DP IB Environmental Systems & Societies (ESS): SL

Your notes

Biomes, Zonation & Succession

Contents

What are Biomes?

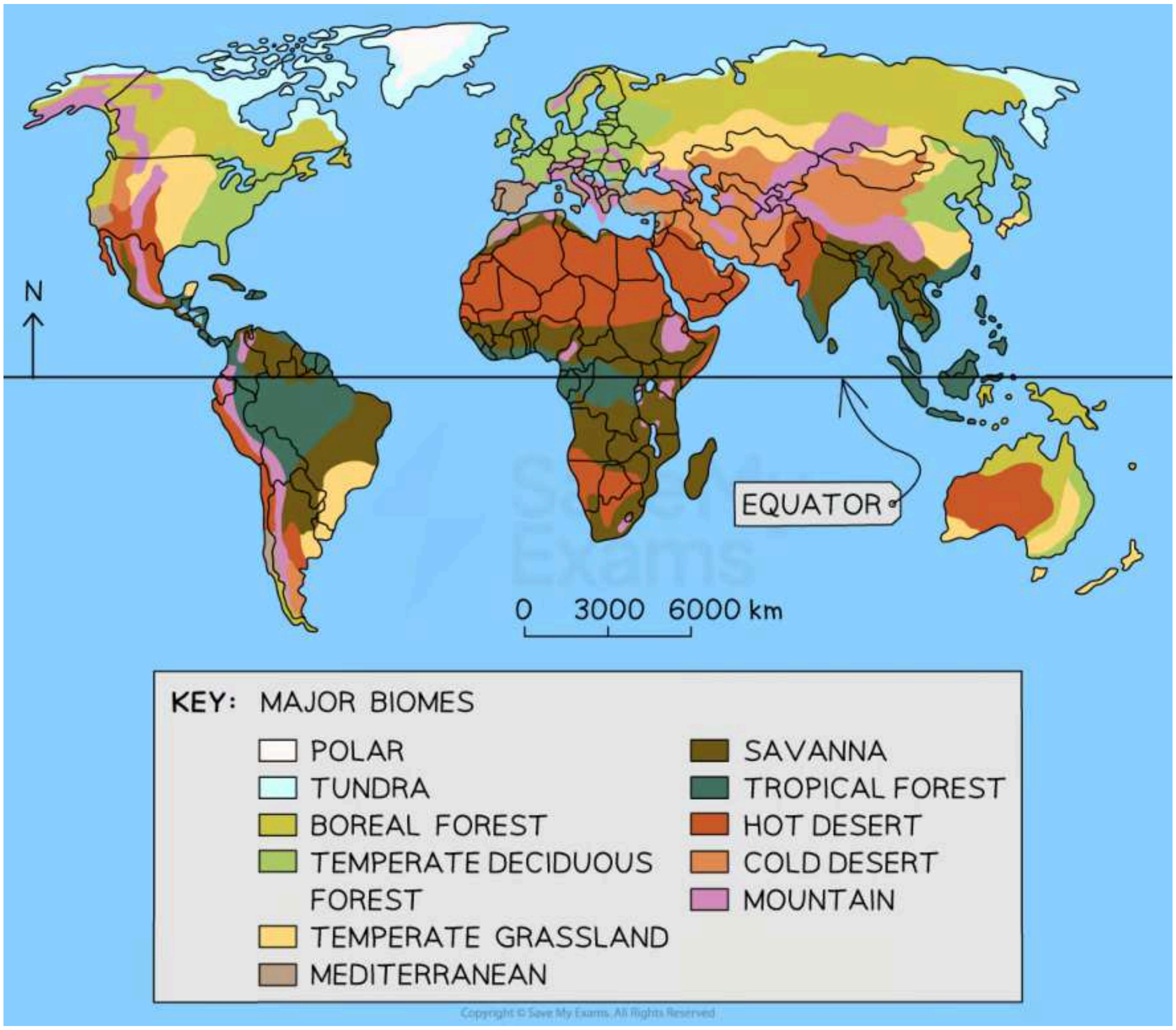
Your notes

Biomes

Biomes Definition

- Biomes are large-scale ecological communities that are characterised by their **dominant vegetation**, **climate**, and other **abiotic factors** that shape their biotic communities
- Biomes are classified into five major classes:
  - Aquatic
  - Forest
  - Grassland
  - Desert
  - Tundra
- These major classes can be divided into further categories, for example:
  - Aquatic biomes are water-based ecosystems that are divided into **freshwater** and **marine** ecosystems, including lakes, rivers, oceans, and coral reefs
  - Forest biomes are dominated by trees and are categorised into **tropical** rainforests, **temperate deciduous** forests, and **boreal** forests
  - Grassland biomes are characterised by grasses and herbaceous plants and are categorised into **savannas** and **temperate** grasslands
  - Desert biomes are characterised by low rainfall and are dominated by cacti and other drought-resistant plants - they can be further divided into subcategories such as **hot** deserts, **cold** deserts, **coastal** deserts, and **semi-arid** deserts
  - Tundra biomes are found in high latitudes and are characterised by low temperatures and permafrost - they can be further divided into subcategories such as **arctic** tundra and **alpine** tundra

Your notes



Biomes of the world

- Each biome has characteristic **limiting factors** that affect **productivity** and **biodiversity**
  - For example, in the desert biome, **water** is the limiting factor for plant growth, while in the tundra biome, **low temperatures** and **permafrost** limit plant growth

Forest Biomes

Characteristics	Tropical Rain Forest	Temperature Forest	Boreal forest
Location	Low latitudes	Between 40°- 60° north and south of the equator	Between 50°- 60° north and south of the equator

Your notes

	Within the Tropics 23.5° north and south of the equator Amazon in South America, New Guinea, Southeast Asia, Zaire Basin	Western Europe, northeast USA, Eastern Asia	Canada, Russia, Scandinavia
Annual Precipitation	Over 2000mm	750–1500mm (all year round)	300–900mm (all year round)
Temperature Range	26–28°C	Over 0° C in winter and summer between 20°C-25° C	-30°C in winter and up to 20°C in summer
Seasons	No seasons: hot and wet all year round	Four seasons of equal length	Two main seasons: winter and summer
Growing Season	All year round	6–8 months	2–3 months
Soils	Infertile due to leaching and rapid uptake of nutrients by plants	Fertile soils Nutrient rich due to the decomposition of organic matter over autumn and winter	Not very fertile often acidic with permafrost Shallow soil with a thick litter layer due to slow decomposition
Biodiversity	Approx. 50% of the world's plant and animal species live within the rainforest biome Four layers of vegetation: mahogany, teak trees, lianas, orchids Toucans, jaguars, frogs, snakes	Wide range of animals and plants with higher biodiversity than boreal forests Deciduous trees: beech, oak, birch Deer, rabbits, squirrels, bears	Less biodiverse than temperate forests Coniferous trees Squirrels, bears, reindeer, wolves

