2. How does succession lead to climax communities?
3. How are stability, succession and biodiversity of an ecosystem linked?

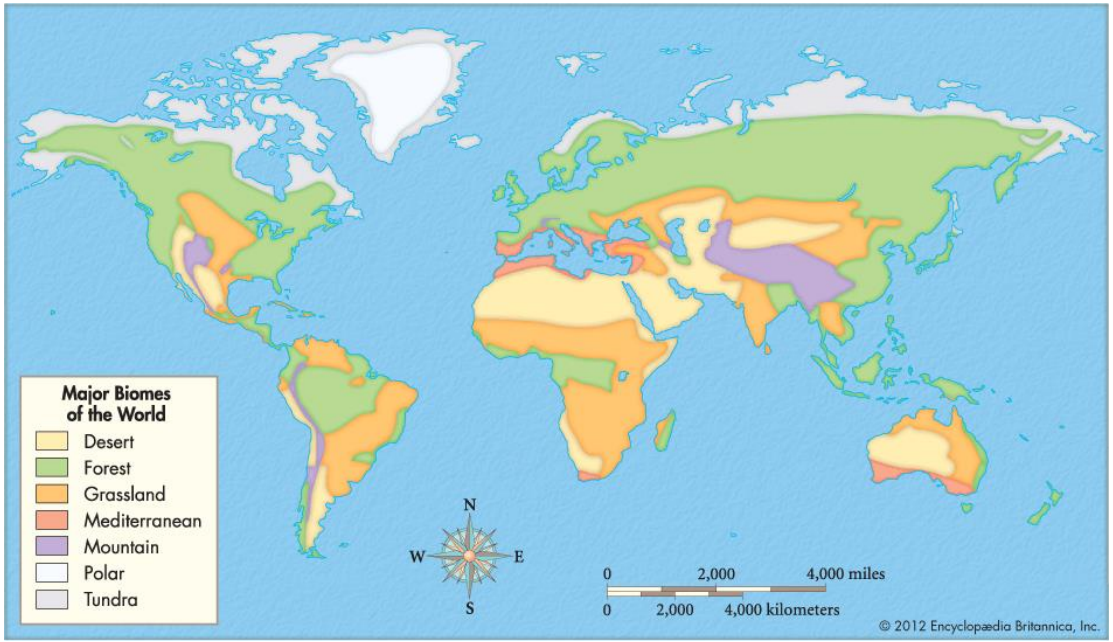
Biome

- Group of ecosystems that share similar climatic conditions & similar patterns of vegetation
  - Key abiotic factors that define biomes:
    - Rainfall
    - Temperature
    - Insolation (sunlight)
  - Latitude & altitude also influence climate/biome distribution
    - Lower latitudes & altitudes = warmer

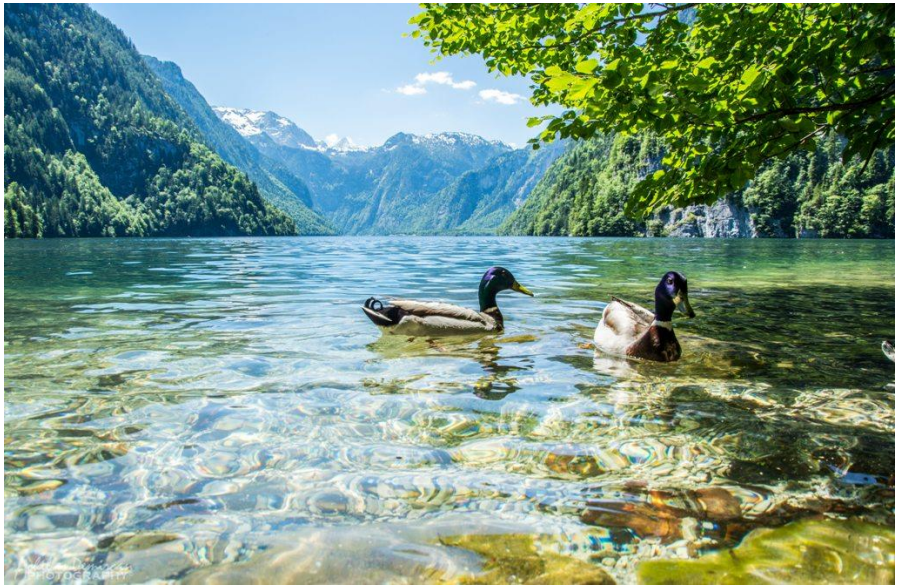
Biomes: 5 major classes

- Aquatic
- Forest
- Grassland
- Desert
- Tundra
    - Each has its own characteristic…
        - Productivity
        - Biodiversity
        - Factors that limit its development

Within these classes are other divisions



Aquatic biomes



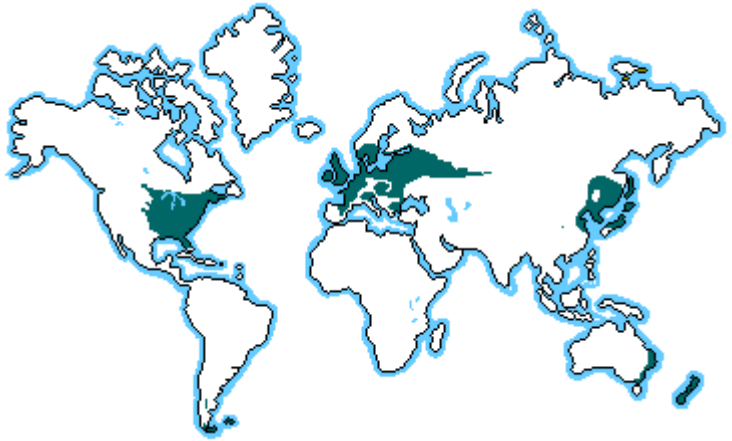
- Water covers 75% of Earth’s surface
- 2 types:
  - **Freshwater biomes** - low salt concentrations (< 1%)
    - EX lakes, rivers, ponds & swamps
    - Ponds & lakes vary in size
    - Temps vary with season
    - Ability of light to penetrate water determines level of photosynthesis
    - Streams & rivers contain flowing water
      - Temps of water = cooler at source of river
      - As water flows to mouth, becomes turbid with sediment & debris
        - Light penetration & species diversity reduced

