Oxford Resources for IB

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ENVIRONMENTAL SYSTEMS AND SOCIETIES

COURSE COMPANION

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Contents

2.5 Zonation, succession and change in ecosystems

Guiding question

- How do ecological systems change over time and over space?

Understandings

1. Zonation refers to changes in community along an environmental gradient.
2. Transects can be used to measure biotic and abiotic factors along an environmental gradient in order to determine the variables that affect the distribution of species.
3. Succession is the replacement of one community by another in an area over time due to changes in biotic and abiotic variables.
4. Each seral community (sere) in a succession causes changes in environmental conditions that allow the next community to replace it through competition until a stable climax community is reached.
5. Primary successions happen on newly formed substratum where there is no soil or pre-existing community, such as rock newly formed by volcanism, moraines revealed by retreating glaciers, wind-blown sand or water-borne silt.
6. Secondary successions happen on bare soil where there has been a pre-existing community, such as a field where agriculture has ceased or a forest after an intense firestorm.
7. Energy flow, productivity, species diversity, soil depth and nutrient cycling change over time during succession.
8. An ecosystem's capacity to tolerate disturbances and maintain equilibrium depends on its diversity and resilience.

AHL

9. The type of community that develops in a succession is influenced by climatic factors, the properties of the local bedrock and soil, geomorphology, together with fire and weather-related events that can occur. There can also be top-down influences from primary consumers or higher trophic levels.
10. Patterns of net productivity (NP) and gross productivity (GP) change over time in a community undergoing succession.
11. *r*- and *K*-strategist species have reproductive strategies that are better adapted to pioneer and climax communities, respectively.
12. The concept of a climax community has been challenged, and there is uncertainty over what ecosystems would develop naturally were there no human influences.
13. Human activity can divert and change the progression of succession leading to a plagioclimax.

Key terms

Succession is the process of change over time in an ecosystem involving pioneer, intermediate and climax communities.

Zonation is the change in community along an environmental gradient due to factors such as changes in altitude, latitude, tidal level or distance from shore, coverage by water.

Succession and zonation

Do not confuse **succession** with **zonation**.

- Succession is how an ecosystem changes over time.
- Zonation is how an ecosystem changes along an environmental gradient (e.g. a gradient in altitude, latitude, tidal level, soil, or distance from water source).

Zonation	Succession
A sequence of vegetation and organisms in space showing a gradual change in distribution.	Dynamic and temporal (takes place over long periods of time).
Caused by an abiotic gradient such as changes in elevation, latitude, tidal level, soil horizons or distance from a water source.	Caused by progressive changes through time (e.g. as vegetation colonizes bare rock).
For example, temperature decreases with increasing altitude, altering the abiotic factors and so changing the species composition.	One community changes the environmental conditions so another community can colonize the area and replace the first through competition.

▲ Table 1 Differences between zonation and succession

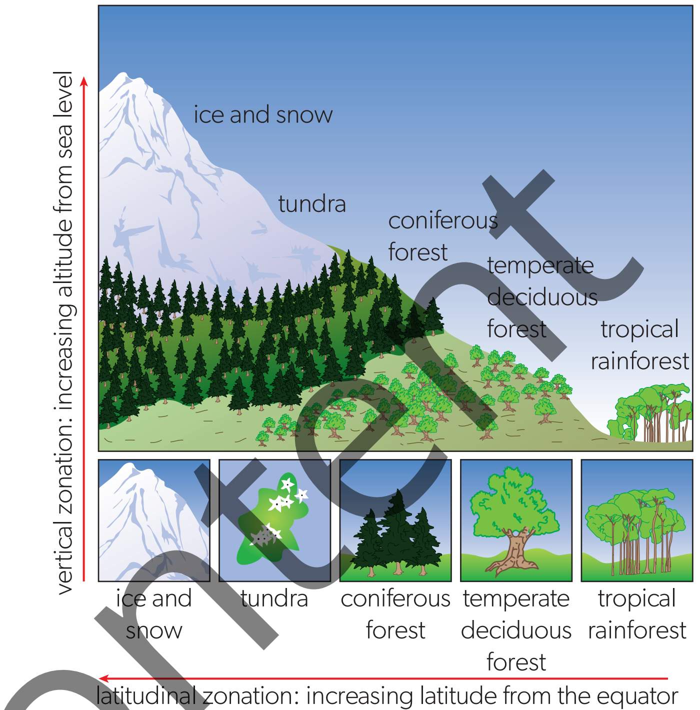
Zonation

For each species, there is an ecological niche. Each niche has boundary limits and outside these, the species cannot live. Many abiotic and biotic factors influence these limits. Here are the most important ones on mountains (Figure 1).