Grassland Biomes

Your notes

Characteristics	Savanna	Temperate Grasslands
Location	North and south of the tropical and monsoon forest biomes 5° - 30° north and south of the equator Central Africa - Tanzania, Kenya	The 'veldts' of South Africa, the 'pampas' of Argentina, and 'steppes' of Russia and the 'plains' of the USA 40˚- 60˚ north and south of the equator
Annual Precipitation	800–900mm	250–750mm
Temperature Range	15°C to 35°C	-40°C to 40°C
Seasons	Wet and dry season	Four seasons
Growing Season	During the wet season (4–5 months)	During the summer (dependent on temperature)
Soils	Free draining with a thin layer of humus Not very fertile most nutrients near the surface	Fertile soil
Biodiversity	Wide range of plant and animal species Grasses, baobab and acacia trees Zebras, elephants, giraffes Greatest diversity of hoofed animals	Large numbers of plant and animal species Grasses, sunflowers Bison, antelopes, rabbits Grasses and trees

Desert Biomes

Characteristics	Hot Desert
Location	15° - 30° north and south of the equator North Africa - Sahara, Southern Africa - Kalahari and Namib, Australia, Middle East

Annual Precipitation	Below 250mm
Temperature Range	Daytime temperatures can reach 50°C but average around 25°C Night time temperatures below 0°C
Seasons	Summer and winter
Growing Season	All year round
Soils	Infertile
Biodiversity	Low diversity Cacti, yucca Spiders, scorpions, camels, meerkats

Tundra Biomes

Characteristics	**Tundra**
Location	North of the Arctic Circle and Antarctica
Annual Precipitation	Less than 250mm
Temperature Range	Below 0°C for 6–10 months
Seasons	Winter and summer
Growing Season	6–10 weeks
Soils	Thin infertile soil Permafrost
Biodiversity	Low biodiversity Snowy owls, snow bunting and tundra swan Arctic foxes, hares and wolves

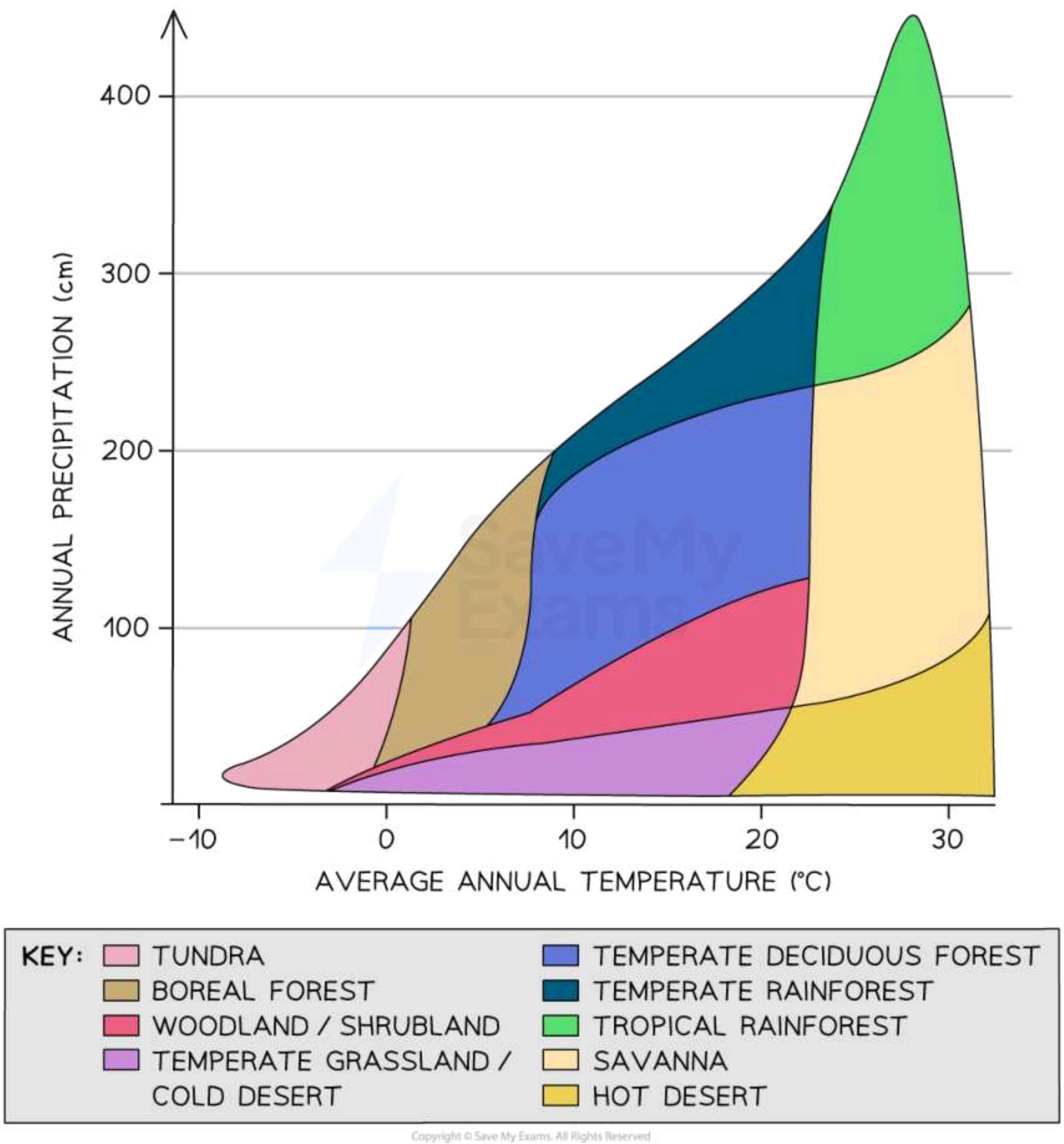
	Polar bears, musk ox and caribou Small grasses, mosses, lichen

Your notes

The Distribution of Biomes

- Insolation, precipitation, and temperature are the main factors governing the distribution of biomes
  - Insolation refers to the amount of solar radiation that reaches the Earth's surface and affects temperature
  - Precipitation affects the availability of water, which is a key limiting factor for many biomes
  - Temperature determines the rate of photosynthesis and respiration in plants, as well as the metabolic rates of animals
- The combination of temperature and precipitation determines the distribution of biomes around the world

Your notes



Precipitation and temperature are the two most important climatic variables that determine the type of biome in a particular location

Worked Example

Your notes

The table below shows the net primary productivity (NPP) and species richness for three biomes: tropical rainforest, temperate deciduous forest, and tundra. Analyse the data and discuss the differences in productivity and biodiversity among the three biomes.

Biome	NPP (kJ/m^2/yr^{-1})	Species Richness
Tropical Rainforest	2200	Very high
Temperate Deciduous Forest	900	High
Tundra	50	Low

Answer

The data suggest that tropical rainforests have the highest rate of photosynthesis and carbon fixation, as well as the greatest number of species, followed by the temperate deciduous forest and then the tundra. One possible reason for the higher productivity and biodiversity in the tropical rainforest and temperate deciduous forest could be the greater availability of water and higher average temperatures compared to the tundra. Higher temperature and higher precipitation contribute to the growth of plants and the cycling of nutrients The difference in temperature is due to the fact that the tropical rainforest is located near the equator, where solar insolation is high and the climate is warm and humid, while the tundra is located in the polar regions, where solar insolation is low and the climate is cold and dry.