Aquatic biomes

- **Marine biomes** - higher salinity
  - EX oceans, coral reefs & estuaries
  - Oceans largest of all
    - Highest diversity of species
  - Salt water evaporation contributes to water cycle
  - Marine algae produce Earth's oxygen & photosynthesize (pulling large amounts of carbon dioxide from atmosphere)
  - Abiotic conditions vary widely

Forest biomes

- **Temperate deciduous forest** - areas with mild, short winters with growing season of at least 120 days free of frost
  - Mild climate
  - Rainfall between 500 - 1500 mm/yr
  - Temps between -30℃ to +30℃
  - Found in seasonal areas
  - Most plant growth in warmer summer months
  - Some regions have maple, elm & oak trees that are deciduous & lose their leaves in winter
  - Some higher altitudes &/or latitude regions have evergreen trees that have leaves or needles year round
  - Rate of photosynthesis & NPP lower than rainforest
    - Lower temps & rainfall
  - Contain fewer species of tree
  - Forest dominated by one tree species = forms a canopy with shrub layer beneath
  - Canopy shades lower layers of forest during summer months
  - Soil enriched with leaf litter in autumn
  - Nutrients recycled rapidly



Forest biomes

- **Tropical rainforests**- most ecologically rich of all biomes
  - High average temps (27℃) consistent throughout year
  - High rainfall (as much as 5000 mm/yr) consistent throughout year
  - Between Tropic of Capricorn and Tropic of Cancer (5°) N & S of equator
  - High insolation, 12 hours/day, throughout year
  - Rapid rate of photosynthesis, few limiting factors
  - Grow vigorously & highly productive
  - Produces greatest amount of organic matter of all biomes
  - High NPP...accounts for 40% of productivity of terrestrial ecosystems
  - Very diverse: lots of different species & high population #s
  - Plants compete for light & grow very tall (up to 80 m high)
  - Highest canopy shades beneath...majority NPP in highest canopy
  - Only 1% of light makes it through the canopy to the ground
  - Epiphytes (vines, orchids, ferns, bromeliads) climb trees to reach light...but provide habitats for many animals)
  - Plants have shallow roots (most nutrients close to surface of soil) ...many have buttress roots for support
  - Rate of decay high BUT soil nutrients low due to heavy rain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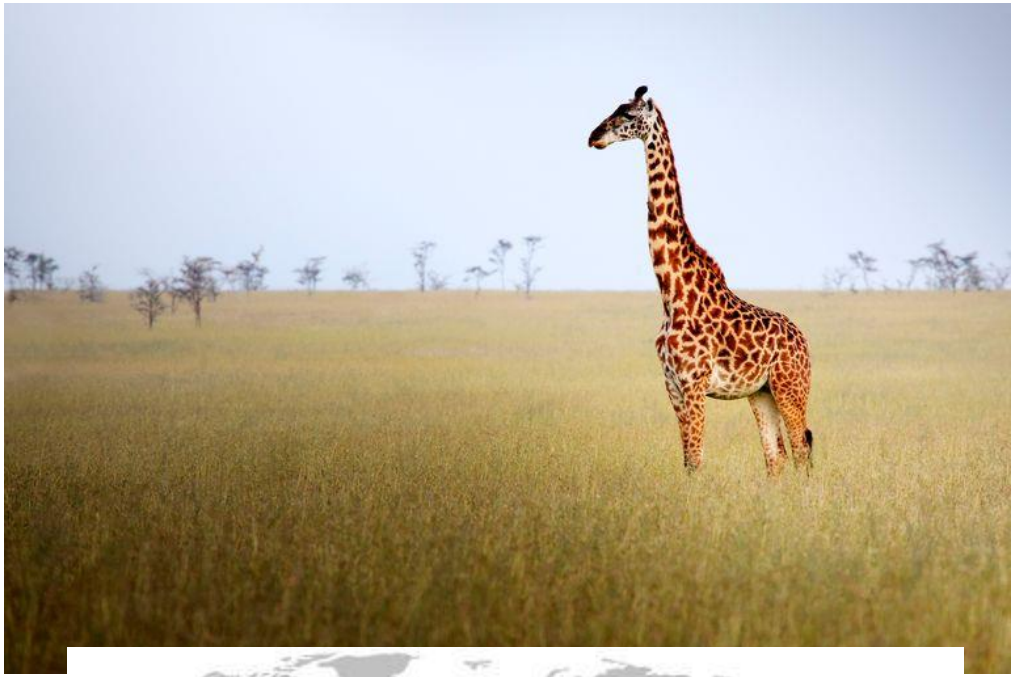
Grassland biome

- Semi-arid area with few trees & inhabited by grazing mammals, ground-nesting birds, insects & few species of reptiles
- Covers about 21% of Earth's land surface
- **Prairies** - humid & covered with tall grass
  - If trees present, found on slopes or close to small rivers
  - Soil rich in nutrients
  - NPP about ⅓ of a tropical rainforest
  - Grazing animals (bison & oxen) feed on prairies, but most now used for agriculture
- **Steppes** - lower rainfall than prairie, with short grass
  - Grazing animals (antelope) feed on grasses
  - Some threatened by overgrazing & may become semi-arid desert
- **Savannah** - warmer & drier than other grasslands
  - May experience drought certain times of year
  - Plants adapted to hot, dry climate -may store water or become dormant during dry periods

