DP IB Environmental Systems & Societies (ESS): HL

Your notes

2.5 Zonation, Succession & Change in Ecosystems

Contents

Zonation

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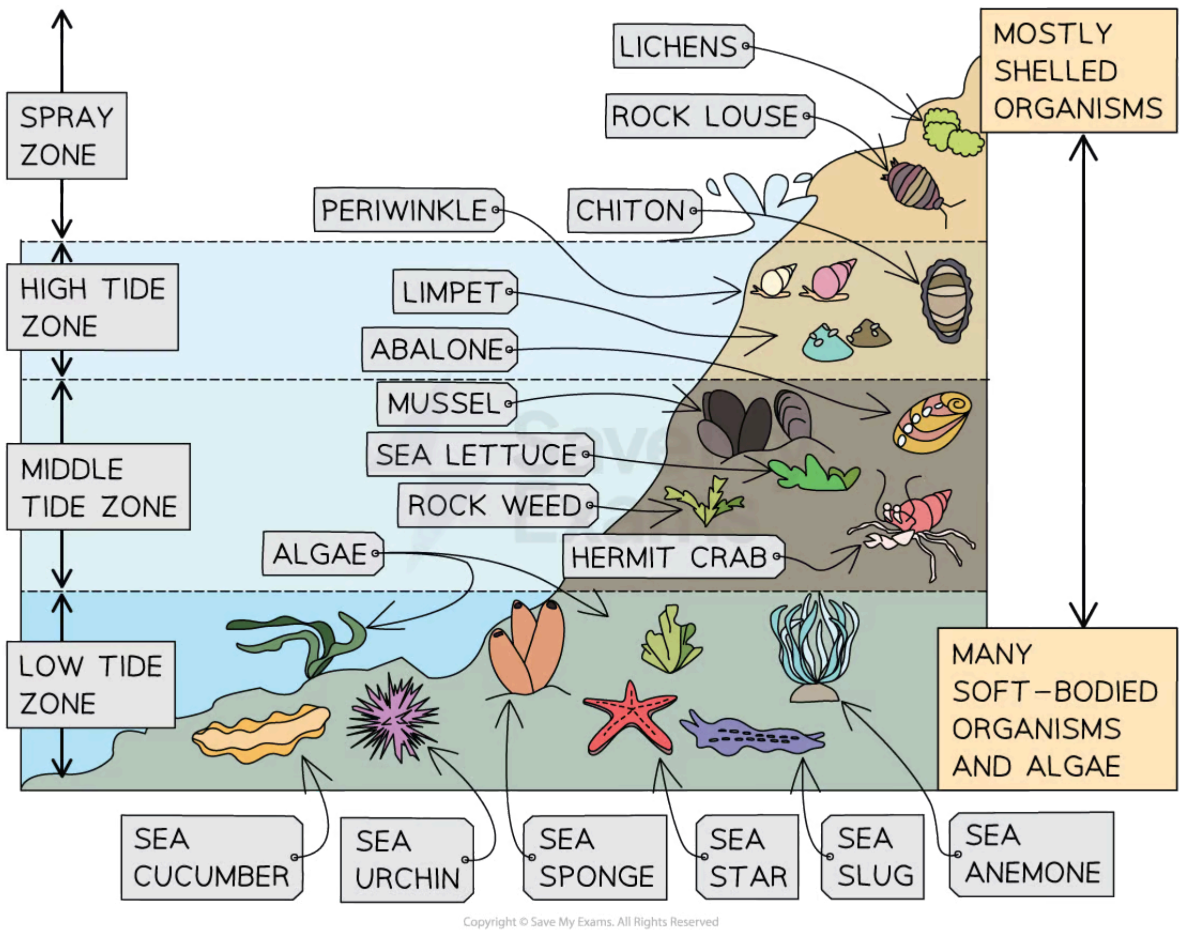
Zonation

- Zonation refers to the gradual change in the composition of species and communities across a landscape, based on a gradient of environmental factors such as:
    - Elevation (altitude)
    - Latitude
    - Tidal level
    - Soil horizons
    - Distance from water source
    - Temperature
    - Moisture
    - Light
- As these factors change, the species present in an ecosystem also change
    - This leads 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 (abiotic factors) and the biological components (biotic factors) of an ecosystem
- An example of zonation can be observed in a **rocky intertidal zone**
    - Here, 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



An example of zonation in a rocky intertidal zone

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Transects

- Transects can be used to measure biotic and abiotic factors along an environmental gradient
  - This data can be used to determine the variables that affect the distribution of a species

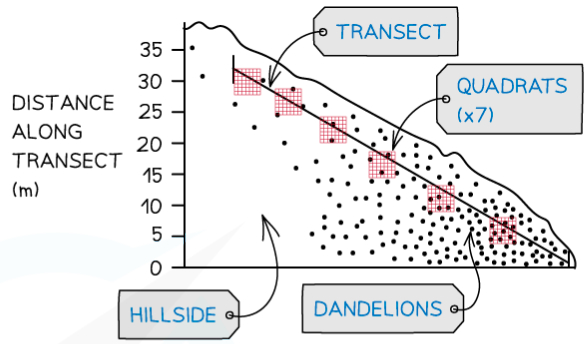
Worked Example

Investigate changes in the distribution of a species along an environmental gradient.