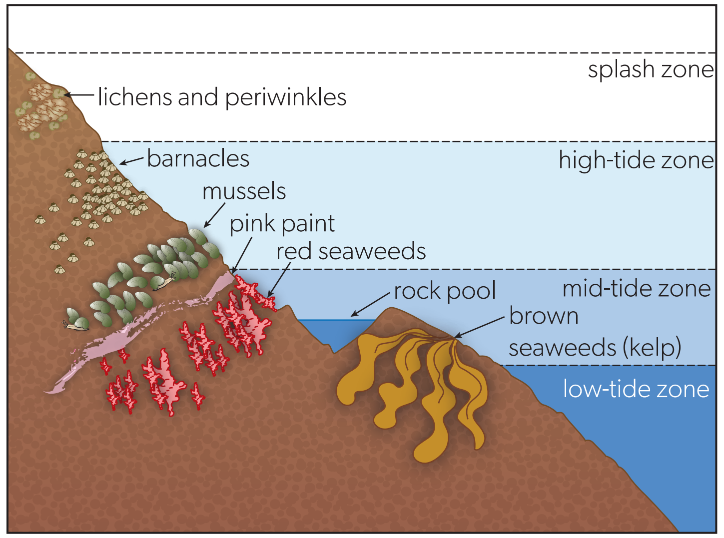
- Temperature—which decreases with increasing altitude and latitude.
- Precipitation—on mountains, most rainfall is at middle altitudes so deciduous forest grows. Higher up, the air is too dry and cold for trees.
- Solar insolation—more intense at higher altitudes so plants have to adapt, often with red pigment in their leaves to protect themselves against too much insolation.
- Soil type—in warmer zones, decomposition is faster so soils are deeper and more fertile. Higher up, decomposition is slow and soils tend to be acidic.
- Interactions between species—competition may crowd out some species and grazing may alter plant composition. Mycorrhizal fungi may be very important in allowing trees to grow in some zones.

Human activities alter zonation. For example, road building on mountains may allow tourism into previously inaccessible areas. Deforestation and agriculture change previously undisturbed areas.

Connections: This links to material covered in subtopic 2.1.

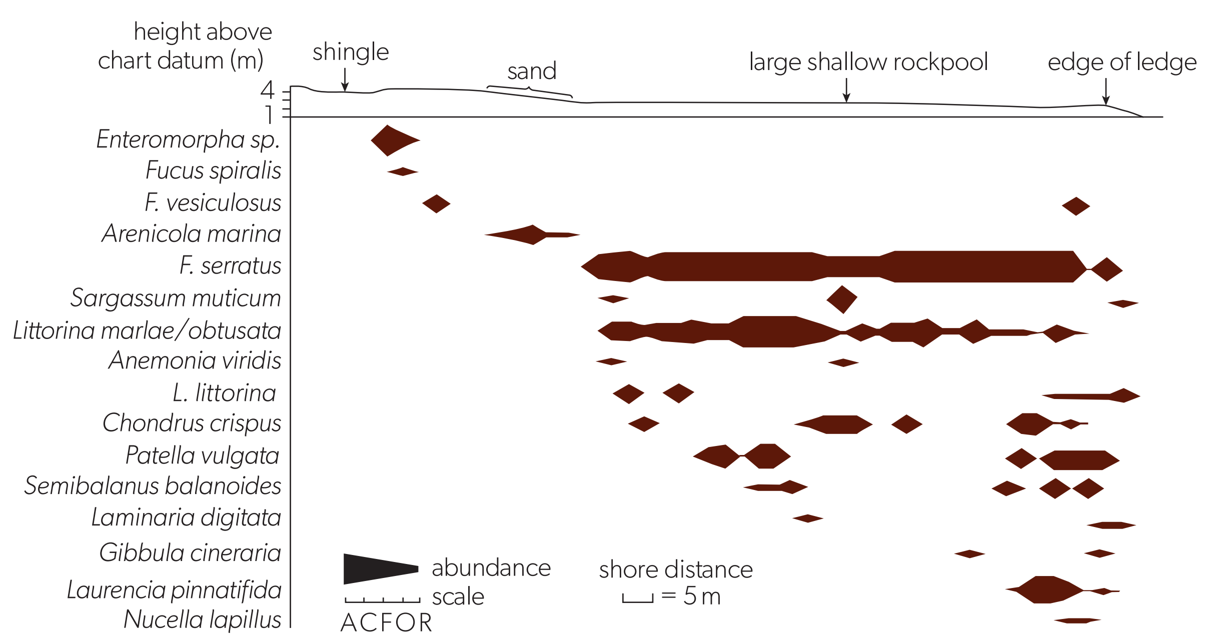


▲ Figure 1 Zonation with increasing altitude on a mountain, and with increasing latitude from the equator



▲ Figure 2 Zonation of species on a rocky shore due to increasing exposure to air higher up the shore

Graphical representation of zonation is often by a kite diagram where the width of the "kites" corresponds to the number of that species (Figure 3).