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Desert biome

- Very dry areas with <250 mm rainfall per year
- Subdivided into 4 categories:
  - Arid, semi-arid, coastal & cold
- Rainfall irregular intervals
- Arid deserts = Hot days & cold nights, cold deserts = frost & cold extremes
- Low NPP & photosynthesis (lack of rainfall limiting factor)
- Temp fluctuation lead to specially adapted plants
  - Xerophytes (cacti & succulents)...very small leaves, thick cuticles to reduce water loss & ability to store water in stems
  - Deep roots to reach water
  - Spreading roots to absorb rainfall before it evaporates
  - Plant biomass low ...leads to few consumers & limited food chains
- Animal adaptations
  - Reptiles only active during cooler part of day
  - Some mammals nocturnal


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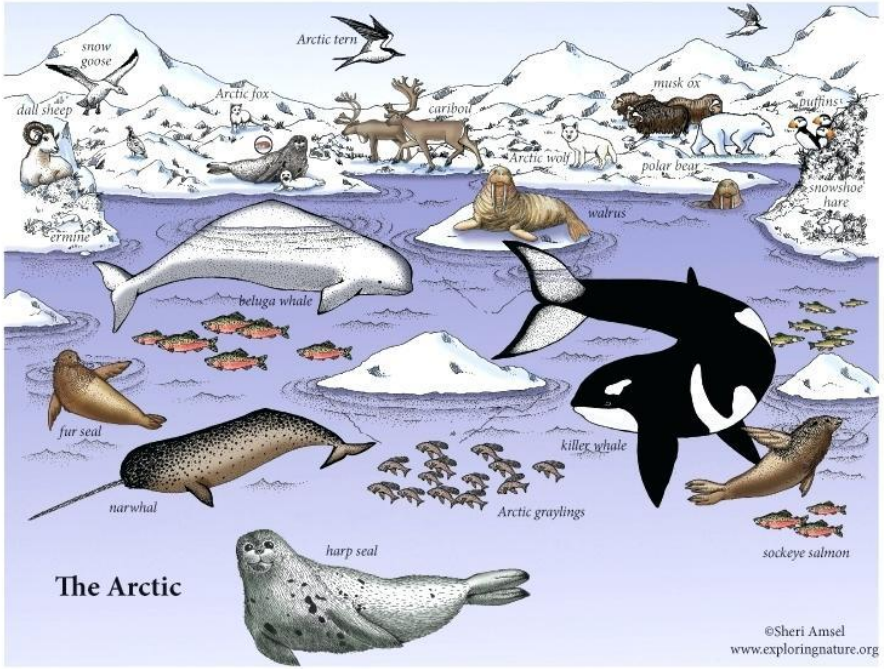
Tundra

- **Arctic tundra** - found south of the arctic ice cap
  - Cold with little rain & long, dark winters
  - Temp as low as -50℃
  - Soil permanently frozen (permafrost)
  - NPP and photosynthesis rate is low (lack of sunlight, low rainfall & cold temps)
  - Recycling of nutrients is slow (cold temps)...leads to formation of peat
  - Spring & summer = days lengthen & plants grow
    - Between May & August
    - Ice melts, releasing water for mosses, grasses & low shrubs to develop
  - Plant adaptations: thick leaves & underground storage organs to prevent dry out
  - No trees (insufficient soil & frozen ground)
  - Animal adaptations: thick fur or feathers to keep them warm, small ears to reduce heat loss, many hibernate in winter


snow goose
Arctic tern
dall sheep
Arctic fox
caribou
musk ox
puffins
Arctic wolf
polar bear
snowshoe hare
ermine
walrus
beluga whale
fur seal
killer whale
narwhal
Arctic graylings
harp seal
sockeye salmon
The Arctic
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Tundra