Your notes

INVESTIGATING THE EFFECT OF A FACTOR ON THE DISTRIBUTION OF A SPECIES METHOD

1 SET YOUR TRANSECT UP THROUGH THE AREA YOU ARE INVESTIGATING. IN THIS CASE, A 30 m TAPE MEASURE IS PLACED UP A HILLSIDE. PLACE A QUADRAT AT EQUAL INTERVALS (e.g. EVERY 5 m) ALONG THE TRANSECT.



Distance along transect (m)	Number of dandelions	Altitude (m)
0	84	2
5	66	4
10	62	6
15	45	8
20	30	10
25	30	12
30	13	14

2 RECORD THE NUMBER OF YOUR CHOSEN PLANT SPECIES INSIDE EACH QUADRAT. RECORD YOUR ABIOTIC FACTOR (e.g. ALTITUDE) AT EACH QUADRAT. RECORD YOUR RESULTS IN A TABLE.

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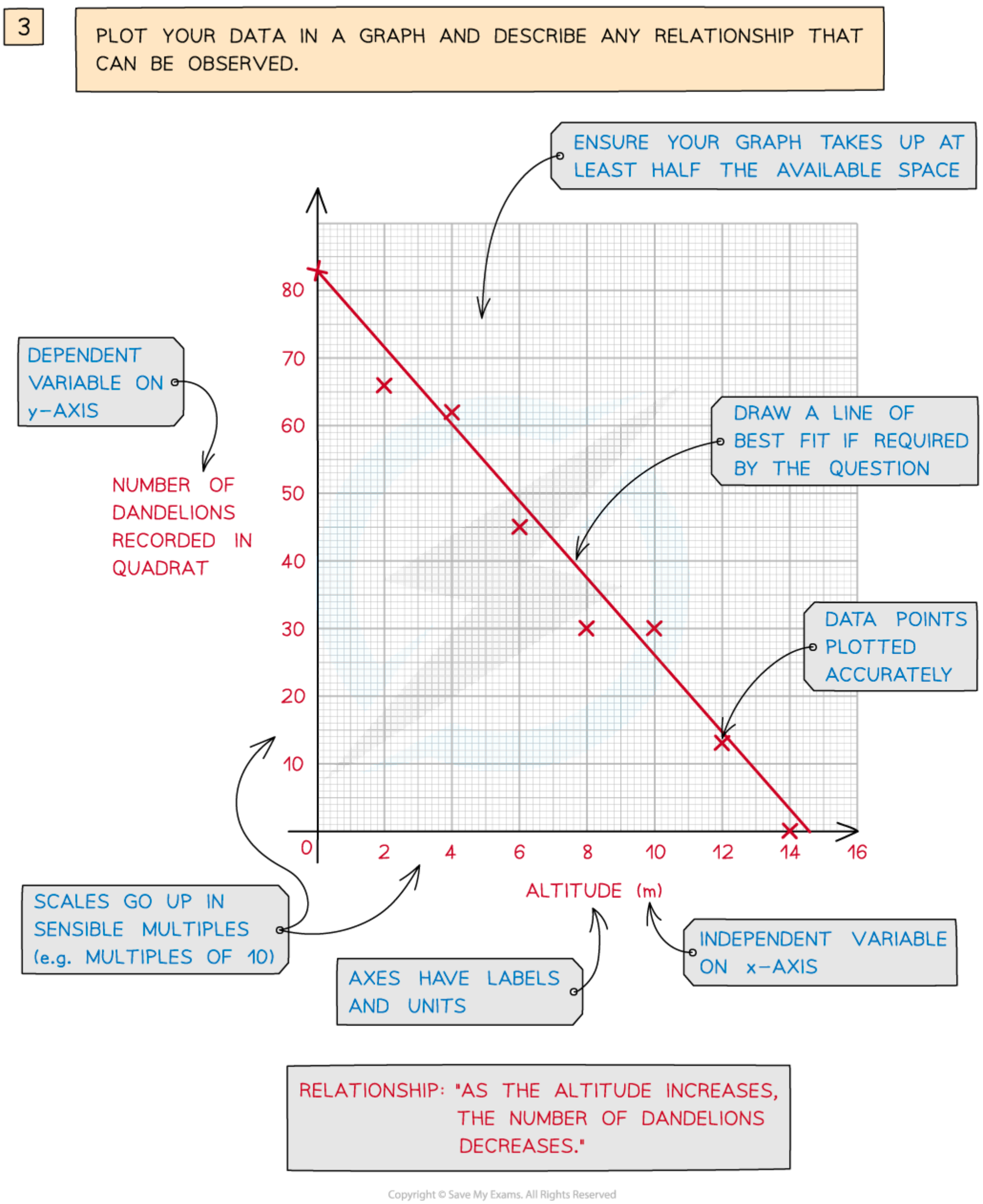


