

3.2 Origins of biodiversity

IB ESS



Learning Objectives:

- Explain that biodiversity arises from evolutionary processes
- Describe how evolution is a gradual change in the genetics of a population, achieved through natural selection
- Outline the mechanism of natural selection
- Explain how environmental change produces new challenges to species that can lead to the survival of some but not others
- Describe how new species can be formed when populations are isolated by barriers that form, such as mountains, and evolve differently
- Understand that mass extinctions have occurred because of factors such as tectonic plate movement and meteorite impact

KEY QUESTIONS:

1. What is evolution and how is it achieved?
2. How is environmental change important in the development of diversity?
3. Which events have caused mass extinctions in the geological past?

Natural selection

- Proposed mechanism that can lead to the formation of new species
 - Pushes evolutionary change over many generations
 - Evolution - gradual change in genetic characteristics of a population
 - Increases diversity of species
 - As changes occur in environment, species (as a whole...NOT as an individual) must adapt and change if they are to survive
 - Speciation - formation of new species from an original population so that the new species cannot interbreed with the original species
 - Reproductively isolated from original species
 - Key mechanism = natural selection (proposed by Charles Darwin & Alfred Wallace in 1859 book *On the Origin of Species*)

Not all offspring survive...

- Living things produce more offspring than are needed to replace themselves when they die
 - Yet, we do not see vast overpopulation in most natural situations
 - Trees produce 1000s of seeds
 - Fish produce 100s of eggs
- Why don't we see more population explosions??

Why don't we see more population explosions??

- Genetic variation between offspring
 - Not all members of species are the same
 - Some birds have brighter plumage than their siblings
 - Some howler monkeys may call more loudly than others
 - Some deer may be stronger than others
- Individuals compete for resources (food, water, mates & nesting sites)
 - Not every individual gets the resources they need
 - 'Struggle for survival' or 'survival of the fittest'
 - Fitness doesn't only mean physical strength, it also includes behavior & appearance
 - Loudest monkey can establish larger territory
 - Stronger deer can fight off its rivals and mate with more females
 - Well-camouflaged mouse may hide better from danger

Why don't we see more population explosions??

- Individuals that survive are those with best adaptations to their environments
 - Go on to produce the next generation
- Offspring inherit genes which give them their parents' successful characteristics

How does it work?

- Overproduction of young + variation + competition + reproduction of individuals = gradual change in a population or species over a long period of time
- Survival characteristics are passed on, and over many generations accumulate so more & more individuals in pop have the favorable characteristics
 - Individuals with unfavorable characteristics die out
 - Some neutral variations make no difference to survival
- Characteristics are passed down from 1 generation to next
 - Proportion of favorable genes in whole pop will increase
 - Gene pool of pop is changed & changes ultimately lead to formation of new species

Artificial selection

- Animal breeding & agriculture
 - Farmers selected their best animals with characteristics they required to produce the next generation
 - People have domesticated & bred plants & animals for 1000s of years...can see the changes that have occurred
 - Modern varieties of wheat = shorter & stronger than varieties 100 yrs ago
 - Lots of differences from the wild grasses that came before them
 - Modern breed of cattle & sheep = produce more milk & better quality wool than in the past

Isolation & formation of new species

- Isolated populations may change so much over time they become unable to breed with original population to produce fertile offspring = new species!
- Increase biodiversity of region
- Isolation by...
 - Geographic barrier
 - Behavioral isolation
 - Genetic isolation
 - Reproductive factors

Geographical isolation

- Occurs when 2 pops of same species separated by a physical barrier (i.e. mountain range or large lake)
 - 2 populations can't interbreed (can't get to each other)
 - Natural selective pressures due to varying environments allow gradual physical or behavioral variations to develop
 - Eventually even if they were to come into contact, it would be physically impossible to breed to produce viable offspring

Geographical isolation

- EXAMPLE: freshwater char (*Salvelinus*) fish in lakes in Switzerland, Scandinavia & the UK
 - Every lake contains different species of them
 - Pops separated by land (barrier)
 - At one time, species of fish could interbreed
 - Millions of years of movements of land & formation of barriers make it impossible now
- EXAMPLE: spotted owl species on west coast of North America
 - 2 subspecies - northern spotted owl & Mexican spotted owl
 - Live in different regions separated from each other
 - Have genetic & morphological differences