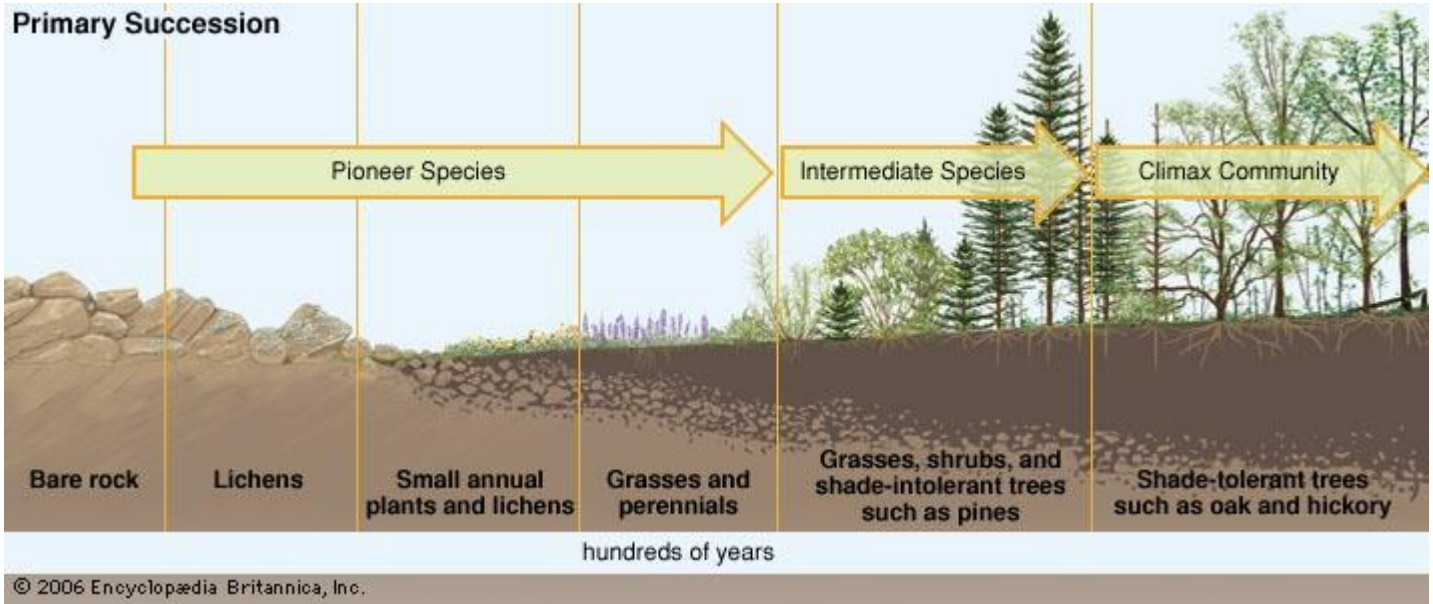
- **Alpine tundra** - exist on rocky mountaintops
  - Very similar to arctic tundra
  - Primary production is small shrubs & small leafy plant like alpine bluegrass
    - Provides food for grazing animals like bighorn sheep & mountain goats

Succession

- Long-term process where communities in a particular area change over a period so that the appearance of the whole area evolves and changes
- Involves interaction between biotic & abiotic components
  - Begins as early pioneer communities
    - Pioneer community - first group of organisms to colonize a bare area of land
    - Grasses & mosses arrive on bare ground
    - Begin to modify the physical environment
    - Low density of producers...gross productivity low
    - Only a little energy is lost through respiration ...so net productivity is high
  - Enable a wider variety of species to move in as intermediate communities
    - Modify physical environment more ...until stable situation is reached
    - More consumers arrive
    - Food chains & webs become more complex
    - Gross productivity increase
    - More consumers & complex community mean energy loss to respiration increases...net productivity becomes almost zero
    - Ratio of productivity to respiration (P:R) = close to 1 as a climax community is reached

succession

- Seral stages - stages in a succession
- Climax community - a stable community that is formed at the end of a succession

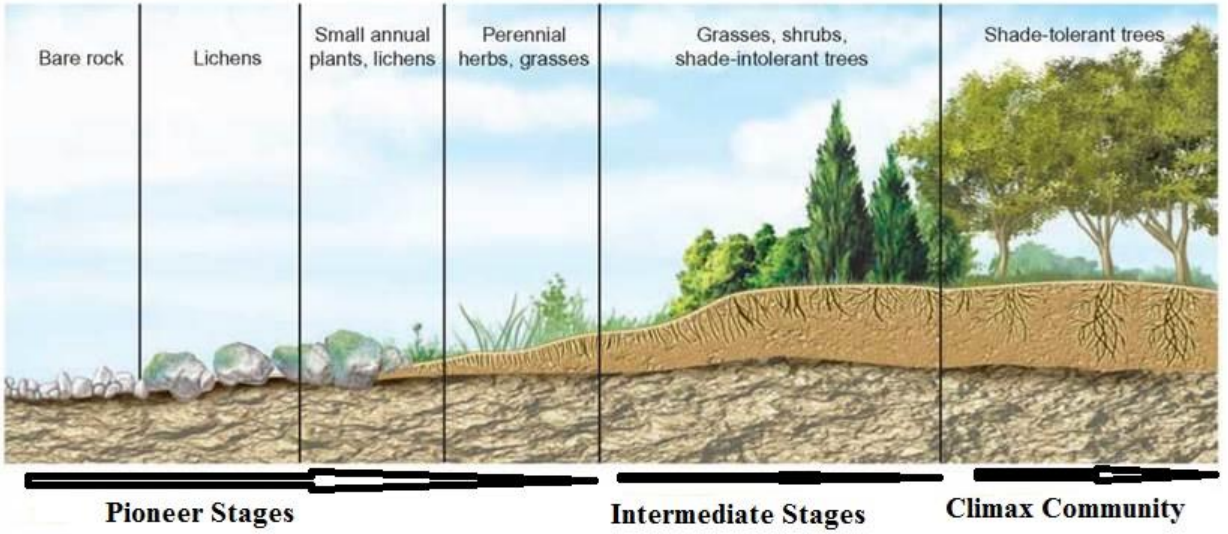


Primary succession

- When an area of bare ground/rock is colonized for the first time
  - Steps:
    - Pioneer communities of lichens & mosses settle on rock surfaces
      - Gradually erode rock & use dissolved minerals for growth
      - As they die, they decompose...leave debris that starts to form humus & soil (after about 10 years)
    - Eventually seeds & grasses & small shrubs start growing
      - Modify structure of ground further...deep layer of soil develops as plants die & decompose
        - Soil holds more moisture & contains more organic matter
    - Later, faster-growing trees (rowan & birch) begin growing
      - Extend roots into soil
      - Bind together & protect from erosion
    - Eventually slower-growing tree species replace those
      - Form a climax community (after 100-200 years)