ACFOR = Abundant, Common, Frequent, Occasional, Rare

▲ Figure 3 Kite diagram showing zonation of species on a rocky shore

Succession

Succession is the replacement of one community by another in an area over time due to changes in biotic and abiotic variables. The process can take hundreds of years.

- Primary succession occurs on bare ground, where soil formation starts the process. Secondary succession occurs where soil is already formed but the vegetation has been removed (e.g. by a forest fire).
- Early in succession, in **pioneer communities**, gross primary productivity (GPP) is high and respiration is low, so net primary productivity (NPP) is high as biomass accumulates.
- In later stages, while GPP may remain high, respiration increases so NPP may approach zero and the productivity:respiration ratio (P:R) approaches 1.
- A **climax community** is reached at the end of a succession when species composition stops changing. There may be several states of a climax community depending on abiotic factors.
- The more complex the ecosystem (higher biodiversity, increasing age), the more stable it tends to be.

In agricultural systems, humans often deliberately stop succession when NPP is high and crops are harvested.

- Humans also interrupt succession by deforestation, grazing with animals or controlled burning.
- Sometimes the ecosystem recovers from this interruption and succession continues; sometimes the interruption is too great and the system is less resilient and so succession is stopped.
- Species biodiversity increases as succession continues, falling a little in a climax community. The higher the diversity, the higher the resilience.
- Mineral cycling also changes over the succession, increasing with time.
- The pollen record in peat bogs gives a record of succession of plant species.
- Each **seral community** changes the environmental conditions and this allows the next seral stage to replace it through competition.

Key terms

A **pioneer community** is the first community that grows on bare ground.

A **climax community** is one that has reached a stable stage of a limited number of species.

Seral communities are stages in succession.

Primary succession is the colonization of bare ground or rock with no existing living things.

Primary succession

Bare land occurs due to volcanic activity, moraines left by glacier retreat or when wind or water leave silt or sand on a surface. However, this land does not stay bare for long.

Plants very quickly start to colonize the bare land and, over time, an entire plant community develops. The change is directional as one community is replaced by another. This process is **primary succession**.

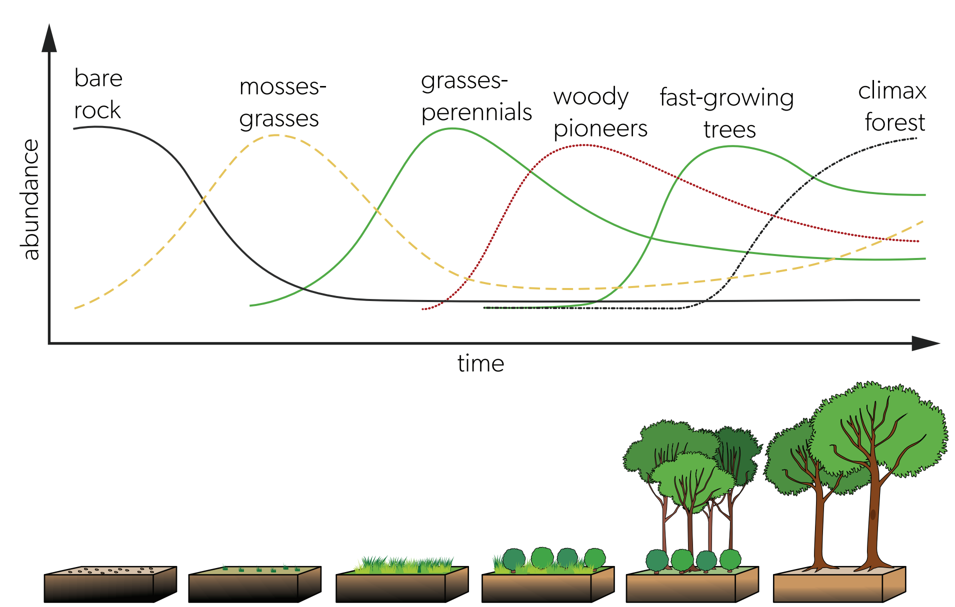
Primary succession:

- occurs on a bare inorganic surface
- involves the colonization of newly created land by organisms
- occurs as new land is either created or uncovered (e.g. river deltas, after volcanic eruptions, on sand dunes).

Table 2 and Figure 4 show the stages of primary succession.