Effect of Climate Change on Biomes

- Climate change is one of the greatest **threats to biodiversity** on Earth
- As the global climate changes, the distribution of biomes is shifting, leading to significant impacts on ecosystems and the services they provide
- Biomes are collections of ecosystems that share **similar climatic conditions**, such as temperature and precipitation
  - As these conditions change, the boundaries between biomes shift, causing changes in the plant and animal species that live there
- Biome shifts can occur in two ways:
  - **Range shifts** - when species move to new areas to find suitable conditions as their current habitats become less hospitable
  - **Biome type changes** - when a biome transitions to a different type, such as a forest becoming a savanna or a tundra becoming a forest

Photo by Peter Burdon on Unsplash

A changing biome type in Namibia

Your notes

- The distribution of biomes is primarily determined by **temperature** and **precipitation**
  - As global temperatures rise, the boundaries between biomes shift poleward or upward in elevation
- This means that the **warmer biomes**, such as tropical rainforests and savannas, are **expanding**, while the **colder biomes**, such as tundra and boreal forests, are **contracting**
- The impacts of biome shifts are significant and far-reaching:
  - As species move to new areas or experience changes in their habitats, they may face new competition, predation, or disease
  - This can lead to **declines** in population numbers and even **extinction** in some cases
  - Biome shifts can also have impacts on the vital **services** that ecosystems provide to living organisms, especially **humans**, such as water regulation, nutrient cycling, and carbon sequestration

Tricellular Model of Atmospheric Circulation

Your notes

Tricellular Model of Atmospheric Circulation

Global Atmospheric Circulation

- The global atmospheric circulation can be described as a worldwide system of winds moving solar heat energy **from the equator to the poles** to reach a balance in temperature

Wind formation

- Air always moves from areas of **higher pressure to lower pressure** and this movement of air generates **wind**
- Winds are large scale movements of air due to differences in air pressure
- This pressure difference is because the Sun heats the Earth's surface unevenly
- **Insolation** that reaches the Earth's surface is greater at the equator than at the poles due to the Earth's curvature and angle of the Earth's tilt

Your notes

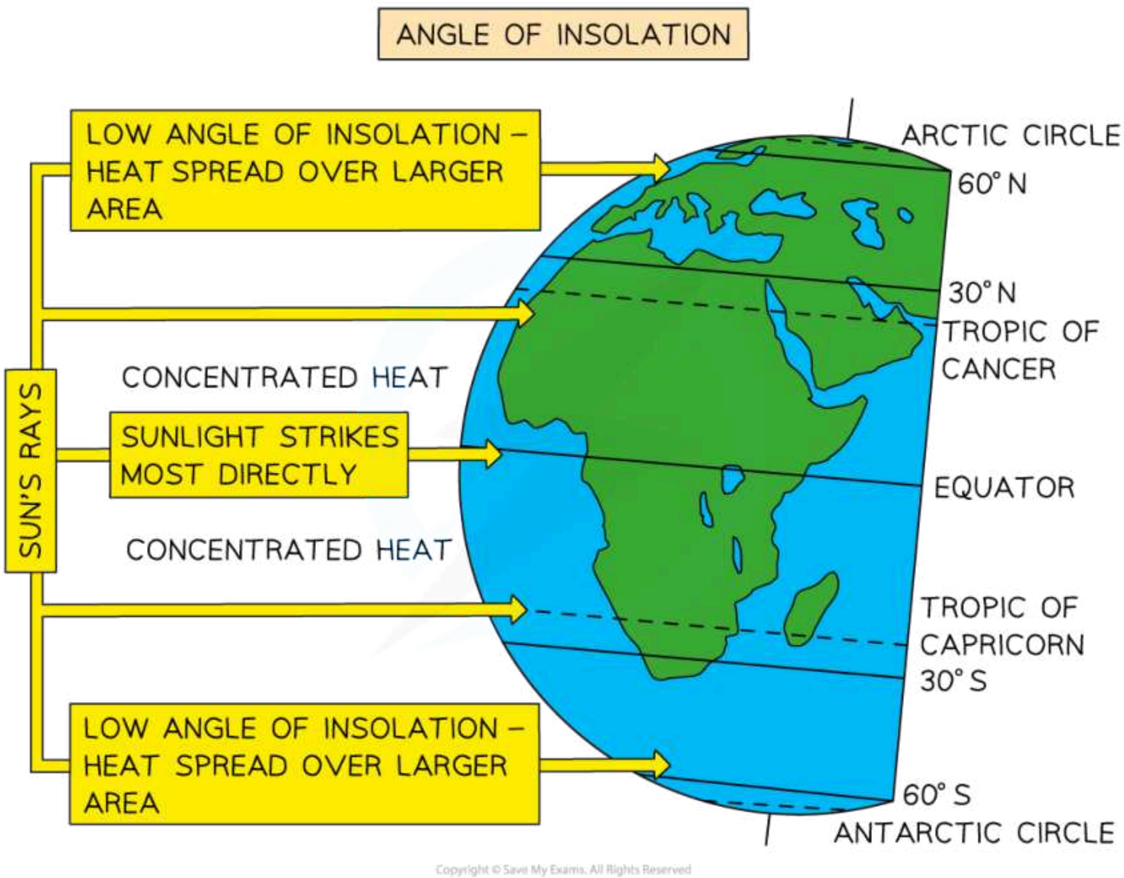
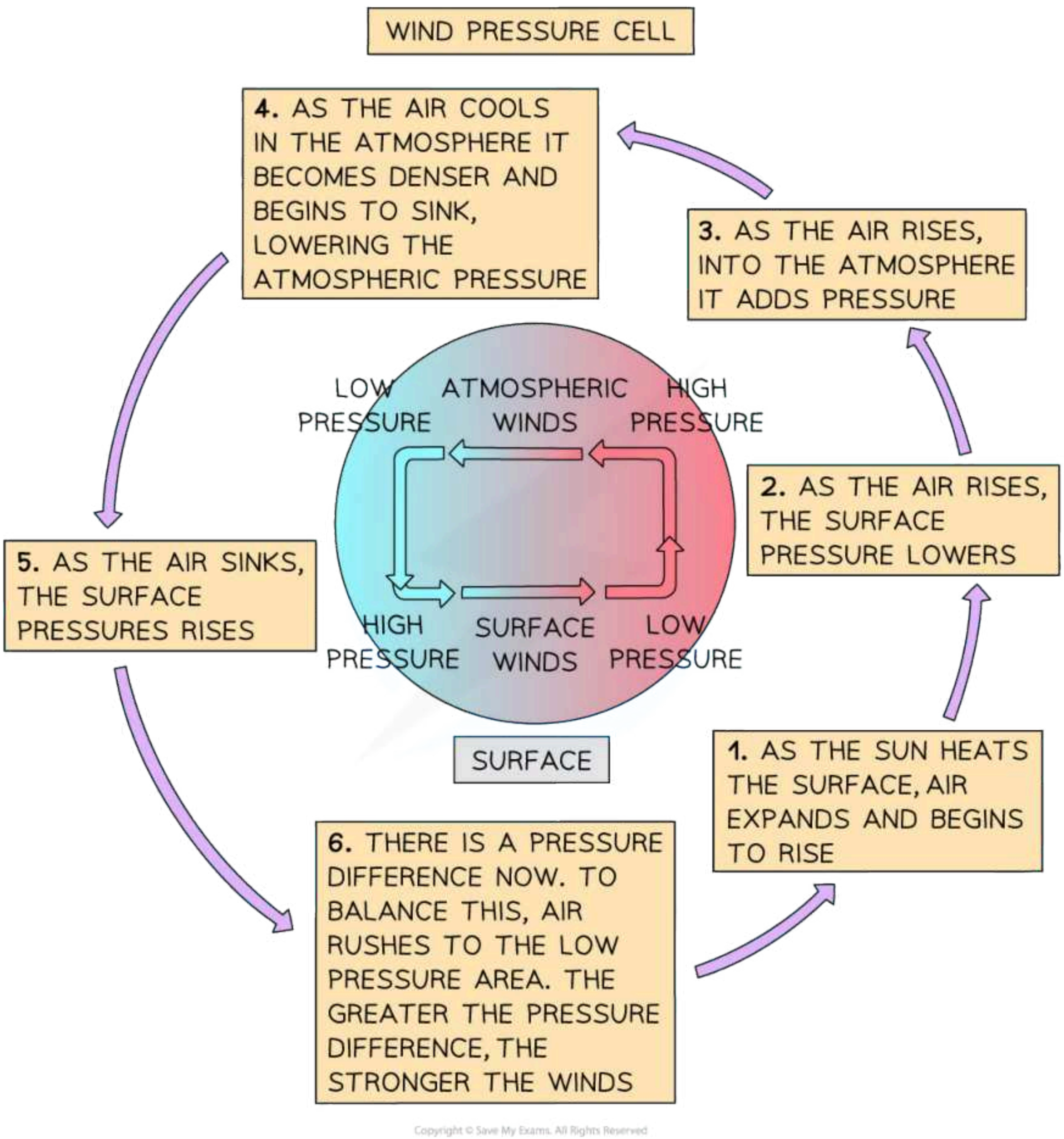