Reproductive isolation

- Behavioral differences lead to reproductive separation
- **Timing**
 - Crucial factor for successful reproduction
 - Timing of breeding of 2 separate populations could not be synchronized
 - 1 pop of plants matures earlier than another (pollen unlikely to come into contact with flowers of other) ...little chance to produce offspring together
 - EX. pine trees (*Pinus radiata* & *Pinus muricata*) grow together in California
 - *P. radiata* sheds pollen in early Feb, while *P. muricata* is April
 - Reproductively isolated...no longer interbreed
 - EX. breeding cycles of *Gryllus pennsylvanicus* & *Gryllus veletis*
 - *G. pennsylvanicus* matures in autumn, while *G. veletis* matures in spring
 - Reproductively isolated...no longer interbreed

Reproductive isolation

- **Behavior**

- Male & female animals fail to mate due to differences in behavior
- Elaborate courtship behaviors & calls
 - If females of one pop do not respond those by another pop, mating doesn't take place
 - Genes will not be exchanged ...larger genetic differences develop & accumulate
 - After a period of time a new species may develop
 - EX. eastern tarsiers living in Tangkoko Japan...very different mating calls
 - Males & females only respond to calls from same species

Reproductive isolation

- **Other causes**

- **Differences in anatomy**

- Males & females cannot physically mate
- EX. chihuahuas and Great Pyreneean hounds so different in size, mating impossible
 - Can be bred by artificial selection

- **Failure of offspring to survive**

- 2 species do interbreed, but offspring fail to survive long enough to breed
- EX. 2 species of Gryllus cricket do occasionally interbreed, but offspring weak & quickly die

Plate tectonics

- Arrangement & distribution of continents has changed as plate tectonics of the Earth have moved over geological time
 - Caused physical barriers & land bridges
 - Separated species
 - Led to climate change
 - Contributed to evolution

Plate tectonics

- 4 distinct Earth layers
 - Inner core - solid, hot center made of iron & nickel
 - Outer core - surrounds inner core, made of liquid iron & nickel of temps of 5000°C
 - Mantle - surround outer core, semi-molten rock (magma). Upper areas hard rock, deep is softer
 - Crust - outermost layer, relatively thin (60 km thick). Continental crust = rock layer we live on, oceanic crust = bed of ocean
- Crust + mantle = lithosphere
 - Floats & moves on the semi-molten magma beneath it
 - Divided into 8 major & several minor tectonic plates
 - Move 50-100 mm/yr (called continental drift)

Plate tectonics

- **Plate tectonics** - theory that the Earth's outer covering is divided into several plates that move over the rocky inner layer above the core
 - Over millions of years...plates collided, slid against one another & overlapped
 - Junction of plates...mountains, earthquakes & volcanoes (evidence of their movement)
 - Slide past one another
 - Fault lines (San Andreas fault in California)
 - Diverging
 - Ridge forms (mid-Atlantic ridge)
 - Volcanic eruptions occur along this & lead to formation of new islands (Surtsey & Iceland)
 - Magma wells up through rifts along ridge
 - New island provide new habitats for colonizing species

Plate tectonics

- Converging plates
 - Continental crust squashed & forced upwards
 - Creates fold mountains as plates crumple & fold under enormous pressure
 - Himalayas & Alps
- Subduction
 - One plate slides under another
 - Known for volcanoes, earthquakes & mountain building
 - Oceanic plates denser than continental plates...ocean plate will go under
 - Ocean plate melts to form magma, earthquakes triggered
 - Magma rises up through cracks as pressure builds up
 - Along area above subduction zone
 - Volcanoes exist in long chains (called volcanic arcs)
 - Extremely explosive (Krakatau, Nevado del Ruiz, Mount Vesuvius)
 - Arcs of islands created in a similar way
 - Aleutians, Japan & the Philippines
 - New island = new habitats for pioneer species

Formation of modern continents

- 250 million years ago...
 - Pangea existed (1 supercontinent)
- 175 million years ago...
 - Pangea split into 2 new continents (Laurasia & Gondwanaland)
 - Laurasia became North America, Europe, Asia & Greenland
 - Gondwanaland became India, Africa, Australia, Antarctica & South America
- 130 million years ago...
 - Continents began to break up & move toward their present-day locations

Formation of modern continents

- Displacement & rearrangement of land masses helped create biological diversity on our planet
 - Separated different groups of organisms from one another
 - Understanding of continental drift helped us understand the fossil record & speciation
- Gondwanaland = home to many types of mammal (i.e. marsupials & placental groups)
 - When split to form South America & Australia these 2 very different types of mammals developed
 - Pouched marsupials thrived in Australia, but most died out in South America
 - In Australia, they developed into modern-day kangaroos, koalas, wallabies & wombats
 - In South America, the only marsupial is the opossum (placental mammals outcompeted the others and came to dominate the new continent)