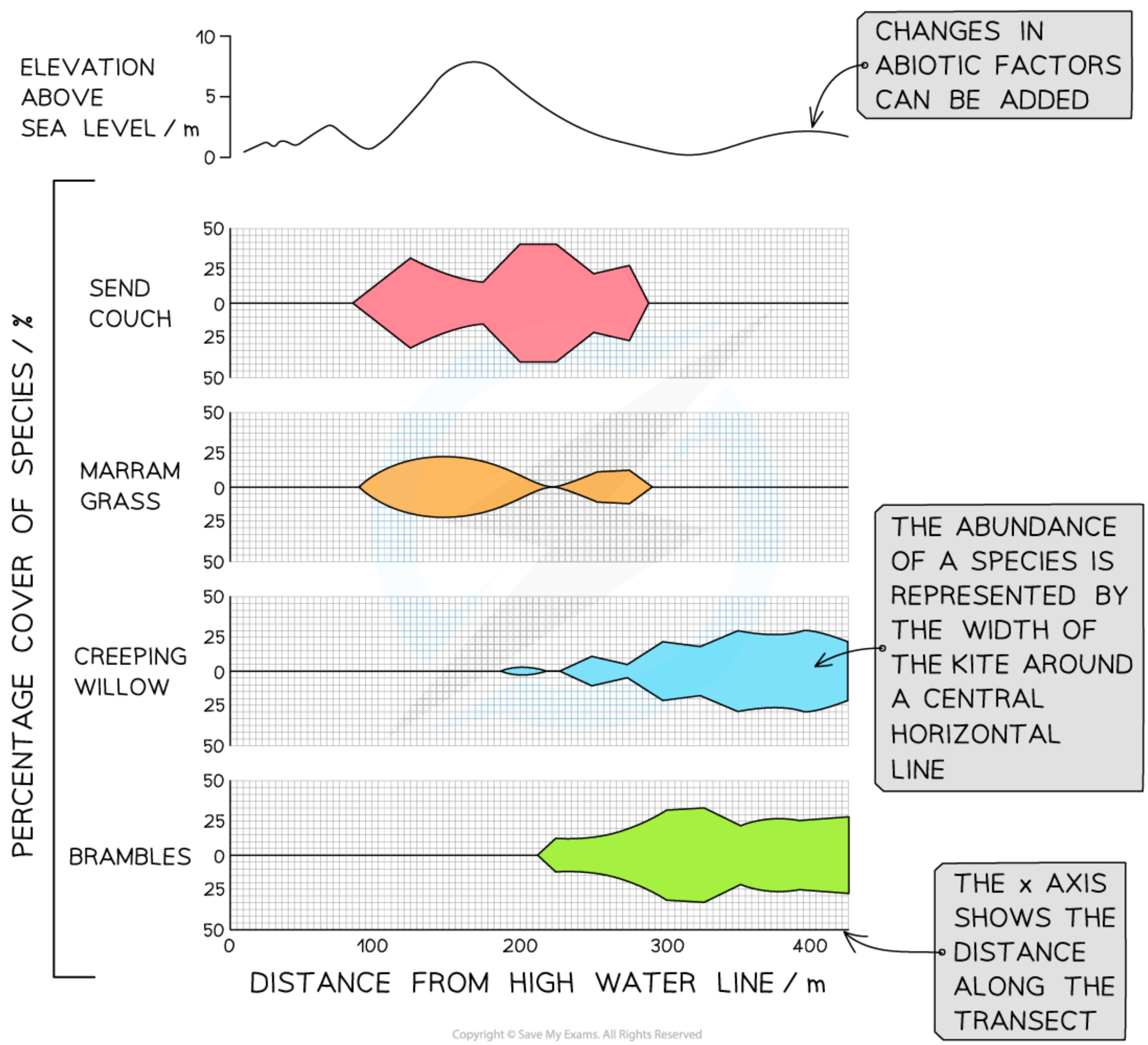
How to investigate the effect of an ecological factor on the number of plants across a survey area

Representing results

- The results of an investigation into the distribution and abundance of organisms can be represented visually using a type of graph known as a kite diagram
- Kite diagrams can show both **distribution** and **abundance**

- The distribution of a species along a transect can be shown by its position along a central horizontal line in each section of a kite diagram
- Each section represents a **different species**
- The distance along the transect is given on the x-axis, to which the horizontal line is parallel
- The abundance of a species can be shown by the **width** of the '**kite**' around the central horizontal line
- The shape is referred to as a kite because it extends an **equal distance** on each side of the central horizontal line

- Additional sections can be added to a kite diagram to show the changes in abiotic factors at different points along a transect e.g. the height above sea level or the pH of soil



Kite diagrams can be used to provide a visual representation of both abundance and distribution of species, as well as changes to abiotic factors such as elevation

Your notes

Succession

Your notes

Succession

- Ecosystems are **dynamic**, meaning that they are constantly changing
- 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**
- **Primary 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:
  - 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
  - When glaciers retreat, they also leave bare rock or moraines
- Primary succession does not only occur on bare rock—any barren terrain that is slowly being colonised by living species is undergoing 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
    - They are also able to tolerate the salty environment i.e. the high concentrations of sodium and calcium ions caused by sea spray
- **Secondary succession** is a very similar process but happens on bare soil where there has been a pre-existing community, such as:
  - An agricultural field that has stopped being used
  - A forest area after an intense forest fire

The stages of succession

- A **seral community** (also known as a **sere**) is a temporary and intermediate stage in the ecological succession of an ecosystem