Diagram showing how angle of insolation spreads solar radiation over a wider area at the poles than the equator

- Hot air **rises** and cooler air **sinks** through the process of convection
- This irregular heating of the Earth's surface creates pressure cells
- Each cell generates different weather patterns

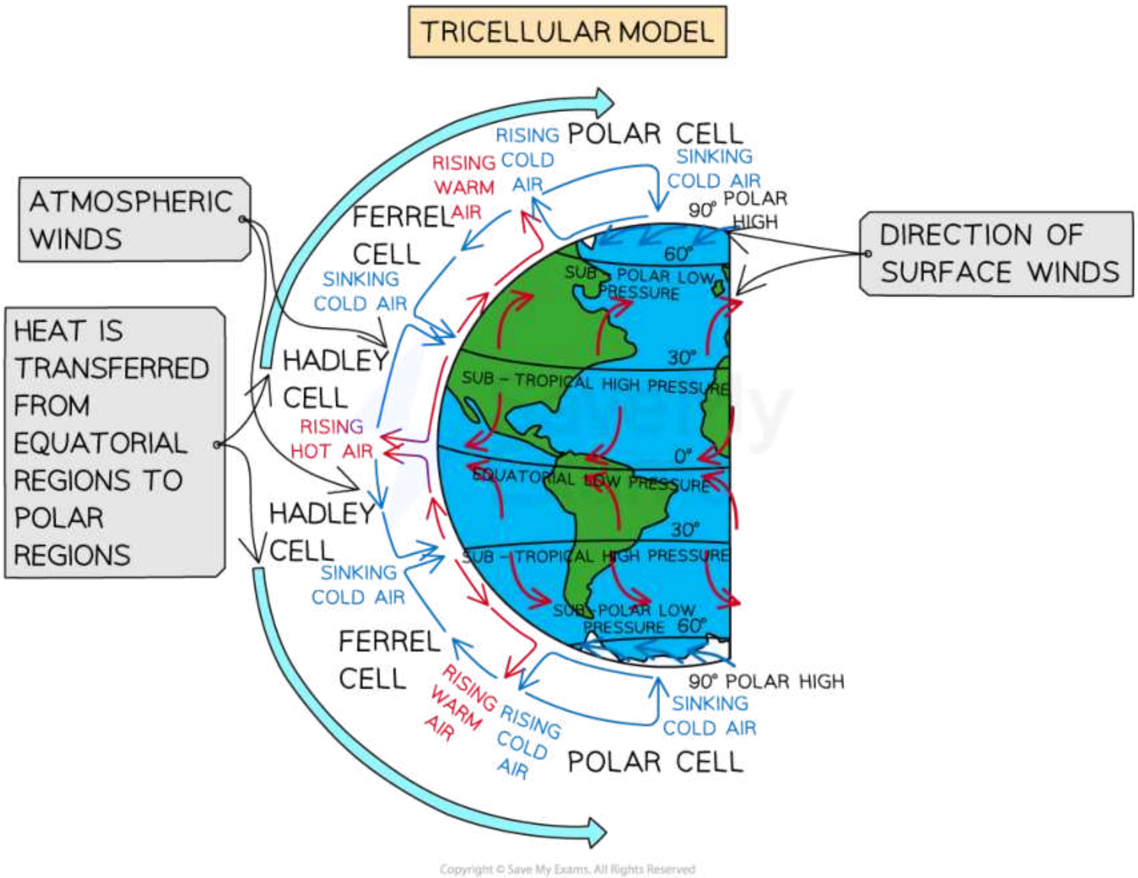


A typical wind pressure cell system showing distribution of pressure at Earth's surface and upper atmosphere

- Air movement within the cell is roughly circular and moves surplus heat from equatorial regions to other parts of the Earth
- In both hemispheres, heat energy transfer occurs where 3 atmospheric circulation cells meet

Your notes

- These are the **Hadley**, **Ferrel** and **Polar cells** and are shown via the tri-cellular model:



Heat energy flow and surface winds can be explained using the tricellular model of atmospheric circulation

The tri-cellular atmospheric wind model

- Each hemisphere has **three cells** (the Hadley cell, Ferrel cell and Polar cell) that circulate air from the surface through the atmosphere and back to the Earth's surface
  - **Hadley cell** is the **largest cell** and extends from the equator to between 30° and 40° north and south
  - Trade winds blow from the tropical regions to the equator and travel in an easterly direction
  - Near the equator, the trade winds meet, and the hot air rises and forms thunderstorms (tropical rainstorms)

Your notes

- From the top of these storms, air flows towards higher latitudes, where it becomes cooler and sinks over subtropical regions
- This brings dry, cloudless air, which is warmed by the Sun as it descends: the climate is warm and dry (hot deserts are usually found here)

- **Ferrel cell** is the **middle cell**, and generally occurs from the edge of the Hadley cell to between 60° and 70° north and south of the equator
  - This is the most complicated cell as it moves in the opposite direction from the Hadley and Polar cells; similar to a cog in a machine
  - Air in this cell joins the sinking air of the Hadley cell and travels at low heights to mid-latitudes where it rises along the border with the cold air of the Polar cell
  - This occurs around the mid-latitudes and accounts for frequent unsettled weather
- **Polar cell** is the **smallest** and **weakest** of the atmospheric cells. It extends from the edge of the Ferrel cell to the poles at 90° north and south
  - Air in these cells is cold and sinks creating high pressure over the highest latitudes
  - The cold air flows out towards the lower latitudes at the surface, where it is slightly warmed and rises to return at altitude to the poles