Formation of modern continents

- Physical separation of marsupials led to
 - Genetic differences
 - Anatomical differences
 - Speciation
- Australia also contains unique plants like eucalyptus & unusual egg-laying monotreme mammals like the duck-billed platypus & echidna (found nowhere else on Earth)
- Island of Madagascar (separated from African mainland millions of years ago) is the only place where lemurs live.
 - Many species of lemurs have evolved ...fill niches occupied by different species in other parts of the world

Formation of modern continents

- Large flightless birds
 - Emus, rheas, ostriches & cassowaries only found on continents once part of Gondwanaland
 - Although each group of birds are found on different continents, the groups are not closely related
 - Groups were separated as continents separated & have evolved to become completely different species
 - These birds cannot fly (can't interbreed)

Formation of modern continents

- Land bridges
 - Link places that were previously separated
 - Give mobile animals a chance to colonize new habitats
 - Isthmus of Panama - land bridge formed between North & South America 4 million years ago (relatively recently)
 - Allows bears to move from North to South America
 - Cut off gene flow between groups of aquatic animals (separated Pacific & Atlantic Oceans)
 - Bering land bridge
 - Connected Asia and North America as sea levels fell during the last Ice Age
 - Sinai Peninsula
 - Links Africa to Europe & Asia

Mass extinctions

- Periods in Earth's history when very large #s of species die out simultaneously or within a short time
 - Most severe = end of Permian period (250 million y.a.)
 - 96% of all species wiped out
 - Today there are 12 million different species present on Earth...represents about 1% of total # of species that lived prior to this mass extinction!
 - What causes these?
 - Movements of continents
 - Huge volcanic eruptions
 - Drought
 - Ice ages
 - Impact of huge meteorites
 - Have mass changes in climate or physical features of Earth
 - Destroy species, present new challenges to survivors & lead to new evolutionary paths
 - Increase in biodiversity = long-term consequence of mass extinctions

Causes of mass extinctions

- Average time between mass extinctions = 100 million years
- Paleontologists recorded 5 mass extinction events throughout Earth's history
- 430 MYA (end of Ordovician period)
 - 1st great mass extinction
 - According to fossil record, 25% of all families of both terrestrial & marine life died
 - CAUSE: Drop in sea level as glaciers formed
- 360 MYA (Late Devonian period)
 - 2nd mass extinction
 - CAUSE: not known
 - 19% of all families became extinct
- 250 MYA (end of Permian era)
 - 3rd mass extinction
 - 54% of all families from warm shallow seas (95% of all marine species) extinct
 - CAUSE: uncertain, but could be from asteroid impact, volcanic material escaping from Siberian Traps (now eastern Russia)
 - Plants & plankton destroyed as huge releases of carbon dioxide (reduced oxygen levels in the sea) ...took 20-30 million years for coral reefs to re-establish & forests to grow

Causes of mass extinctions

- 200 MYA (End Triassic extinction)
 - 23% of all families (50% all marine invertebrates, 80% of all land quadrupeds)
 - Oddly, plant species were not so affected
 - LIKELY CAUSE: flood-like lava escaping from a volcano in Atlantic Ocean
- 65 MYA (Cretaceous-Tertiary mass extinction)
 - Extinction of dinosaurs
 - Virtually no large land animal survived
 - Plants greatly affected
 - 50% of marine life wiped out
 - Sea levels over 300 m higher than now
 - Oceans flooded up to 40% of continents
 - LIKELY CAUSE: asteroid or comet colliding with Earth in sea near Yucatan peninsula in Mexico

Human activities - 6th mass extinction

- Species unable to adapt to speed of changes on Earth due to human activities
- 2 main reasons:
 - The way humans have spread & occupied territories throughout Earth
 - Development of agriculture in last 10,000 years
- Human pop growing at exponential rate
 - More people = more land need = more species exploited
 - Species do not have a chance to move to new areas
 - Pollution & climate change add to destruction of ecosystems
- International Union for Conservation of Nature (IUCN) - organization dedicated to nature conservation
 - Assessed species most at risk (based on data relating to critically endangered, endangered, & vulnerable species)
 - Estimations are 30% of reptiles seriously under threat
 - Many smaller invertebrates may become extinct before discovered & given names