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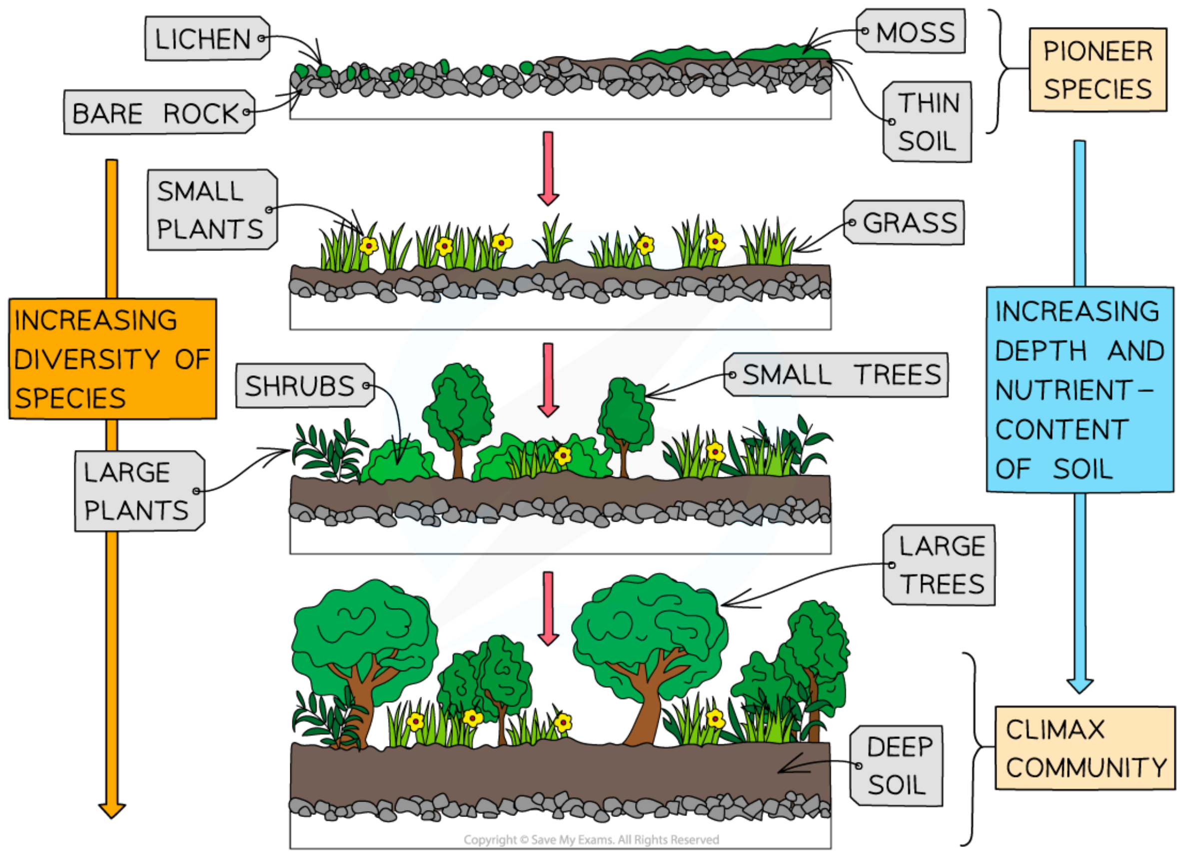
- Each seral community, in succession, causes changes in **environmental conditions**
  - These changes allow the next community to **replace it** (e.g. through competition) until a stable climax community is reached
- First, seeds and spores carried by the wind land on the exposed rock and start to 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 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**



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, species diversity and nutrient cycling that ecosystem

1. **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
2. **Productivity:**
    - During the early stages of succession, gross productivity and net productivity are low because there are only a few species present

- This means 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

3. **Species 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
    - This means more species are able to coexist within the same habitats in the ecosystem

4. **Nutrient cycling:**
    - Nutrient cycling refers to the movement of nutrients through an ecosystem
    - During the early stages of succession, nutrient cycling is relatively simple
    - This is because there are only a few species present and abiotic processes dominate nutrient cycling
    - As the ecosystem becomes more complex, nutrient cycling becomes more complex
    - This is 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 ones provided here. 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

Resilience & Stability of Ecosystems

- An ecosystem's capacity to tolerate disturbances and maintain equilibrium depends on its diversity and resilience
  - Diversity refers to the variety of species, genetic variations, habitats and ecological functions within an ecosystem
  - Resilience refers to the ability of an ecosystem to recover after a disturbance
    - High resilience = ecosystem quickly returns to its original state after disturbance
    - Low resilience = ecosystem takes a long time to recover or does not fully recover after disturbance
- Greater diversity often means greater resilience—two main reasons for this include:
  - Species redundancy:
    - Multiple species perform similar roles, so if one species is lost, others can fill its ecological role
  - Genetic variation:
    - More genetic diversity within a species can help it adapt to changing conditions

Human impacts 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
  - They lead to changes in the biotic and abiotic components, ultimately altering the course of ecological succession within the ecosystem
    - For example, controlled fires are often used to clear land for agricultural purposes or to manage the spread of wildfires

Your notes

- 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
- This can, in turn, affect the composition of the species in the ecosystem

Human activities often simplify ecosystems, rendering them unstable (Photo by Randy Fath on Unsplash)