Spatial & Temporal Changes in Communities

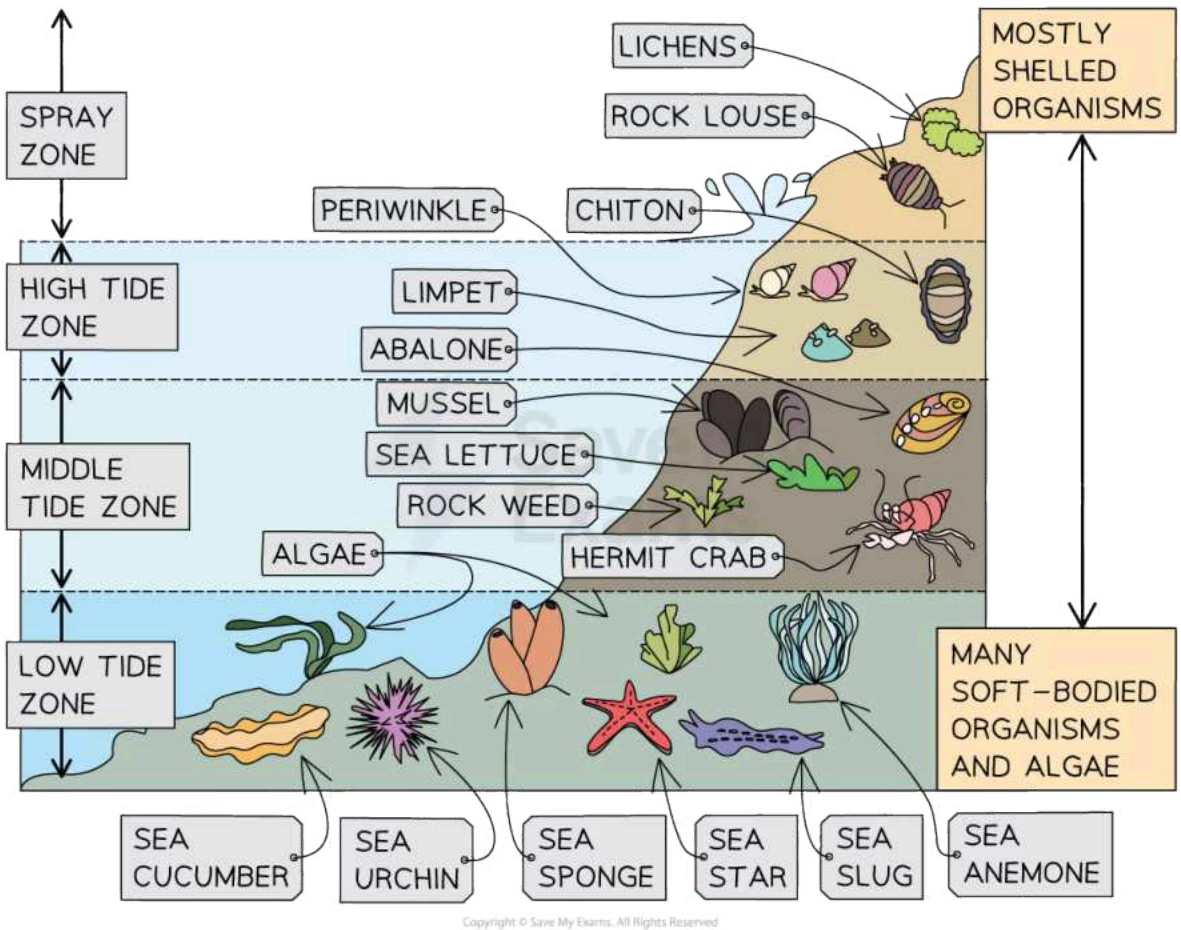
Your notes

Zonation & Succession

Zonation

- Zonation in ecology refers to the gradual change in the composition of species and communities across a landscape, based on a gradient of environmental factors such as:
  - Altitude
  - Latitude
  - Temperature
  - Moisture
  - Light
- As these factors change, the species present in an ecosystem also change, leading to distinct **zones** or bands of organisms that can be observed in the ecosystem
  - This process occurs due to the **interactions** between the physical environment and the biological components of an ecosystem
- An example of zonation can be observed in a **rocky intertidal zone**, where the physical and biological characteristics of the ecosystem change gradually from the high tide mark to the low tide mark
  - At the highest point (sometimes referred to as the spray zone), the zone is usually dry and dominated by lichen and other hardy plants that can withstand long periods of exposure to air and sunlight
  - In the high tide zone, the environment becomes more hospitable for other organisms such as barnacles, mussels, chitons, limpets and sea snails that can attach themselves to the rocks and withstand waves
  - Further down towards the low tide zone, the environment becomes even more favourable for marine organisms such as sea stars, anemones, and sea urchins that require the constant presence of water

Your notes



An example of zonation in a rocky intertidal zone

Succession

- Ecosystems are **dynamic**, meaning that they are constantly changing
- Sometimes, ecosystems change from being very simple to being relatively complex
  - This process is known as **succession**
  - During succession, the **biotic** conditions (i.e. the living factors) and the **abiotic** conditions (i.e. the non-living factors) **change over time**
- Succession is the process that occurs when newly formed or newly exposed land (with no species present) is gradually **colonised** (inhabited) by an increasing number of species
- This new uninhabited land can be created in several ways. For example:

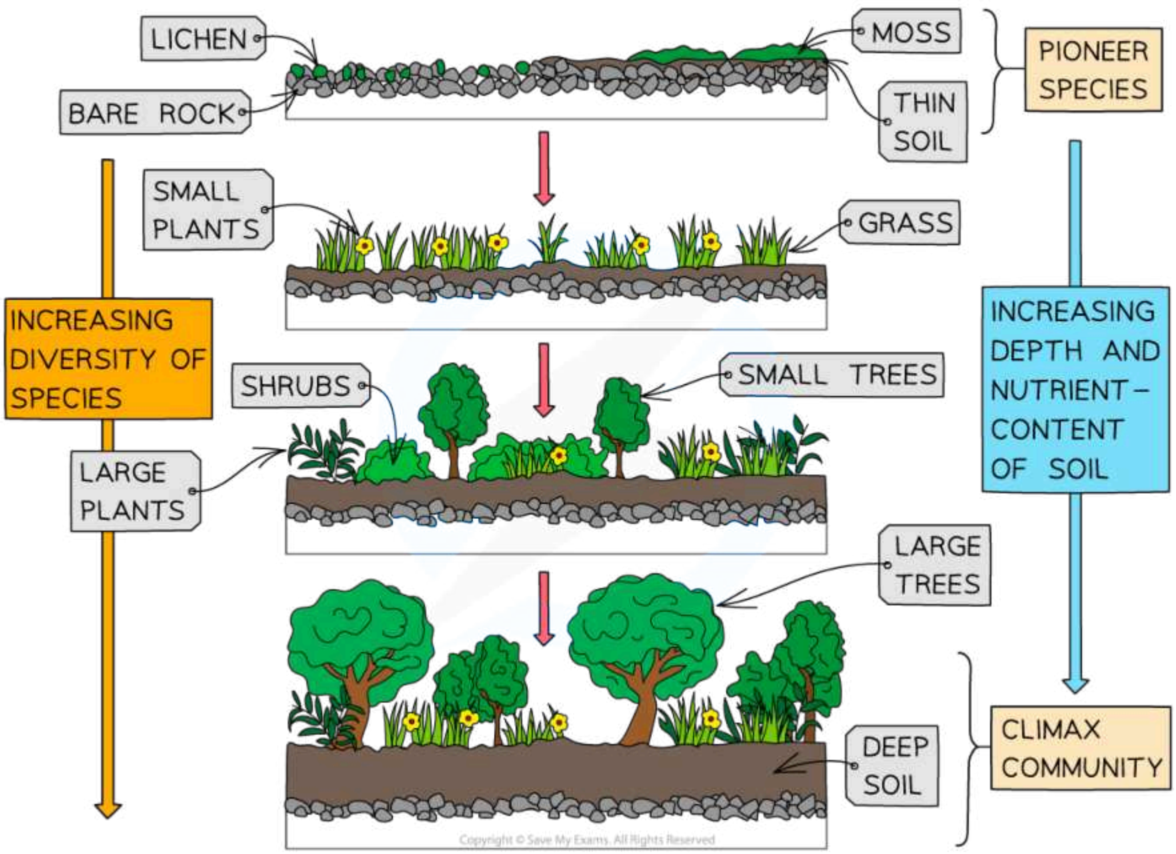
Your notes

- The magma from erupting volcanoes cools and often leads to the formation of new rock surfaces or even new rocky islands in the sea
- Another way new land can be exposed is by sea-level dropping or the drying up of a lake, leaving areas of bare rock
- Succession does not only occur on bare rock. Any barren terrain that is slowly being colonised by living species is undergoing **primary succession**. For example:
  - Sand dunes in coastal areas
  - Marram grasses are the pioneer species in these environments as they have deep roots to access water that other plants can't reach and they are also able to tolerate the salty environment i.e. the high concentrations of sodium and calcium ions caused by sea spray

Succession Occurs in a Series of Stages

- Firstly, seeds and spores that are carried by the wind land on the exposed rock and begin to grow
  - These first species to colonise the new land (often moss and lichens) are known as **pioneer species**
  - As these pioneer species die and decompose, the dead organic matter (humus) forms a **basic soil**
- Seeds of small plants and grasses, sometimes also carried in the wind or sometimes transported other ways (e.g. in bird faeces) land on this basic soil and begin to grow (these smaller plants are adapted to survive in shallow, relatively nutrient-poor soils)
  - As these small plants and shrubs die and decompose, the new soil becomes **deeper** and more **nutrient-rich**
  - The roots of these small plants and shrubs also form a **network** that helps to **hold the soil** in place and prevent it from being washed away
- Larger plants and shrubs, as well as small trees, that require deeper, more nutrient-rich soil, can now begin to grow
  - These larger plants and small trees also require more water, which can be stored in deeper soils
- Finally, the soil is sufficiently deep, contains enough nutrients and can hold enough water to support the growth of **large trees**
  - These final species to colonise the new land become the **dominant species** of the now relatively complex ecosystem
  - The final community formed, containing all the different plant and animal species that have now colonised the new land, is known as the **climax community**

Your notes



Succession is the process of ecosystem change over time, beginning with newly formed or newly exposed land

Changes Occurring During Succession

- As the the structure and species composition of an ecosystem changes during succession, so do the patterns of energy flow, productivity, diversity, and mineral cycling that ecosystem
- **Energy Flow:**
  - During the early stages of succession, the energy flow in the ecosystem is relatively low
  - This is because there are only a few species present, and most of the energy is used to build biomass
  - As the ecosystem becomes more complex, energy flow increases
- **Gross and Net Productivity:**

- During the early stages of succession, gross productivity and net productivity is low because there are only a few species present so the ecosystem's overall gain in energy and biomass per unit area per unit time is relatively small
- As the ecosystem becomes more complex, gross productivity and net productivity increase

- **Diversity:**
  - Diversity refers to the number of species present in an ecosystem
  - During the early stages of succession, diversity is low because there are only a few species present
  - As the ecosystem becomes more complex, diversity increases because there are more niches available, and more species are able to coexist within the same habitats in the ecosystem
- **Mineral Cycling:**
  - Mineral cycling refers to the movement of nutrients through an ecosystem
  - During the early stages of succession, mineral cycling is relatively simple as there are only a few species present and nutrient cycling is largely driven by abiotic processes
  - As the ecosystem becomes more complex, nutrient cycling becomes more complex because there are more species present and each species has unique nutrient requirements and cycling processes

Examiner Tips and Tricks

You could be presented with an example of succession other than the one provided here e.g. succession on a sand dune. As long as you understand the principles of the stages of succession you should be able to apply your knowledge to any example that an exam question might throw at you.