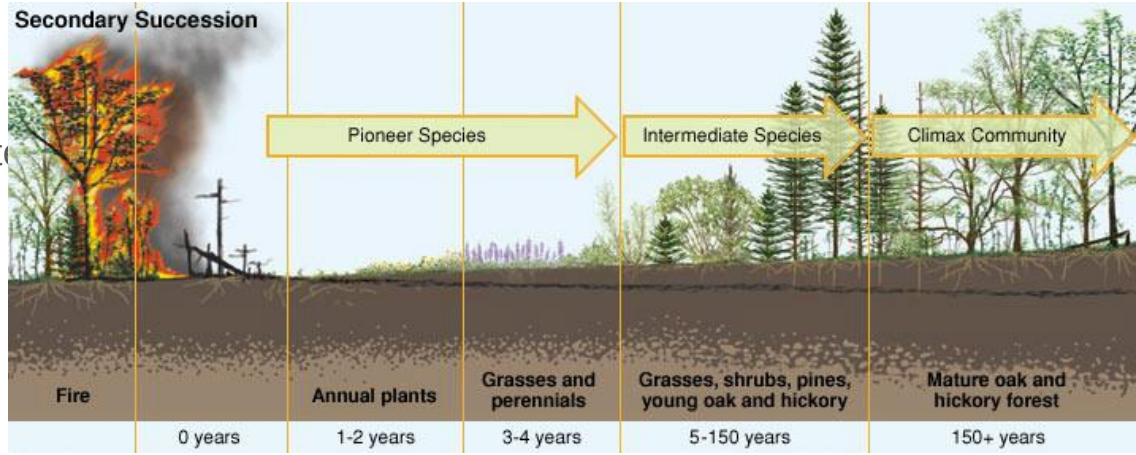
Primary succession

- Sere - each stage in succession
- Tend to follow similar patterns & named according to environment
  - Ex. hydrosere develop in water
  - Ex. halosere develop in salt marsh
- Sequence may be different if on bare rock or if on volcanic ash or a moraine from a glacier melting



Secondary succession

- Takes place after an area of land has been cleared (by a fire or landslide) and soil is already present
  - Proceeds more rapidly
  - Annual grasses may be present aft 1-2 years
  - Followed by low-growing shrubs after 3-5 years
  - Followed by scrub of small trees
  - Then shrubs & broadleaf trees
  - Then climax community of mature woodland



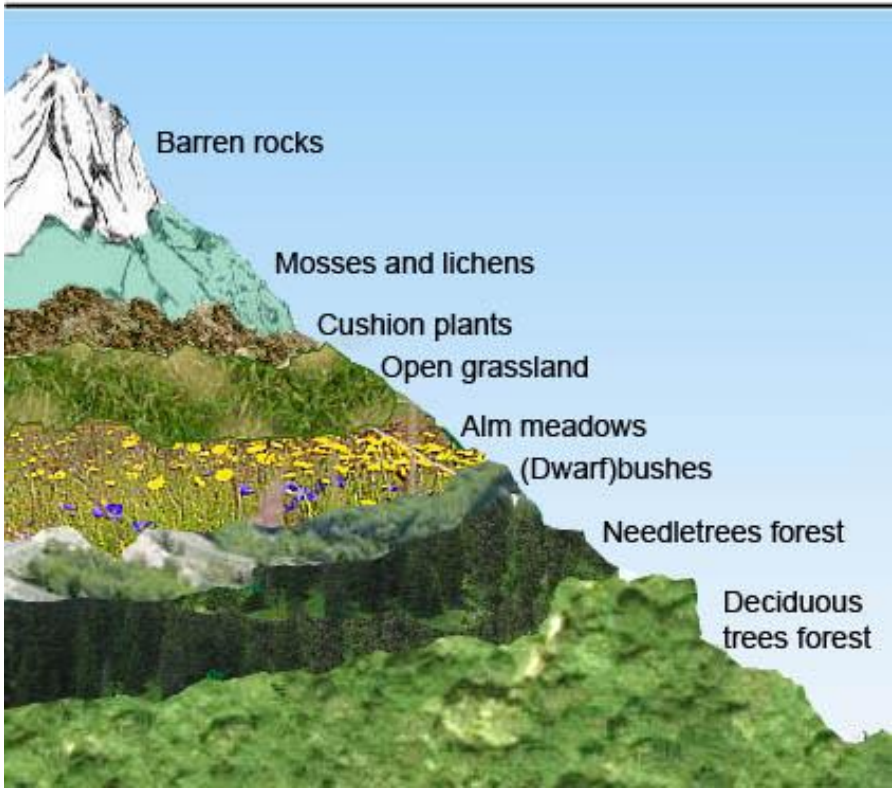
Secondary succession - a climax community

