

Natural selection What is the mechanism driving evolutionary change?	Natural selection Paradigm shift
Natural selection Why must traits be heritable for evolution to occur?	Natural selection Role of mutation in variation
Natural selection Role of sexual reproduction in variation	Natural selection Carrying capacity
Natural selection Give an example of an abiotic, density-independent selection pressure.	Natural selection Fitness

A fundamental change in the accepted theory of a field, e.g. Darwin's natural selection replacing Lamarckism.

Natural selection, operating continuously over billions of years and producing the biodiversity of life on Earth.

Mutation generates new alleles by changing the base sequence of a gene.

Only traits encoded in the base sequence of genes pass to offspring. Acquired characteristics are not encoded in genes, so are not heritable.

The maximum population size an environment can support sustainably. Limited by resources such as food, water, nest sites, light and minerals.

Generates new combinations of alleles: crossing over and random orientation in meiosis, plus random fertilisation.

The survival value and reproductive potential of a genotype compared with others.

Very high or very low temperatures, e.g. a hard frost; also drought or flooding.

Natural selection Sexual selection	Natural selection Endler's guppies: effect of a strong predator (Crenicichla)
Natural selection Endler's guppies: effect of no predator or Rivulus	Natural selection HL only Gene pool
Natural selection HL only Why do geographically isolated populations differ in allele frequencies?	Natural selection HL only Neo-Darwinism
Natural selection HL only Directional vs stabilizing vs disruptive selection	Natural selection HL only Artificial selection

Males evolved fewer spots: conspicuous males were eaten, so natural selection outweighed female preference.

Selection for traits that increase success in attracting a mate, e.g. plumage of male birds of paradise, which signals overall fitness.

All the genes and their different alleles present in a population.

Males evolved more spots, because sexual selection by female choice for colourful males dominated.

Darwin's theory of natural selection integrated with genetics: evolution as change in allele frequency in a gene pool.

No gene flow; different mutations, selection pressures and chance events, e.g. lactase-persistence alleles common in northern Europe, rare in East Asia.

Deliberate choice by humans of individuals with desirable traits for breeding, e.g. wild cabbage into broccoli and kale.

Directional favours one extreme; stabilizing favours the intermediate; disruptive favours both extremes. All change allele frequency.

Natural selection **HL only**

Is antibiotic resistance artificial selection?

Natural selection **HL only**

Hardy-Weinberg equations

Natural selection **HL only**

Hardy-Weinberg conditions

Natural selection **HL only**

What does a population not fitting Hardy-Weinberg show?

Stability and change

Give evidence that ecosystems can be stable.

Stability and change

Four requirements for ecosystem stability

Stability and change

Tipping point

Stability and change

Why does the Amazon need a large area of forest?

$p + q = 1$ and $p^2 + 2pq + q^2 = 1$. $p^2 = AA$, $2pq = Aa$, $q^2 = aa$.

No. It is an unintended consequence of human action, so it is natural selection.

At least one condition is not met, e.g. mating is non-random or survival rates vary between genotypes.

Large population, random mating, no mutation, no migration, no natural selection.

Supply of energy, recycling of nutrients, genetic diversity, climatic variables within tolerance levels.

Some have persisted for tens of millions of years, e.g. rainforest in the Daintree region of Australia and the Namib Desert (arid for at least 55 million years).

Transpiration generates water vapour, causing cooling, air flows and rainfall inland. The minimum area needed is uncertain.

A critical threshold beyond which a small change causes a large, often irreversible, shift to a different state.

Stability and change

Percentage change formula

Stability and change

Mesocosm

Stability and change

Keystone species

Stability and change

Condition for sustainable harvesting

Stability and change

How is the sustainability of cod fishing assessed?

Stability and change

Factors affecting sustainability of agriculture

Stability and change

Biochemical oxygen demand (BOD)

Stability and change

Why do fish die in eutrophication?

A small experimental ecosystem used as a model; best in sealed glass vessels so matter cannot enter or leave but energy can.

$$(\text{final} - \text{original}) \div \text{original} \times 100.$$

The rate of harvesting is lower than the rate of replacement.

A species with a disproportionate impact on community structure; removing it risks ecosystem collapse, e.g. sea otters in kelp forests.

Soil erosion, leaching of nutrients, supply of fertilizers and other inputs, pollution by agrochemicals, carbon footprint.

Stock assessments of breeding adults from catches and surveys; age structure of the catch; quotas and mesh sizes set accordingly.

Dead algae and plants are decomposed by aerobic bacteria; BOD rises, dissolved oxygen falls.

Oxygen used by microorganisms in a water sample over a set time to break down organic matter.