Your notes

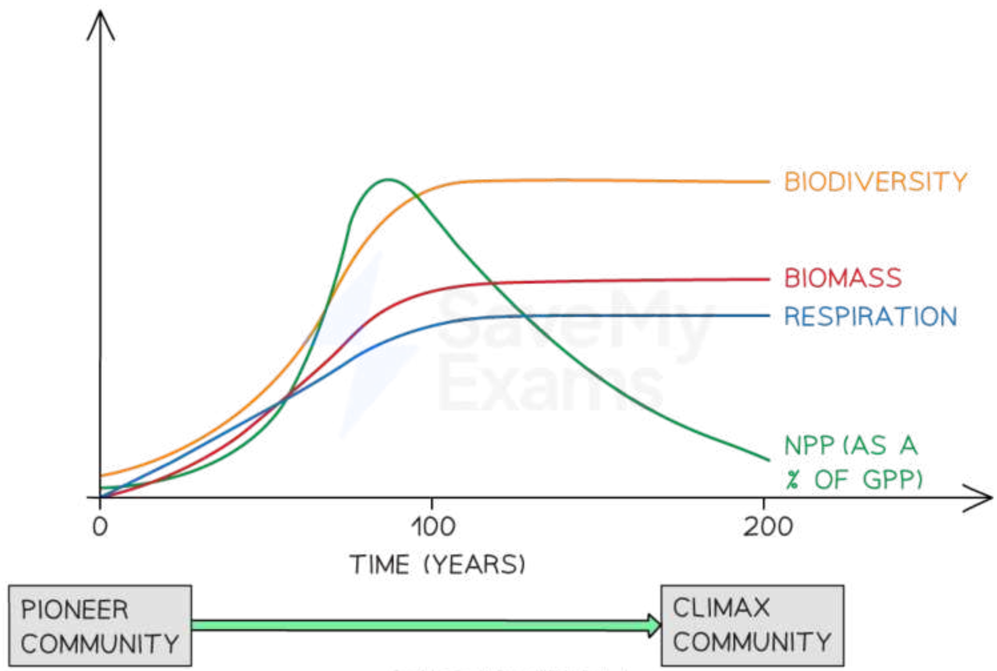
Pioneer & Climax Communities

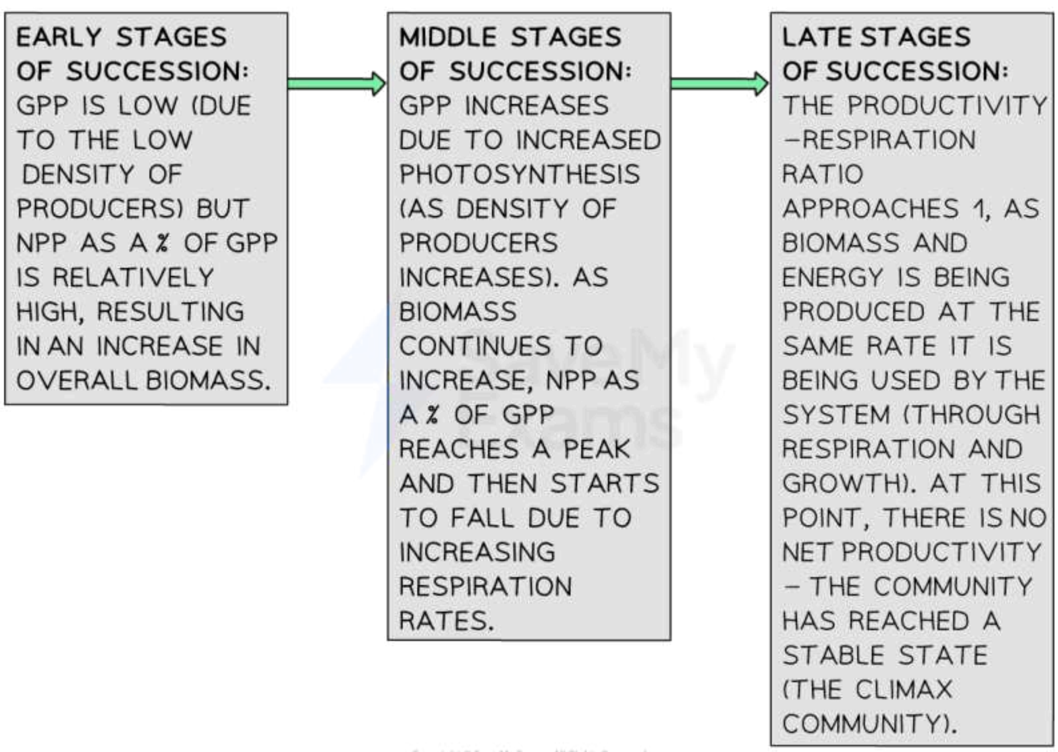
What are pioneer communities?

- In pioneer communities (i.e. in the early stages of succession), gross productivity is low due to the unfavourable initial conditions and low density of producers (low gross primary productivity)
- However, the proportion of energy lost through community respiration is also relatively low
- This means that net productivity in pioneer communities is relatively high
- This allows the pioneer community system to grow and accumulate biomass

What are climax communities?

- In climax communities (i.e. in the later stages of succession), gross productivity may be relatively high, due to a high density of producers (high gross primary productivity) and consumers (high gross secondary productivity)
- However, this relatively high gross productivity is balanced by the large amounts of energy lost from the climax community system through respiration
- This causes the net productivity of a climax community to approach 0
- As this happens, the productivity–respiration (P:R) ratio approaches 1
    - This ratio reaches 1 when biomass and energy is being produced by the system at the same rate as it is being used
    - If the ratio >1, then excess energy and biomass is being produced
    - If the ratio <1, then more biomass and energy is being consumed than is being produced
    - To reach a stable (climax) community, there has to be an equilibrium between the community production and the community respiration
- There is no one climax community, but rather a set of alternative stable states for a given ecosystem
    - What the climax community eventually looks like depends on a large variety of factors, including climate, the local soil properties, and a range of random events that can occur over time (e.g. extreme weather events, human interventions)


BIODIVERSITY
BIOMASS
RESPIRATION
NPP (AS A % OF GPP)
0
100
200
TIME (YEARS)
PIONEER COMMUNITY
CLIMAX COMMUNITY
Copyright © Save My Exams. All Rights Reserved


EARLY STAGES OF SUCCESSION: GPP IS LOW (DUE TO THE LOW DENSITY OF PRODUCERS) BUT NPP AS A % OF GPP IS RELATIVELY HIGH, RESULTING IN AN INCREASE IN OVERALL BIOMASS.
MIDDLE STAGES OF SUCCESSION: GPP INCREASES DUE TO INCREASED PHOTOSYNTHESIS (AS DENSITY OF PRODUCERS INCREASES). AS BIOMASS CONTINUES TO INCREASE, NPP AS A % OF GPP REACHES A PEAK AND THEN STARTS TO FALL DUE TO INCREASING RESPIRATION RATES.
LATE STAGES OF SUCCESSION: THE PRODUCTIVITY –RESPIRATION RATIO APPROACHES 1, AS BIOMASS AND ENERGY IS BEING PRODUCED AT THE SAME RATE IT IS BEING USED BY THE SYSTEM (THROUGH RESPIRATION AND GROWTH). AT THIS POINT, THERE IS NO NET PRODUCTIVITY – THE COMMUNITY HAS REACHED A STABLE STATE (THE CLIMAX COMMUNITY).
Copyright © Save My Exams. All Rights Reserved

Changes occurring in a community as it develops from a pioneer community into a climax community through the process of succession

Comparison of Pioneer and Climax Communities

Feature	Pioneer Communities	Climax Communities
Stage in succession	Early stages	Later Stages
GPP	Low	High
NPP as a % of GPP	High	Low
Species Richness and Diversity	Low	High
Niches	Fewer, wider	Many, narrow
Size of organisms	Small	Large
Species composition	Fewer species, adapted to harsh conditions	More species, adapted to stable conditions
Total biomass (amount of organic matter)	Low	High
Soil depth	Shallow	Deep
Soil quality	Poor (little nutrients and organic material)	High (nutrient-rich and full of organic matter)
Growth rate	Rapid	Slower
Energy flow	Simple and linear	Complex and cyclic
Nutrient cycling	Less efficient, open system (external inputs)	More efficient, closed system (nutrients are recycled)

Dominant organisms	Lichens, mosses, algae, bacteria, and fungi	Woody plants, trees, and shrubs
Stability	Unstable, prone to disturbance and colonisation	Stable, resistant to disturbance and colonisation
Examples	Pioneer species like lichens and mosses on rocks	Ancient oak forests

Your notes

Reproductive Strategies

Density-dependent and Density-independent Factors

- In ecology, population growth and regulation are influenced by a range of biotic and abiotic factors. Some of these factors are influenced by the population density, while others are not
- Density-dependent factors include factors such as competition, predation, parasitism, and disease
- As the population density increases, the impact of these factors becomes more significant, resulting in a decline in the population growth rate
- In this way, density-dependent factors acts as negative feedback mechanisms, leading to the stability and regulation of populations
- Density-independent factors include natural phenomena such as floods, fires, hurricanes, and droughts, as well as **anthropogenic** activities like pollution, deforestation, and climate change
- These factors affect the population growth rate irrespective of the population density, so their impact is similar across all populations regardless of their density

r-strategist Species

- r-strategists are characterised by having a high reproductive rate, small body size, early maturity, and short lifespan
- They are adapted to unstable and unpredictable environments and tend to be found in pioneer communities
- These species tend to have a high growth rate and reproduce quickly, producing large numbers of offspring with little investment in each
- They have a lower survival rate, but their high reproductive rate enables them to quickly recolonize and establish themselves after disturbances

- Examples of r-strategist species include cockroaches, flies and some small mammal species
- Populations of r-strategists are controlled by density-independent factors

Photo by MOHD AZRIEN AWANG BESAR on Unsplash

Flies are r-strategists

K-strategist Species

- K-strategists are characterised by having a low reproductive rate, large body size, late maturity, and long lifespan
- They are adapted to stable and predictable environments and tend to be found in climax communities
- These species tend to have a lower growth rate but invest more in each offspring, resulting in a higher survival rate
- They are better able to withstand disturbances, allowing them to persist in stable environments
- Examples of K-strategist species include large mammals
- Populations of K-strategists are controlled by density-dependent factors