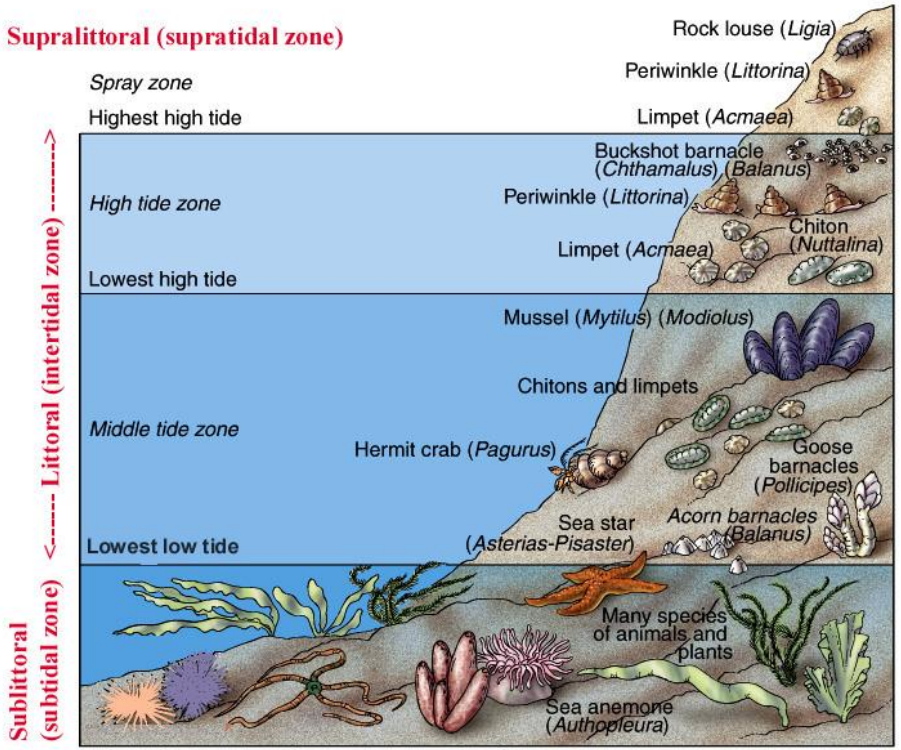
- Contain mature trees that shade shrubs beneath
- Shrub layer replaced by shade-tolerant species (survive low light)
- Leaf litter & humus from death of plants from earlier stages
- Microbes break down
- Animals feeding on plants excrete feces adding nutrients to soil
- Nutrients available to plants
- Soil depth continues to increase as organic matter accumulates
    - Enriched by water & mineral retention in humus
    - Mineral nutrients recycled & remain ...not leached away
- Ultimately climax community reaches high #s of plants & animals species, many niches & high species diversity

zonation

- Spatial pattern of organisms over a particular area
  - Examples seen on rocky shores
    - Bands of organisms with different tolerances to environmental conditions (immersion & desication) at different distances from the sea
    - Different species of mangrove trees determined by elevation & salinity

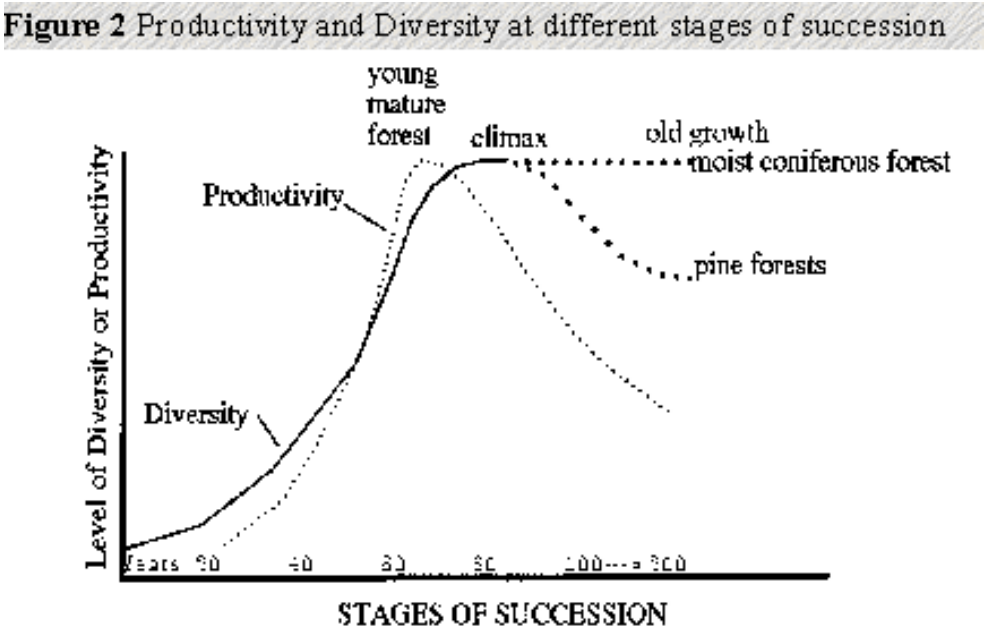
VEGETATION ZONATION IN MOUNTAINS





Succession & productivity changes

- First stages
  - Few producers present ...gross productivity low
  - Energy loss in respiration is also low...net productivity high
    - Ecosystem growing & accumulating biomass
- Middle stages
  - More consumers present...gross productivity high
  - More complex feeding interactions & food webs ...net productivity increases
- Climax community
  - GPP & NPP stabilize