Stability and change

**Which fertilizers cause eutrophication
by leaching?**

Stability and change

Biomagnification

Stability and change

Effect of DDT on birds of prey

Stability and change

Mercury biomagnification

Stability and change

Why are plastics persistent?

Stability and change

Macroplastic vs microplastic effects

Stability and change

Three methods of rewilding

Stability and change

Hinewai Reserve

Increase in concentration of a toxin in the tissues of consumers at each higher trophic level.

Nitrogen (nitrate) and phosphate fertilizers.

From coal burning and mining; bacteria make methylmercury; highest in large predatory fish such as tuna; damages the nervous system.

Thin eggshells that broke, so populations of ospreys and peregrine falcons crashed.

Macroplastic: entanglement and swallowing (blocked guts). Microplastic (under 5 mm): eaten by plankton and filter feeders, passes along food chains.

They are non-biodegradable: decomposers lack enzymes to break them down.

Former farmland in New Zealand where, with grazing removed and minimal interference, native forest regenerates through gorse.

Reintroduce apex predators and keystone species; reconnect habitats over large areas; minimise human impact.

Stability and change **HL only**

Causes of ecological succession

Stability and change **HL only**

Five changes during primary succession

Stability and change **HL only**

Role of marram grass in sand dune succession

Stability and change **HL only**

Cyclical succession example

Stability and change **HL only**

Arrested succession

Stability and change **HL only**

Climax community

Climate change

Anthropogenic causes of climate change

Climate change

Five positive feedback cycles in global warming

Increases in plant size, primary production, species diversity, food web complexity and nutrient cycling.

Changes in the abiotic environment (e.g. new land) and biotic factors (organisms forming soil, shading, adding nitrogen).

Heather heathland: pioneer, building, mature and degenerate phases repeat instead of one fixed climax.

Grows up through new sand and stabilises dunes, allowing soil to form for later species.

The relatively stable community that succession tends to reach under given environmental conditions.

Human influences stop the climax community developing, e.g. grazing by farm livestock, drainage of wetlands.

CO₂ from deep ocean; loss of reflective ice; decomposition of peat and permafrost; methane from permafrost; droughts and forest fires.

Human increases in atmospheric CO₂ (fossil fuels, deforestation) and methane (livestock, rice fields, landfill).

Climate change

How does loss of snow and ice cause further warming?

Climate change

Legacy carbon

Climate change

Why could boreal forests become a net carbon source?

Climate change

Threat to emperor penguins

Climate change

Threat to walruses

Climate change

Effect of warmer surface water on upwelling

Climate change

Ocean acidification and corals

Climate change

Coral bleaching

Old organic carbon in deep boreal forest soils that survived earlier fires; burned by more intense fires.

Darker land and sea absorb more solar radiation than reflective ice.

Early breakout of landfast ice before chicks fledge destroys breeding grounds.

Warmer, less snowy winters cause drought, lower primary production, forest browning and more intense fires.

Prevents nutrient upwelling, decreasing ocean primary production and energy flow through marine food chains.

Loss of Arctic sea ice used for resting and nursing between feeding dives.

Higher water temperature makes corals expel symbiotic algae; prolonged bleaching kills corals and the reef ecosystem collapses.

More dissolved CO₂ lowers pH and carbonate availability, suppressing calcification.

Climate change

Upslope range shift example

Climate change

Range shifts in North American trees

Climate change

Why are mountain-top species at risk?

Climate change

Three approaches to carbon sequestration

Climate change

Why does peat store carbon?

Climate change

The debate over tree planting for carbon

Climate change **HL only**

Phenology

Climate change **HL only**

Two variables that cue phenological events

Range contraction at the warm southern edge and northward spread at the cool edge.

Tropical-zone montane bird species in New Guinea now live higher up mountains.

Afforestation, forest regeneration, restoration of peat-forming wetlands.

As ranges shift upslope they have nowhere higher to move.

Non-native plantations absorb CO₂ fast but have low biodiversity; native rewilding is more biodiverse and resilient.

Waterlogged soil is anaerobic, so dead plant matter decomposes very slowly and accumulates.

Photoperiod and temperature patterns.

Research into the timing of biological events, e.g. flowering, budburst, bud set, migration, nesting.

Climate change **HL only**

Chickweed and reindeer mismatch

Climate change **HL only**

Spruce bark beetle and climate change

Climate change **HL only**

Tawny owl colour variants and climate change

Warming allows two or more generations a year instead of one, causing outbreaks that kill spruce.

Chickweed growth is cued by temperature and now earlier; reindeer arrive by photoperiod, so calves miss peak food.

With less snow cover, brown owls' fitness has risen relative to grey owls, so brown has become more common.