- These activities, which divert the progression of succession, may be temporary or permanent, depending upon the resilience of the ecosystem
  - If the human disturbance is mild and the ecosystem is highly resilient, it may be able to recover and return to its original state
  - If the disturbance is severe and the ecosystem is less resilient, the ecosystem will be **permanently changed**
    - This eventually leads 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 in order to minimise their negative effects on the ecosystem
    - It is essential to protect natural ecological processes, such as succession

Your notes

Case Study

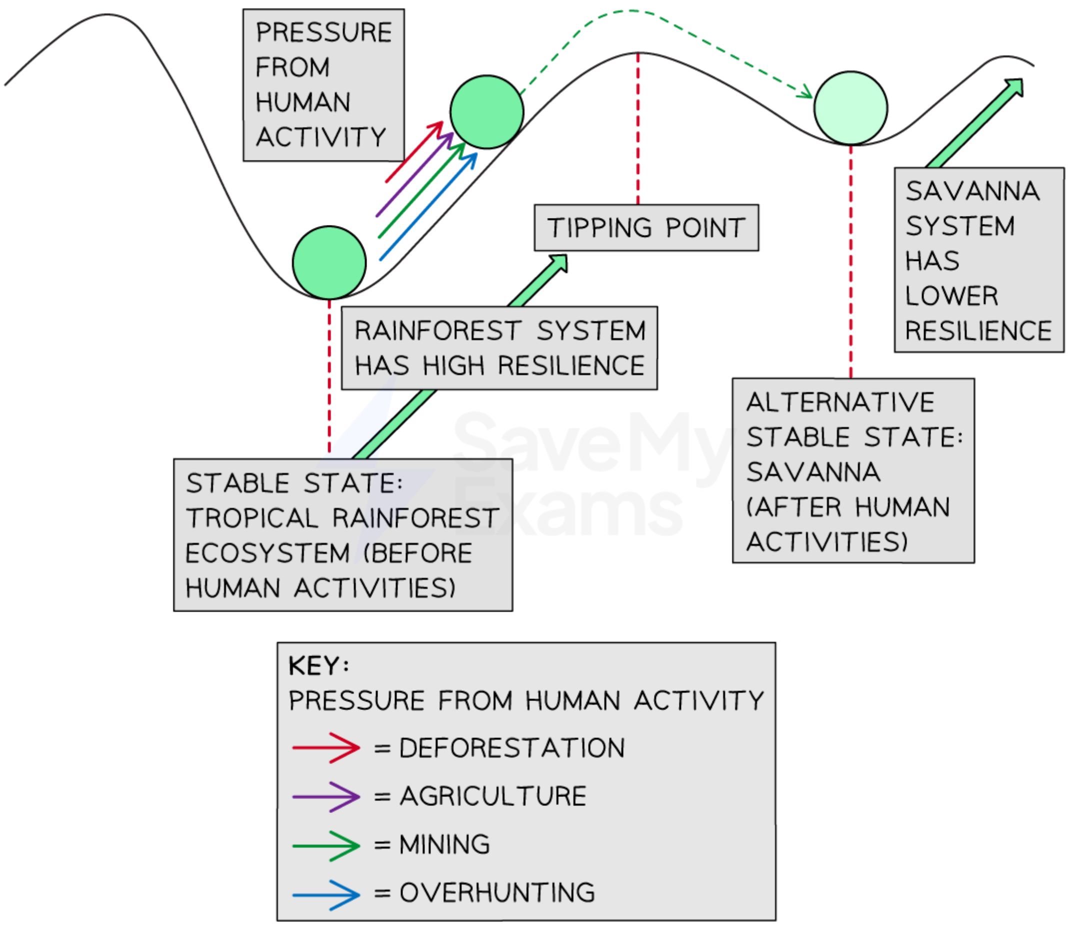
Human disturbances to succession in tropical rainforests

- Even highly resilient ecosystems like tropical rainforests can shift to alternative stable states under enough human pressure

1. **Deforestation and agriculture:**
    - Trees removed to create grazing land
    - Reduces habitat complexity and leads to biodiversity loss
    - Disrupts nutrient cycling and changes the hydrological cycle
    - Causes soil erosion and loss of topsoil, leading to lower soil fertility
    - Results in decreased primary productivity
    - Can trigger the process of desertification
2. **Mining:**
    - It involves the removal of topsoil and vegetation
    - Leads to soil erosion and landslides
    - Chemicals used in mining can pollute water sources
    - Water pollution negatively impacts aquatic life within the ecosystem.

Formation of alternative stable states

- Deforestation can transform tropical rainforests into savannas or grasslands
    - These new ecosystems are less resilient compared to rainforests
    - They have lower biodiversity and productivity
    - They have different abiotic and biotic factors from the original forest ecosystem
- These new states have lower resilience and are less capable of recovering to their original forested condition



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

Your notes

Factors Influencing Succession (HL)

Your notes

Factors Influencing Succession

- Succession refers to the gradual process by which ecosystems change and develop over time
  - Various **abiotic** and **biotic factors** influence the succession process and the type of community that forms