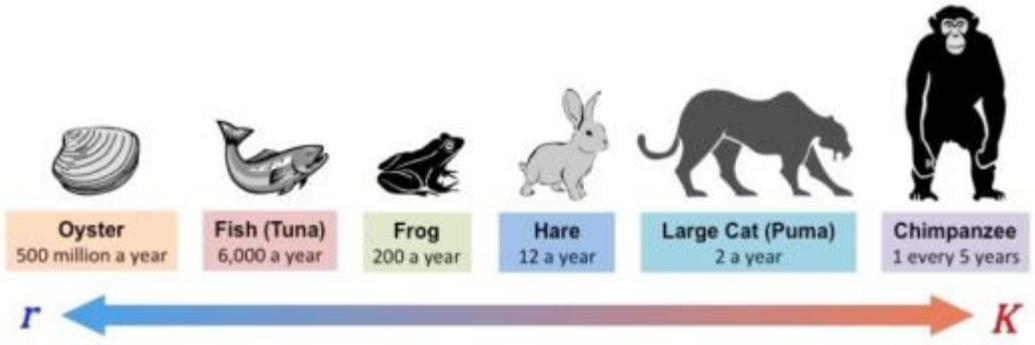


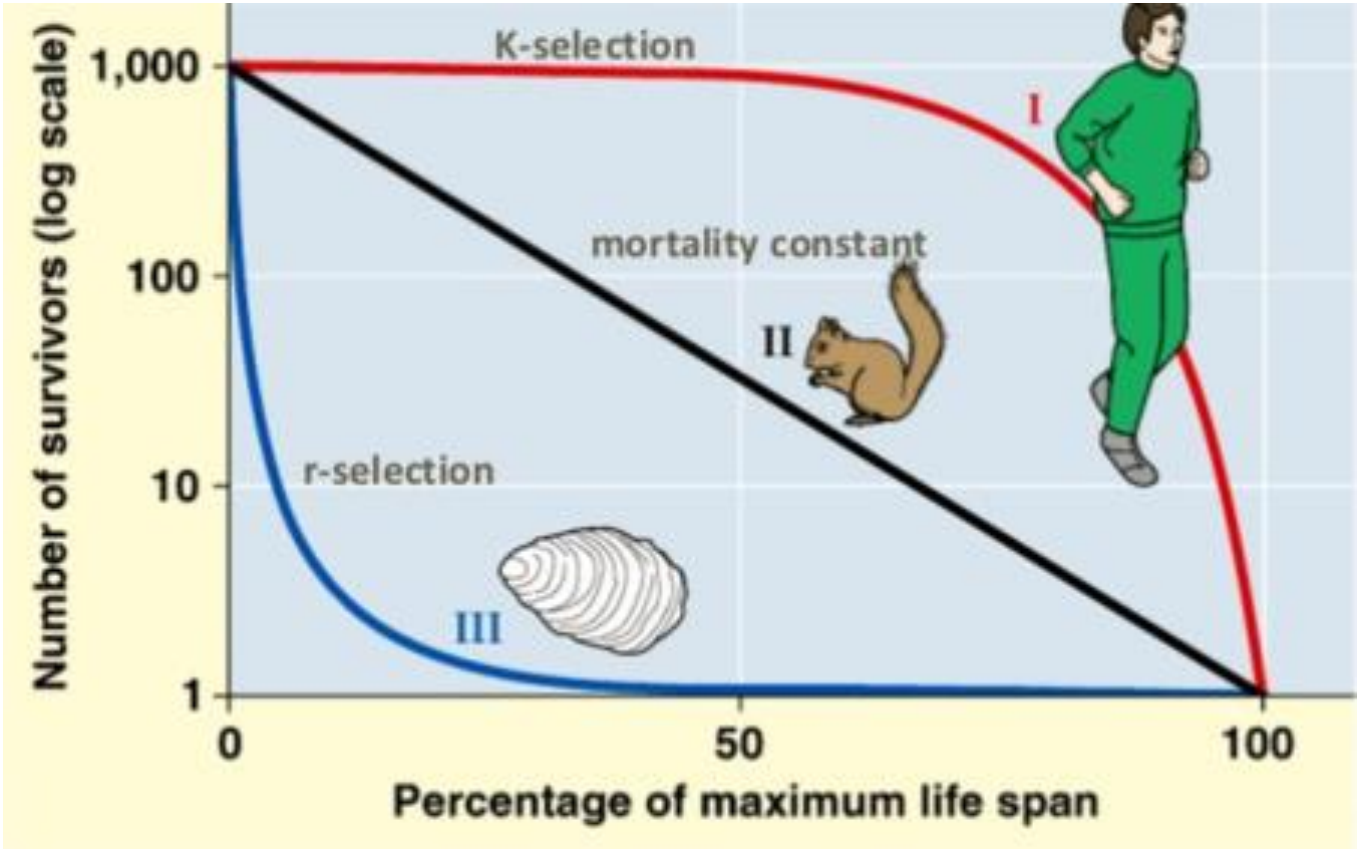
Succession & productivity changes

- P:R ratio
  - Ratio of production to respiration
  - Succession leads to a max accumulation of biomass
  - Upper limit of biomass reached when R almost equal to GPP (when P:R is almost equal to 1)
    - If P:R = 1 production is equal to respiration, steady state community (climax community)
    - If P:R > 1 biomass accumulates
    - If P:R < 1 biomass is lost
- Climax community
  - GPP and R may be high so that NPP (GPP-R) approaches 0 and P:R ratio approaches 1
- Greater habitat diversity leads to increase in diversity of species & genetic diversity

Survivorship strategies

- 2 groups: *K*-strategists & *r*-strategists
  - Defined by amount of energy & time they invest in rearing their offspring
  - Identified by ecologists & not all fit perfectly into the 2 categories
  - Allow useful comparisons to be made
- Opposite ends of the spectrum
  - Patterns of reproduction, many organisms fall between the extremes
  - Birds & reptiles produce & care for more eggs than would be expected for K-strategist, but allows for loss of young through predation, starvation & disease




K-selection
mortality constant
r-selection
I
II
III
1,000
100
10
1
0
50
100
Number of survivors (log scale)
Percentage of maximum life span