Bare, inorganic surface ↓	A lifeless abiotic environment becomes available for colonization by pioneer plant and animal species. Soil is little more than mineral particles, nutrient-poor and with an erratic water supply.
Stage 1: Colonization ↓	First species to colonize an area—called **pioneers**—are adapted to extreme conditions. Pioneers are typically ***r*-selected species** showing small size, short life cycles, rapid growth and production of many offspring or seeds. Simple soil starts from windblown dust and mineral particles.
Stage 2: Establishment ↓	Species diversity increases. Invertebrate species begin to visit and live in the soil, increasing humus (organic material) content and water-holding capacity. Weathering enriches soil with nutrients.
Stage 3: Competition ↓	Microclimate continues to change as new species colonize. Larger plants increase cover and provide shelter, enabling ***K*-selected species** to become established. Temperatures, sunlight and wind are less extreme. Earlier pioneer *r*-species are unable to compete with *K*-species for space, nutrients or light, and are lost from the community.
Stage 4: Stabilization ↓	Fewer new species colonize as late colonizers become established, shading out early colonizers. Complex food webs develop. *K*-selected species are specialists with narrower niches. They are generally larger and less productive (slower growing) with longer life cycles and delayed reproduction.
Climax community	The final stage or **climax community** is stable and self-perpetuating. It exists in a steady-state dynamic equilibrium. The climax represents the maximum possible development that a community can reach under the prevailing environmental conditions of temperature, light and rainfall.

▲ Table 2 Stages of primary succession. Stages 2, 3 and 4 are intermediate

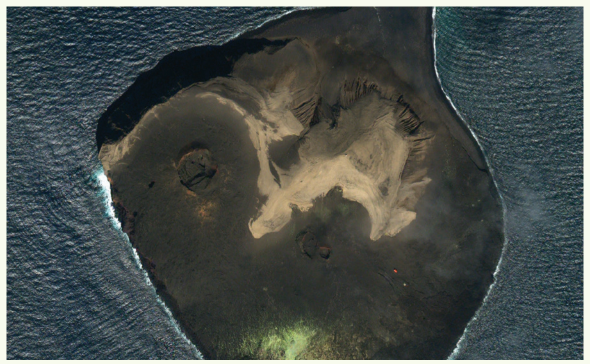


▲ Figure 4 Primary succession leading to a forest community
Adapted from: The Open University

Case study 6

Surtsey Island—an example of primary succession

Surtsey is an island about 1 km^2 in area off the southern coast of Iceland. It was formed by a volcanic eruption starting in 1963 and continuing until 1967. Its size is reducing due to wave erosion. It was declared a nature reserve and is studied as an example of primary succession on bare rock.



▲ Figure 5 Surtsey Island

There are now around 89 bird species and about 335 species of invertebrate. The flora of Surtsey now includes moss, lichens and 60 species of vascular plant.

Order of observation of living things:

- insects in 1964
- a vascular plant
- mosses and lichens
- seals breeding in 1987
- 20 species of vascular plant by 1987
- birds nesting—fulmar and guillemot first
- earthworms in 1993
- slugs, spiders, beetles in 1998
- a willow shrub in 1999
- 69 species by 2008 (compared with 460 species on mainland Iceland)
- a golden plover nesting in 2009
- about 2–5 new species each year.

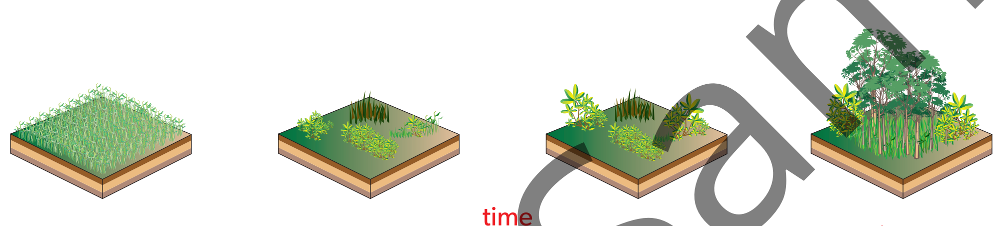
Key term

Secondary succession is a succession started by an event such as forest fire or flood when seeds that are dormant may be in the soil.

Secondary succession

Where an already established community is suddenly destroyed—for example, by fire or flood or by human activity such as ploughing or deforestation—a shortened version of succession occurs.

This **secondary succession** occurs on soils that are already developed and ready to accept seeds carried in by the wind. There may also be dormant seeds left in the soil from the previous community. This shortens the number of stages the community goes through (Figure 6).



▲ Figure 6 Stages of secondary succession in abandoned agricultural land

Examples of secondary succession have been studied in abandoned farmland in North Carolina in the USA. The farmland had become infertile because farmers did not return enough nutrients to the soil after crops had been taken, and through wind erosion. As the land became unproductive and uneconomical to farm, farmers simply abandoned the land. This process created a patchwork of former farmland that was of various ages following abandonment.

ATL Activity 23

ATL skills used: thinking, communication, social, research, self-management

Work as a class.

1. Find a local example of an area that has been cleared of vegetation. Clearance could be by fire, flooding or human activity removing vegetation—leaving either bare soil (primary succession) or an area that has been harvested, cut or thinned (secondary succession). You could clear an area yourself, with permission.
2. Map the area using an online mapping tool of your choice. Consider scale, a key to mark types of vegetation, slope, aspect and other factors.
3. Try to find satellite data (using Google Earth or an alternative mapping site), or historical data to investigate how the area has changed over time. Record the changes.
4. Return every few weeks and record what is growing. Use a suitable sampling technique. What changes do you observe? Record these changes on your mapping tool to show how succession occurs.