Climatic factors

- **Climate** plays a key role in determining the direction and speed of succession
  - Areas with **high rainfall** and **warm temperatures** generally experience faster succession, as conditions favour plant growth
  - **Cold climates** or areas with **limited rainfall** may experience slower succession due to harsh growing conditions
- **Wind** and **extreme temperatures** can impact which species are able to survive in a given area, therefore shaping the community
  - For example, in **desert ecosystems**, high winds and extreme heat can:
    - Slow down plant growth
    - Allow only drought-tolerant species to thrive

Local bedrock and soil properties

- The type of **bedrock** and **soil** in an area affect **nutrient availability** and **water retention**
  - This directly influences the plant species that can grow, for example:
    - **Sandy soils** drain quickly, favouring species that tolerate dry conditions
    - **Clay-rich soils** retain more water, favouring moisture-loving species
- **Soil pH** is another important factor
  - **Acidic soils** (such as those found over granite) support different plants compared to **alkaline soils** (such as those over limestone).
    - For example: in **calcareous grasslands** found on limestone, many species are adapted to high pH and calcium-rich conditions

Geomorphology and topography

- **Steep slopes** can restrict soil development because rainwater and gravity cause erosion
  - This makes it difficult for plants to establish and soil to accumulate
    - For example, **mountain ecosystems** often have thin soils on slopes, supporting hardy plant species like grasses and shrubs
- **Waterlogging** occurs when the land is poorly drained
  - This prevents oxygen from reaching plant roots
  - This leads to the development of **wetland ecosystems** with specialised plants like reeds, rushes, and mosses
- **Geomorphology** also includes the shape and structure of the land, which influences water flow, drainage patterns, and sunlight exposure, affecting plant growth

Fire and weather-related events

- **Fires** can significantly influence succession, creating new opportunities for different species to dominate
  - Some ecosystems, like **savannahs** or **Mediterranean scrublands**, are fire-adapted
    - They contain plants that can regrow quickly after being burned
    - Fire helps the seeds of some plant species break dormancy and germinate
    - Fires can also clear away competing vegetation and create nutrient-rich ash in which new plants can sprout and thrive
- **Storms**, **floods**, or **droughts** also shape the direction of succession by removing dominant species or altering the landscape
  - These events create conditions for new species to establish
  - For example, **hurricanes** can knock down trees in a forest, allowing light to reach the forest floor, promoting the growth of shade-intolerant species

Biotic influences (top-down effects)

- **Herbivores** and **carnivores** can have top-down effects on the community structure during succession
- **Primary consumers**, like grazing animals, can limit plant growth by consuming young plants
  - This can alter which plant species dominate the ecosystem
  - For example, in **Yellowstone National Park**, the reintroduction of **wolves** controlled **elk populations**, allowing vegetation like willow and aspen to regenerate

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- **Keystone species** (species that have a disproportionate effect on their environment) often drive changes in succession
  - For example, **elephants** in **African savannahs** knock down trees
  - This opens up space for grasses and other shrubs to thrive, maintaining the grassland ecosystem

Human impacts on succession

- **Deforestation**, **urbanisation**, and **agriculture** can halt natural succession
  - These actions convert natural landscapes to human-dominated systems
  - For example, agricultural fields are frequently disturbed, preventing natural succession from occurring, and crops are continuously planted instead of allowing a forest or grassland to regrow

Your notes

Productivity During Succession (HL)

Productivity During Succession

- **Productivity** in ecosystems is the rate at which energy is produced and stored, measured as **gross productivity (GP)** and **net productivity (NP)**
  - Gross productivity is the total amount of energy captured by producers (like plants) through photosynthesis
  - Net productivity is the energy that remains after respiration by the producers, which is available for growth and consumption by other organisms

Early stages of succession (pioneer community)

- In the early stages of succession, **gross productivity** is **low** due to:
  - **Harsh environmental conditions** (e.g. bare rock or poor soil)
  - **Low nutrient availability** (limits the growth of producers)
  - **Low density of producers**:
    - Pioneer species like mosses and lichens are the first to colonise these areas
    - There are fewer plants or algae to carry out photosynthesis
    - The conditions are not yet favourable for large-scale plant growth
- **Net productivity** is **relatively high** and **increases quickly** at this stage because:
  - Most energy produced through photosynthesis goes toward growth and biomass accumulation
  - There is less cellular respiration taking place, as the ecosystem has fewer organisms, especially consumers