K-strategists

- Usually found in climax communities
- Have few offspring
- Invest large amount of time into caring for offspring so most survive
- Examples: great apes & elephants
- Take a long time to mature
- May reproduce several times during adulthood
- Pop size close to carrying capacity
- Predominant species

r-strategists

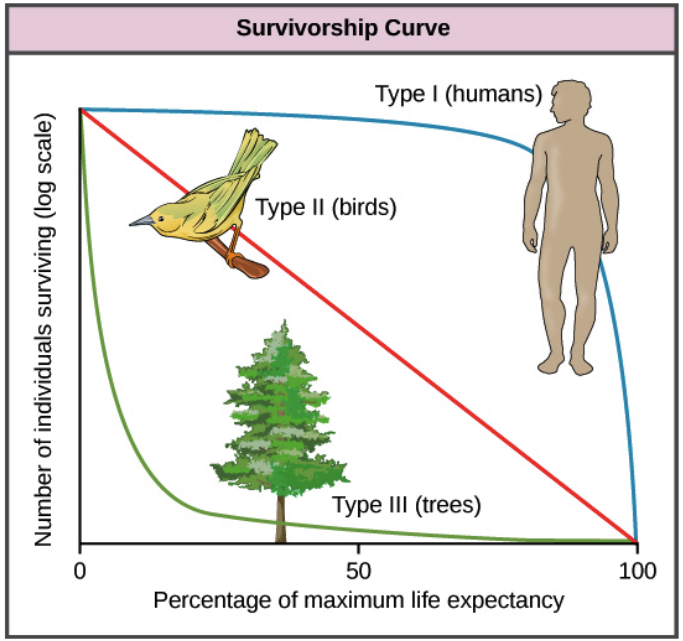
- Pioneer species (able to colonize quickly)
- Short lifespan
- Reproduce once & quickly, producing large # of offspring
- Unlikely to care for offspring (cannot invest time & energy with so many)
- Small #s survive to produce next generation
- Mature quickly & usually small
- Examples: insects, fish, frogs, weeds
- Make good use of short-lived resources
- Common in unstable ecosystems

Survivorship curves

- % of individuals that die before reproductive age = main factor to affect pop size
- To maintain pop size, an ave of 2 offspring from each pair must survive to reproduce
    - Lead to different-shaped survivorship curves
- Most plants & animals age once they have passed maturity
    - Strength declines & die as they reach natural life expectancy

Survivorship curves

- Traces the survival of a group of individuals of a species
  - 3 theoretical curves:

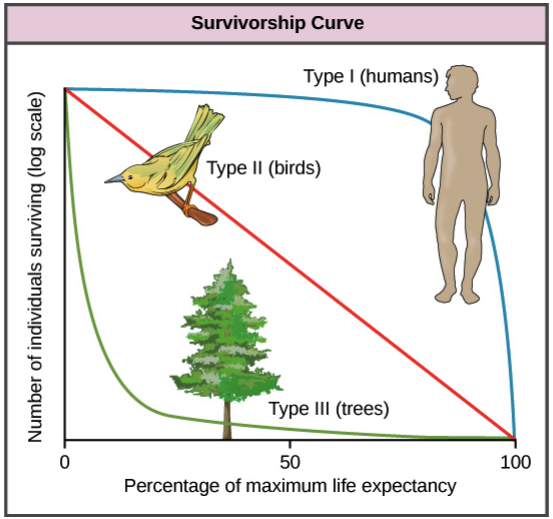


Survivorship curves

Line 1 - K-strategists - young members survive due to parental care - most individuals reach reproductive age - most reach expected lifespan - EX. humans, big cats, eagles, elephants, whales

Line 2 - species has an equal likelihood of dying at any age - death could be due to hunting or disease or chance - EX. mice, coral, many reptiles, many birds, squirrels

Line 3 - r-strategists - most individuals die at a young age, but those that survive will life for their expected lifespan - EX most invertebrates, plants, frogs & organisms with free-swimming juvenile stages like barnacles



Factors affecting climax communities

- Stable ecosystems regulated by feedback mechanisms ...enable system to rebalance itself if changes occur
  - Negative feedback - returns a system to its steady-state position
  - Climax communities - complex food webs & interactions between diverse species = consumers have alt food sources in times of shortage & plants have good reservoir of nutrients & organic matter (not dependent on inputs from outside the system)
- Edaphic factors - physical, chemical & biological properties of soil (water content, texture & pH)
  - Determine exact nature of a climax community
- Climax community - reached a steady state, has higher biomass & species diversity, richer soil structure & organic content
  - Contains larger, longer-lived species, more K-strategists, greater complexity & habitat diversity

Human interference in climax communities

- Clear land, mow away grass or use land for grazing animals
- Natural events (fires & landslides) interrupt progress of succession
- Climax community resulting after these types of interruption are different from the naturally occurring
    - Deflected succession - interruption of a succession so that it does not become a climax community
    - Plagioclimax - community that is produced when a succession is deflected

Plagioclimax

- **Clearing rainforest**
  - burning/cutting down rainforest (South America & Asia)
  - Cleared land planted with crops or used for grazing...prevents re-establishment of a climax community
  - Nutrients have been lost & topsoil eroded
  - Rainforest cover 6% of Earth’s surface but an area equal to a small country is lost every year due to clearance
- **Changing the face of the prairies**
  - Temperate grassland on American prairies (interior of USA)
  - Fire & human use left buffalo grass & blue grama in place of trees
  - These limit tree growth due to tight growth of grass and deep roots so succession does not continue
  - Grass roots & rhizomes store nutrients & reduce erosion
  - Grassland maintained by grazing species like sheep & cattle

Plagioclimax

- **Moorland**
  - Large areas of uplands (northern UK) were once forested are now treeless & covered by heather moorland
  - Heather dominated area 7000 years ago when people first cut down trees
  - Coincided with wetter period...peat bogs of moss and rushes established in poorly drained areas, while heather & grass dominated dry areas
  - Woodland clearance for fuel, construction & farming continued
  - Heather survives in poorer, acidic soils which now dominate the moorlands
  - Grazing animals prevent regrowth of young trees
  - People regularly burn heather to maintain the moors
    - Controlled burning in rotation so each area burned every 10-20 yrs
    - Potash left from fires enriches the soil for heather regrowth
    - Moorland made up of patchwork of mature & developing vegetation