Species diversity in successions

In the early stages of succession, there are only a few species within the community. As the community passes through subsequent stages, the number of species increases. Very few pioneer species are ever totally replaced as succession continues. The result is increasing diversity (i.e. more species). This increase tends to continue until a balance is reached between possibilities for new species to establish and existing species to expand their range, and local extinction.

Evidence following the eruption of the Mt St Helens volcano in 1980 has provided ecologists with a natural laboratory to study succession. In the first 10 years after the eruption, species diversity increased dramatically but after 20 years very little additional increase in diversity occurred (Figure 7).[2]

▲ Figure 7 Generalized graph of species diversity over time, following Mt St Helens eruption

Disturbance

Early ideas about succession suggested that the climax community of any area was almost self-perpetuating. This is unrealistic as all communities are affected by periods of disturbance to a greater or lesser extent. Even in large forests, trees eventually age, die and fall over, leaving gaps. Other communities are affected by flood, fire, landslides, earthquakes, hurricanes and other natural hazards. All of these events create gaps that can be colonized by pioneer species within the surrounding community. This adds to both the productivity and diversity of the community (Figure 8).

[2] Carey, Susan, John Harte & Roger del Moral. 2006. Effect of community assembly and primary succession on the species-area relationship in disturbed systems. *Ecography* 29:866-872

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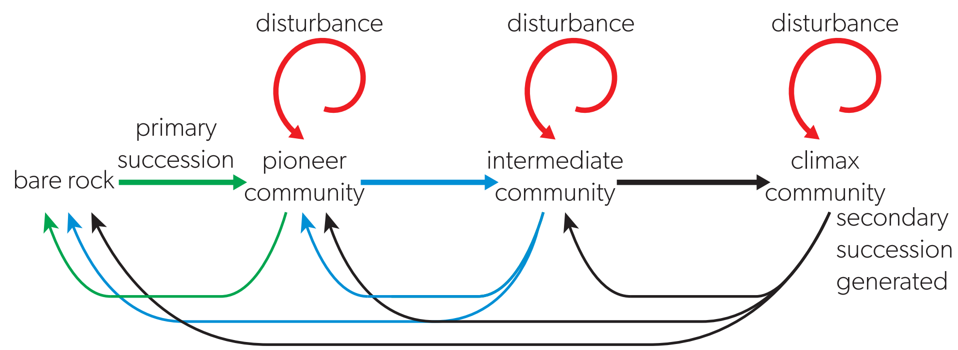


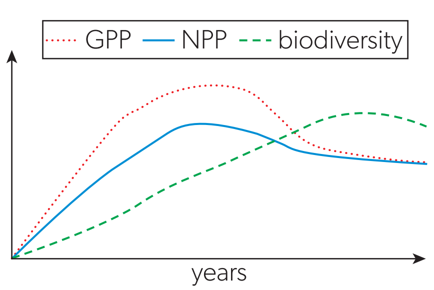
disturbance can send any seral stage back to an earlier seral stage or create gaps in a later community that then regenerate, increasing both productivity and diversity of the whole community

▲ Figure 8 Effects of disturbance in a succession

Changes in a succession

During a succession the following changes occur:

- The size of organisms increases with trees creating a more hospitable environment.
- Energy flow becomes more complex as simple food chains become complex food webs.
- Soil depth, humus, water-holding capacity, mineral content and cycling all increase.
- Biodiversity increases as more niches (lifestyle opportunities) appear and then falls as the climax community is reached (Figure 9).
- NPP and GPP rise and then fall.
- Productivity: respiration ratio falls.



▲ Figure 9 Changes in GPP, NPP and biodiversity in a succession

Factor	Pioneer	Climax
NPP	high	low
GPP	low	high
Complexity	low	high
Biodiversity	low	high
Soil depth	shallow	deep
Organism strategy	*r*-strategist	*K*-strategist
Energy flow	simple	more complex

▲ Table 3 Table of changes during succession

Primary productivity varies with time (Figure 10). When plants first colonize bare ground, it is low as there are not many plants and they are starting from a seed. It rises quickly as more plants germinate and the biomass accumulates. When a climax community is reached (stable community of plant and animal species), productivity levels off. This is because the rate at which energy is fixed by the producers is approximately equal to the rate at which energy is used in respiration and emitted as heat.

AHL

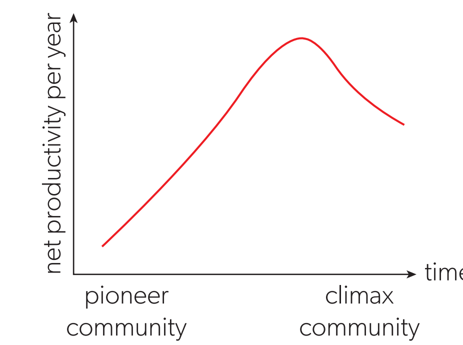
In early stages, **gross primary productivity** is low due to the initial conditions and low density of producers. The proportion of energy lost through community respiration is relatively low too, so **net productivity** is high (i.e. the system is growing and biomass is accumulating).