Photo by Glen Carrie on Unsplash

Large mammals such as rhinos are K-strategists

Comparison of r- and K-strategist Species

Feature	r-strategist species	K-strategist species
Reproductive rate	High	Low
Body size	Small	Large
Maturity	Early	Late
Lifespan	Short	Long
Growth rate	High	Low

Your notes

Investment in offspring (parental care)	Low	High
Survival rate	Low	High
Level of specialisation	Generalist species	Specialist species
Controlled by	Density-independent factors	Density-dependent factors
Adapted to	Pioneer communities	Climax communities
Examples	Annual plants, insects, small mammals	Large mammals, trees, some reptiles

Your notes

Your notes

Human Impact on Succession

Human Impact on Succession

- Human activities can divert the progression of succession to an alternative stable state by modifying the ecosystem through various activities, such as:
  - Burning
  - Agriculture
  - Grazing pressure
  - Resource use (such as deforestation)
- These activities can have both **direct** and **indirect** impacts on the ecosystem, leading to changes in the biotic and abiotic components, and ultimately altering the course of ecological succession within the ecosystem
  - For instance, controlled fires are often used to clear land for agricultural purposes or to manage the spread of wildfires
  - However, fire can have serious negative effects on the ecosystem by killing off plants, reducing soil fertility, and altering nutrient cycles
  - Similarly, agriculture and grazing can cause soil erosion, loss of vegetation cover, and changes in nutrient cycling, which can in turn affect the composition of the species in the ecosystem

Photo by Randy Fath on Unsplash

Human activities often simplify ecosystems, rendering them unstable

- These activities, which divert the progression of succession, may be temporary or permanent depending upon the resilience of the ecosystem
  - Resilience refers to the ability of an ecosystem to **recover** from a **disturbance** and return to its **original state**
- If the human disturbance is mild and the ecosystem is highly resilient, then it may be able to recover from the diversion to the process of succession and return to its original state
- However, if the disturbance is severe and the ecosystem is less resilient, the diversion may be **permanent**, leading to a new stable state with a different set of species and ecological interactions
- This is one reason why it is so important to carefully consider the environmental impacts of human activities and strive to minimise their negative effects on the ecosystem, to protect natural ecological processes, such as succession

Your notes

Worked Example

Giving a specific example of an ecosystem, discuss the human activities and factors which could disrupt the process of succession and lead to an alternative stable state in that ecosystem.

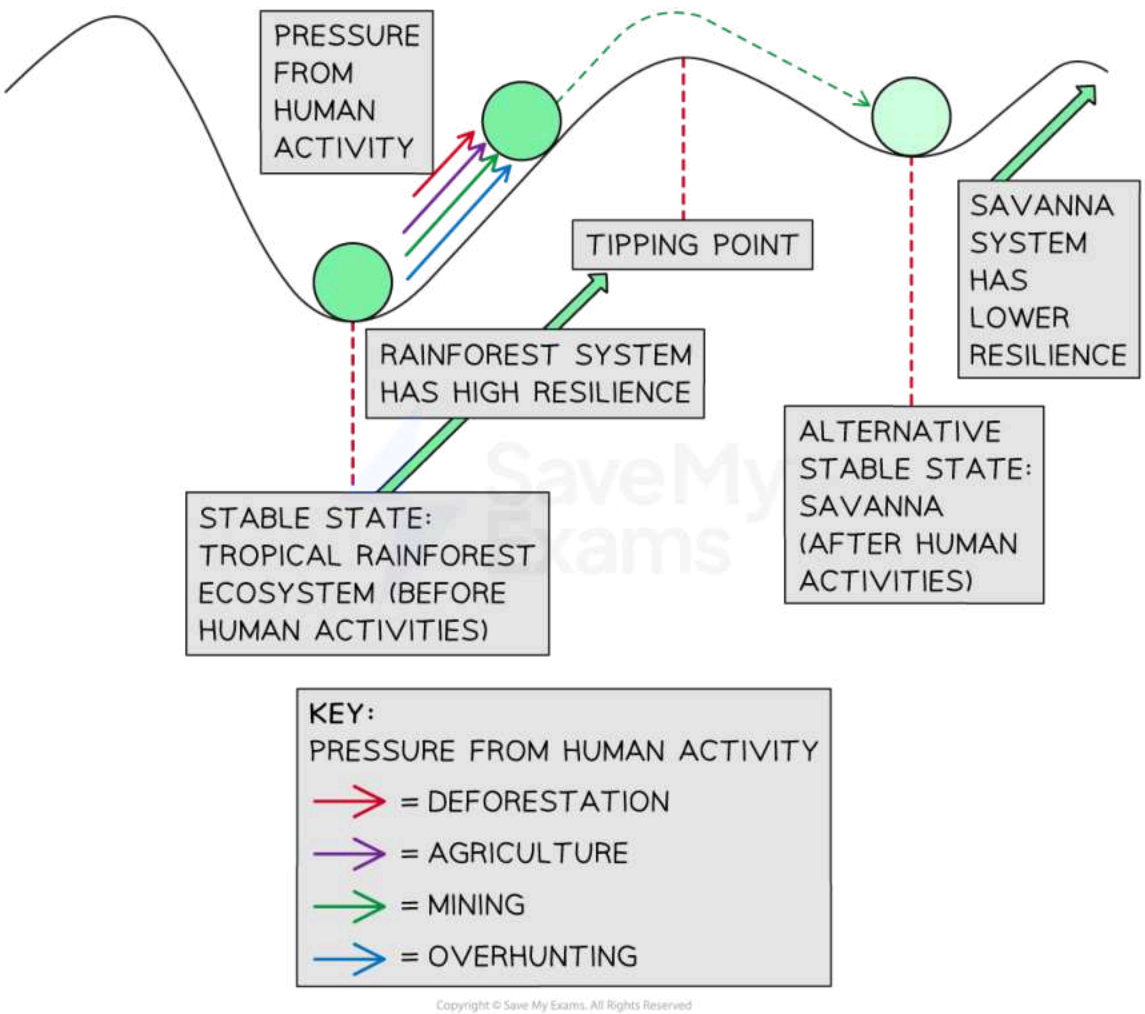
Answer

Tropical rainforests are being affected by human activities, resulting in alternative stable states. Human activities such as deforestation, mining, and agriculture can disrupt the natural progression of succession in rainforests and lead to alternative stable states.

Deforestation and agriculture is the most significant human activity that can disrupt the succession process. The removal of trees from the system to create grazing land reduces the complexity of the habitat, resulting in the loss of biodiversity, decreased nutrient cycling, and changes in the hydrological cycle. Deforestation leads to soil erosion and loss of topsoil, which can result in lower soil fertility, decreased primary productivity and can allow the process of desertification to begin.

Mining is another human activity that can disrupt the natural succession process. Mining results in the removal of topsoil and vegetation, which can lead to soil erosion and landslides. The use of chemicals in mining can also result in water pollution, which can negatively impact aquatic life within the ecosystem.

These human activities can lead to alternative stable states in the tropical rainforest. For example, deforestation can lead to the formation of savannas or grasslands instead of the original forest ecosystem. These alternative stable states have lower resilience compared to rainforests, as they have lower biodiversity, decreased productivity, and different abiotic and biotic factors compared to the original ecosystem. The ability of the rainforest ecosystem to recover depends on the resilience of the ecosystem - even naturally ecologically resilient systems like rainforests can shift to an alternative stable state given enough pressure from human activities.



Human activities can divert the process of ecological succession and push the ecosystem towards an alternative stable state