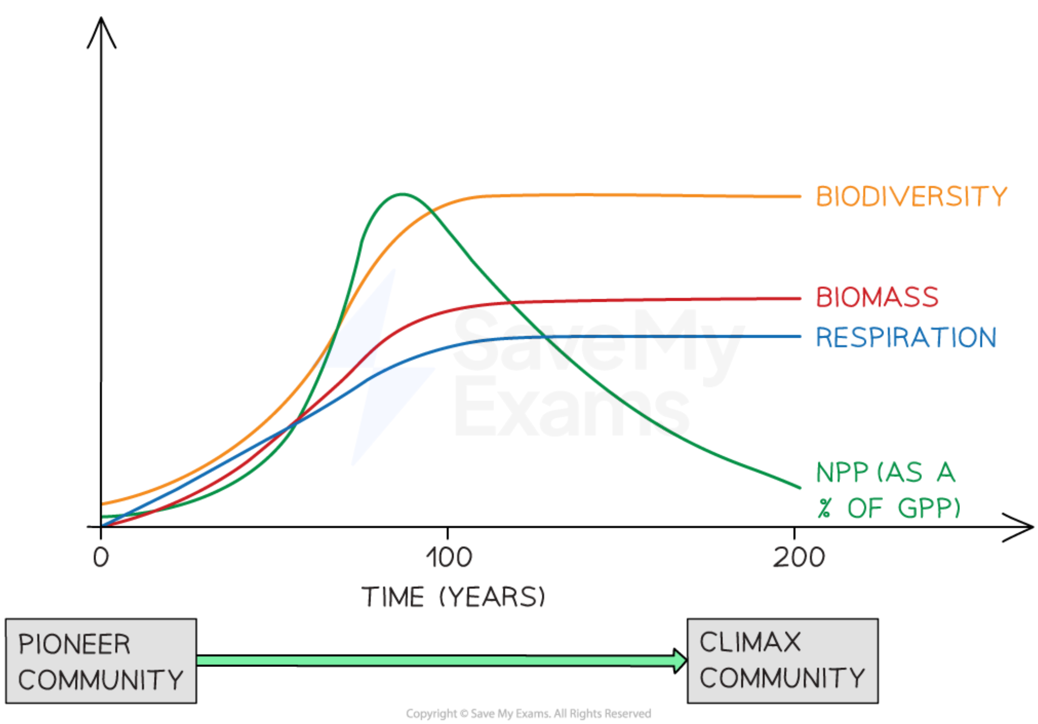
Mid-stages of succession

- As succession progresses, conditions improve:
  - **Soil formation** occurs, allowing larger plants like shrubs and trees to establish
  - More **nutrients** become available, and the number of producers increases
- Gross productivity **rises**:
  - More plants are present to carry out photosynthesis
  - Plant diversity increases, which increases the efficiency of energy capture

- Net productivity still increases but the rate of increase slows and will eventually reach a peak
- The rate of biomass accumulation **slows** because:
  - **Respiration increases** as more organisms, including herbivores and decomposers, become part of the system
  - There is more competition for resources like light, water, and nutrients, slowing the growth of new biomass

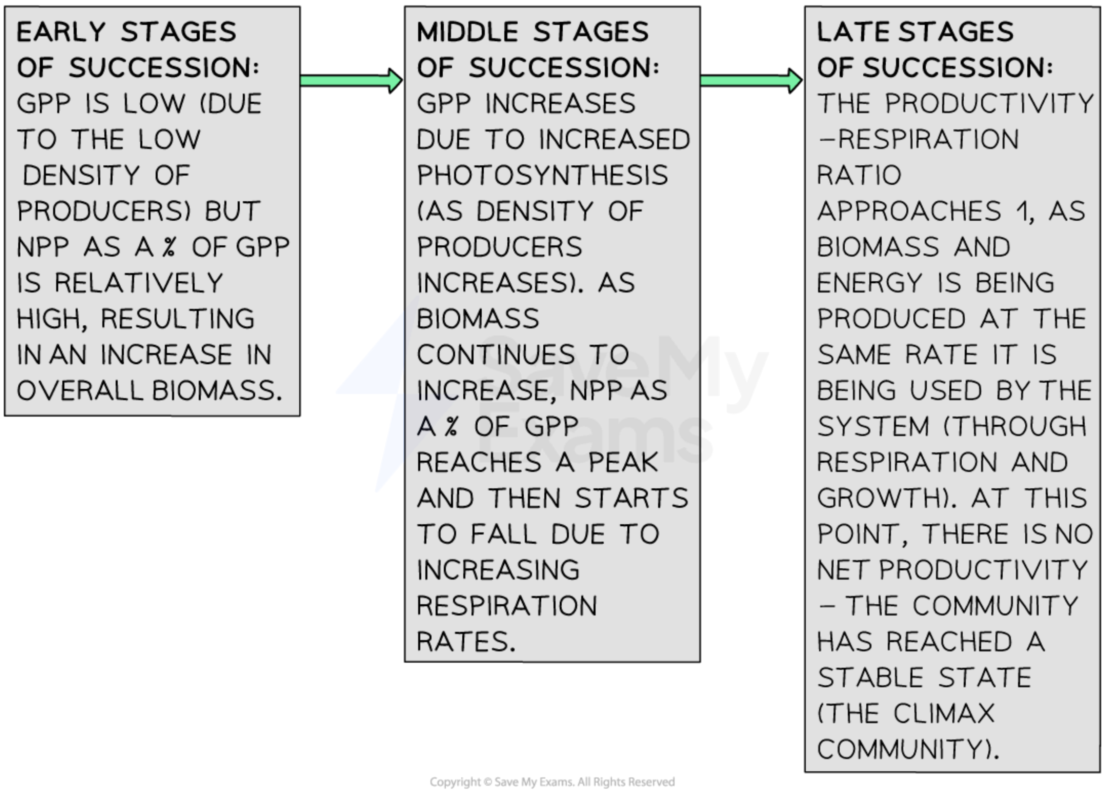
Late stages of succession (climax community)

- In the final stages of succession:
  - The ecosystem reaches a **stable state** with a mature community of species e.g. large trees in a mature forest or diverse plant species in grasslands
  - Gross productivity may be **high**, as the large number of producers continue to photosynthesise
  - However, net productivity decreases and approaches **zero** because:
    - Most of the energy produced through photosynthesis is used up by **cellular respiration** of both producers and consumers
    - Biomass no longer accumulates significantly; instead, it cycles between organisms



Your notes

Your notes



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

	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

Examiner Tips and Tricks

Don't confuse NP with biomass; NP is the **rate** of energy available for growth, while biomass is the **stored** energy.