In later stages, with an increased producer, consumer and decomposer community, gross productivity continues to rise to a maximum in the climax community. However, this is balanced by equally high rates of respiration, particularly by decomposers. So net productivity approaches 0 and the productivity: respiration (P:R) ratio approaches 1.

During succession, GPP tends to increase through the pioneer and early stages and then decreases as the climax community reaches maturity. This increase in productivity is linked to growth and biomass.

Early stages are usually marked by rapid growth and biomass accumulation—grasses, herbs and small shrubs. GPP is low but NPP tends to be a large proportion of GPP as, with little biomass in the early stages, respiration is low. As the community develops towards woodland and biomass increases, so does productivity. But NPP as a percentage of GPP can fall as respiration rates increase with more biomass.

Studies have shown that standing crop (biomass) in succession to deciduous woodland reaches a peak within the first few centuries. Following the establishment of mature climax forest, biomass tends to fall as trees age, growth slows and an extended canopy crowds out ground cover. Also, older trees become less photosynthetically efficient and more NPP is allocated to non-photosynthetic structural biomass such as root systems (Table 4).



▲ Figure 10 Productivity changes in a succession

Early stage	Middle stage	Late stage
low GPP but high percentage NPP little increase in biomass	GPP high increased photosynthesis increases in biomass as plant forms become bigger	trees reach their maximum size ratio of NPP to R is roughly equal

▲ Table 4 Biomass accumulation and successional stage in deciduous woodland

r- and *K*-strategists

Reread the section on *r*- and *K*-strategies (in subtopic 2.1).

In pioneer communities, *r*-strategist species dominate. They produce large numbers of offspring so they can colonize new habitats quickly and make use of short-lived resources. Later in succession, *K*-strategist species produce a small number of offspring, which increases their survival rate and enables them to survive in long-term climax communities. For example, in a temperate woodland, birch trees, brambles and alder are pioneers, and oak or beech trees are long-lived climax species.

Influences on development of a community

Exactly what community develops in a succession depends on many variables:

- climatic factors
- properties of the local bedrock and soil—parent rock may lead to very acidic or alkaline soils
- geomorphology—steep slopes restrict soil development; lack of drainage leads to waterlogging
- fire and weather-related events
- presence of primary consumers or top carnivores.

TOK

What kinds of explanations do natural scientists offer?

Case study 7

Grey Wolves in Yellowstone

Yellowstone National Park in western USA was created in 1872 but wildlife was not protected. By 1926, the wolves were locally extinct. In 1995, they were reintroduced. Wolves are a **keystone species and apex predator** (see subtopic 2.1).

Once the wolves were gone, their prey species, elk, increased greatly. There were so many elk that they overgrazed the trees. The park service started trapping and moving the elk and eventually killing them. In the late 1960s, elk-killing stopped and populations rose again.

With no wolves, coyote populations also increased and they prey on pronghorn antelope.

▲ Figure 11 Grey wolf

Much debate raged around reintroducing the grey wolf. Finally in 1995, 21 wolves were captured in Alberta, Canada and taken to Yellowstone. In 2020 there were 123 wolves in the park. As expected, since 1995 elk numbers have declined.

Wolves kill 22 elk per wolf per year. Elk have changed their behaviour and moved to less hospitable areas of the park, with less food. They have produced fewer offspring.

Wolves prey on coyotes too and outcompete them for other foods. Coyote numbers have declined and they have moved to steeper slopes where wolves cannot run as fast. Both wolves and coyotes eat each other's pups.

Coyotes prey on foxes. With fewer coyotes, fox numbers have increased. Foxes prey on deer and hares, rodents and ground-nesting birds. With more foxes, there are fewer hares and young deer. Decreased populations of fox prey animals have led to changes in numbers of their food plants and insects.

Increased wolf populations have led to increased beaver populations, as elk have moved away from eating the willows which beavers rely on for winter food. More beavers build more dams, reducing run-off and erosion and creating ponds for fish habitat. Wolf carcasses provide food for scavengers such as ravens, wolverines, bald eagles and grizzly bears.

Wolves also claim kills made by cougars so the cougars have moved back up the mountains.

This is a **trophic cascade**—a series of powerful indirect interactions that can control entire ecosystems. Trophic cascades occur when predators limit the density and/or behaviour of their prey and thereby enhance survival of the next lower trophic level.

Yellowstone offered a unique opportunity to observe the effect of reintroducing a key species. It is often the loss of a key species that changes an ecosystem.

Questions

1. Draw two food webs for Yellowstone:
   a. with wolves
   b. without wolves.
2. Research the role of sea otters in kelp forest (see subtopic 2.1 and many online sources) and make short notes.
3. a. Research the role of elephants in the savanna of Africa, referring to the Global Conservation website and other sites.
   b. Research numbers of elephants on the savanna now and the change over time. There is some relevant data in Table 5.
   c. Draw a graph of your results. Think carefully about what type of scale will be appropriate.
   d. State if these elephants are on the IUCN Red List and explain why.

Year	1800	1976	1987	1989	2003	2021
Estimated population	26 million*	1.34 million*	760k*	608k*	200k–430k	~350k

▲ Table 5 Global population size of the Savanna elephant over time

These historical numbers are forest and savanna elephants combined, as they were not recognized as separate species until 2021

Climax community debate

Features of climax communities:

- high tolerance of disturbances
- moderate conditions
- high species diversity, complex food webs
- large size of organisms
- specialist niches
- NPP low, biomass and organic matter high
- low cycling of minerals and nutrient exchange.

All climax communities have these features but, in practice, a steady-state climax community is very rare. Some ecologists think it cannot exist and that there are many different possibilities for any climax community depending on the path of succession and factors influencing it.

Hypotheses

- Climate is the control—climate determines the climax community: same climate, same climax.
- Several environmental factors may dominate (e.g. slope, soil type, human interference) leading to different stable communities. Random events determine the climax community.
- All environmental factors are equally important—environmental gradients determine the community and a series of climax communities develop in parallel to each other.

AHL

Vera wood–pasture hypothesis

Historically, Europe after the last ice age was thought to be all primary forest. But the Dutch scientist Frans Vera hypothesized that the predominant ecosystem was actually semi-open wood and pasture kept open by grazing of tree seedlings by large herbivores.

This was a highly controversial hypothesis as it had been assumed that humans gradually cleared prevalent forests to grow crops and livestock.

Rewilding

Connections: This links to material covered in subtopic 3.3.

Rewilding is restoring ecosystems by allowing the natural world to restore degraded landscapes. This is not merely leaving things alone. It is providing the conditions for natural forest regeneration and reintroducing species that have been lost.

In many areas, rewilding involves large herbivores ranging fairly freely in large stretches of land, grazing among forest trees as well as in open pastures. In Europe in particular, large keystone species and top predators have been lost and rewilding involves reintroducing some of these. This is controversial as beavers, bison and wolves are being reintroduced in various sites.

Case study 8

Rewilding example

Knepp, southern England is a 1,000-hectare estate with farms that were not very profitable. Its owners decided to regenerate the land by taking out all but perimeter fences and having free-roaming pigs, deer, cattle and ponies. Since this started over 20 years ago, rare species have arrived and are breeding. Examples include nightingales, white stork, turtle doves, peregrine falcons and purple emperor butterflies. The estate faced local opposition at first because it appeared the land was overrun by weed species. However, the ecosystem established a balance of broadleaved woodland, wood pasture, rivers and streams, grassland and meadow. It still produces meat for sale and is now an educational and tourist site.

▲ Figure 12 Longhorn cattle grazing in wood pasture

Question

Visit the website of Rewilding Europe and read about some of their projects.

Choose one of these projects, or a rewilding project local to you, and write a short paragraph about its aims, challenges and successes.

AHL

Plagioclimax

Plagioclimax is an altered or reduced climax of a plant ecosystem caused by human activity. The plagioclimax may be caused by a variety of disturbances, such as:

- burning—forest clearance
- felling existing vegetation
- planting crops or trees
- grazing and trampling by livestock
- harvesting crops.

Most farmland is a plagioclimax. So are grouse moors, paths through woods and fields, coppiced woodland and anywhere humans stop a climax community forming. A particular example is sand dunes where humans trample across the dunes.

Case study 9

Sand dunes at Studland Bay

Studland Bay is on the southern coast of England in Dorset. Sand dunes have continued to be formed there since the 16th century.