Reproductive Strategies (HL)

Reproductive Strategies

- **r-strategist species** and **K-strategist species** have different reproductive strategies that make them suited to different ecological roles:
  - **r-strategists** thrive in unstable or early-stage ecosystems (like pioneer communities)
  - **K-strategists** are better suited to stable, long-established ecosystems (like climax communities)

r-strategist species

- **r-strategists** are species that produce large numbers of offspring quickly
  - They are adapted to **maximise reproduction** in a short amount of time, especially in environments where resources are **temporary** or **unpredictable**
- They invest **little energy** in the care of each individual offspring, meaning survival rates for each individual are **low**
- These species are often found in environments recovering from disturbances, such as areas cleared by wildfires or abandoned agricultural land
- r-strategists are particularly successful in **pioneer communities**, where they can rapidly colonise **bare** or **disturbed ground** and take advantage of the sudden availability of resources like nutrients and sunlight
  - In these environments, **competition is low**, and the conditions are favourable for rapid population growth

K-strategist species

- **K-strategists** producing **fewer offspring** but investing **more energy** into their **care** (quality over quantity)
- They typically live in **stable environments** where competition for resources is **high**, so producing fewer offspring and ensuring their survival is a better strategy
- These species usually have **longer life spans** and a **slower reproductive rate**
- K-strategists are particularly successful in **climax communities**, where ecosystems are fully developed and competition for space, nutrients, and light is intense
- K-strategists are better suited to **long-term survival** and tend to be found in environments that have reached their **carrying capacity**, meaning the ecosystem can support only a limited number of individuals

Your notes

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
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

Climax Communities (HL)

Climax Communities

What is a climax community?

- A climax community is the **final**, **stable stage** in ecological succession
  - It is a state of **equilibrium** where the ecosystem has reached its full potential in terms of species diversity and complexity
- In a climax community, populations of organisms remain relatively stable, and the ecosystem is in balance
  - The species present are **well-adapted** to the local conditions
  - **Competition** for resources, such as light, water, and nutrients, is **high**
  - Examples of climax communities include mature forests, like temperate rainforests, or savannas where large mammals dominate

Changing views on climax communities

- The traditional idea of a climax community being the ultimate stable stage of an ecosystem has been **challenged** in recent years
  - Ecosystems are **dynamic** and continually changing, which makes it difficult to define a permanent **'final' stage**
  - **Human influences** (such as agriculture, urbanisation, and pollution) affect what ecosystems may develop naturally
    - This complicates the prediction of **true climax communities**
  - Some ecologists suggest that multiple **stable states** can exist depending on the starting conditions and random events
    - These multiple states are known as **alternative stable states**

Alternative stable states

- An alternative stable state means that an ecosystem can follow **multiple pathways** and end up in different 'stable' configurations depending on the **conditions** and **random events** that influence it
  - For example, a forest ecosystem might be dominated by one type of tree in some areas and a different type of tree in others due to variations in local conditions, fire events, or animal populations

- These alternative stable states show how **ecosystems are not always predictable** and are shaped by chance events like fires or storms, which can move them from one developmental path and onto another

The Vera wood-pasture hypothesis

- The Vera wood-pasture hypothesis is a **theory** that challenges the idea of closed-canopy, forested climax communities
- It suggests that large herbivores, like **bison** or **wild cattle**, would have naturally prevented forests from completely closing by **grazing** and **creating open spaces**
  - This would have led to a landscape that was more like a **mosaic** of grasslands and woodlands
- This hypothesis suggests that **herbivores** play a larger role in shaping climax communities than previously thought
  - Without these **primary consumers**, we might not see the natural mix of trees, shrubs, and grasses that would otherwise form
  - A **local example** of this might be how **deer populations** in parts of the UK impact forest regeneration by eating young tree saplings, which alters the forest structure

Human impact on climax communities

- Human activities can **disrupt** the natural progression of ecosystems towards climax communities
  - **Deforestation**, **agriculture**, and **urbanisation** all significantly alter the environment and prevent ecosystems from reaching their natural climax stages
- This diversion of succession by human activity can lead to a **plagioclimax**
- This is where the ecosystem remains in a **semi-stable state** that is maintained artificially, e.g. through grazing or regular mowing
  - **Overgrazing by domesticated livestock**:
    - Grazing by cows or sheep can prevent forests from regenerating
    - This maintains grasslands or shrublands instead of allowing trees to grow back
  - **The removal of top predators**:
    - In areas where top carnivores like wolves or lions have been removed, prey populations (like deer or antelope) can grow unchecked
    - This overpopulation can prevent forests from regenerating as herbivores eat young plants
  - **Heathlands in the UK**:

- Historically maintained by grazing and cutting, these areas represent a plagioclimax where human intervention has prevented forests from developing

Your notes

Examiner Tips and Tricks

When discussing how factors like grazing or fires influence climax communities, make sure you explain why they impact succession. For example, include what effects they have on biodiversity, species competition, or ecosystem stability.