▲ Figure 13 Sand dunes at Studland Bay, Dorset, UK

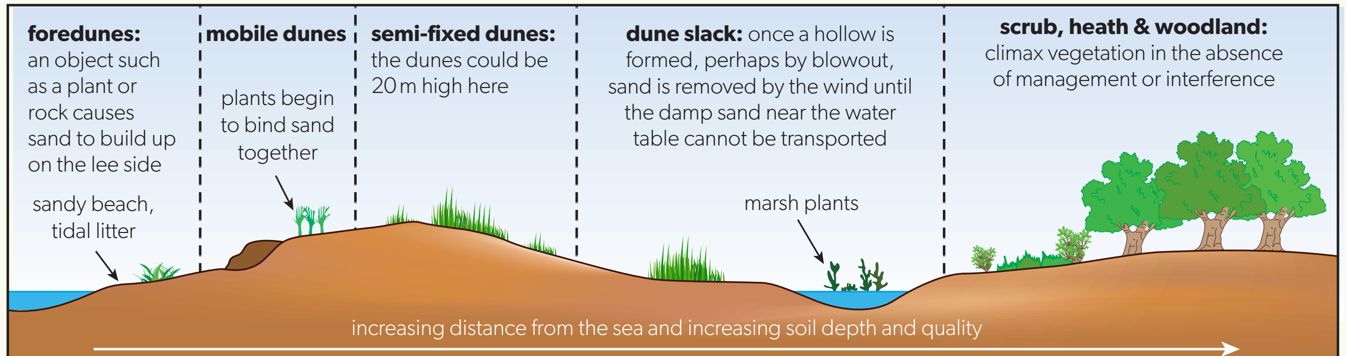
Succession begins with a bare surface of sand. Vegetation colonizes the sand. The pioneer plants tend to be low growing—why? They have fat fleshy leaves with a waxy coating and can survive being temporarily submerged.

Later, the predominant plant species is marram grass on the seaward side due to its ability to cope with the environmental conditions. Like the other grasses, it has leaves which are able to fold to reduce their surface area. The leaves are waxy to reduce transpiration and can be aligned to the wind direction. It incorporates silica into its cell structure to give the leaves extra strength and flexibility.

As a result of the humus from the previous stages, a sandy soil develops. This is able to support "pasture" grasses and bushes. Species such as hawthorn, elder, brambles and sea buckthorn (which has nitrogen-fixing root nodules so can thrive in nutrient-poor soil) are present. As the scrub develops, shorter species are shaded out.

The oldest dunes have forest. First pines and finally oak and ash woodland grow. This is the climax vegetation for the area. Henceforward, species diversity declines due to competition.

In every case, vegetation colonizes in a series of stages. The final stage is in dynamic equilibrium with its climatic environment and is known as climax vegetation for that climate. In the British Isles, this is temperate deciduous forest. As succession develops, there are increases in vegetation cover, soil depth and humus content, soil acidity, moisture content and sand stability (Figure 14).



distance from the sea (m)	0–20	20–80	80–150	150–300	300–500	500–700	(400) variable	700–2,500	2,500+
approximate age (years)	–	0–50	50–100	100–125	125–150	150–250	–	250–400	>400
soil colour	–	yellow			yellow/grey		grey	brown	
soil surface pH	8.5	8.0	7.5	7.0	6.5		6.0		4.5
% calcium carbonate	10	8	8	5	1	<0.1			
% humus	<1			2.5	5	10		20	>40
dominant plant species	sea rocket, saltwort	sand couch, lyme grass	marram, grass, sea holly	marram, sand sedge	harebell, willow	creeping willow, common sallow	birch, brambles	heather, gorse	pines, oaks

▲ Figure 14 Diagram of natural sand dune succession

Questions

1. State where the calcium carbonate is from and why it decreases.
2. In the climax vegetation of oak and pine, there are fewer species due to competition. Explain what these species are competing for.
3. Explain why the percentage of humus increases.
4. Explain what happens to the succession if these sand dunes are in a popular tourist area and many people walk across the dunes to get to the sea.

ATL Activity 24

ATL skills used: thinking, communication, research

1. Find a local example of a plagioclimax, such as:
   - farmland with either crops or livestock
   - an ecosystem where the top carnivore or keystone species has disappeared
   - a managed woodland
   - a garden or park
   - a footpath through natural vegetation.

   a. Describe the community there.

   b. Describe the community that would develop if the human activity stopped.

Check your understanding

In this subtopic, you have covered:

- zonation and succession
- primary and secondary succession
- changes during succession
- net and gross productivity
- how succession is disrupted
- how succession is influenced
- primary productivity
- different reproductive strategies
- concept of a climax community
- plagioclimaxes.

AHL

How do ecological systems change over time and over space?

1. Describe the difference between succession and zonation.
2. Explain why zonation occurs.
3. Explain why succession occurs.
4. Describe what influences the type of climax community.
5. Describe what biotic factors change during succession and why they change.
6. Explain how pioneer and climax community species differ.
7. To what extent do humans affect succession?

AHL

Taking it further

- Research what was on your school site before the school was built (or what was there before a new block was built).
- Map how the school grounds have changed over time and how much green space remains.
- Produce an infographic or poster for the school to inform others about the fieldwork in which you have participated.
- Encourage your school to improve green spaces by tree planting, leaving grass to grow or creating wetland areas.

TOK

Feeding relationships can be represented by different models. How can we decide when one model is better than another?

What role does indigenous knowledge play in passing on scientific knowledge?

When is quantitative data superior to qualitative data in giving us knowledge about the world?

Controlled laboratory experiments are often seen as the hallmark of the scientific method. To what extent is the knowledge obtained by observational natural experiment less scientific than that from a manipulated laboratory experiment?

Why do we use internationally standardized methods of ecological study when making comparisons across international boundaries?