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PPT Slides 01 TO 180

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Merged File date 08/07/2021

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Paleontology as a science

Topic No.1

Paleontology in the modern world

Paleontology as a science

What is Paleontology?

- **The branch of science concerned with fossil animals and plants.**
- **the study of fossils to determine organisms'**

Paleontology as a science

What is Paleontology?

- **Originates from Greek “palaios-old”, “ontos-creature" “logos-study"**
- **Paleontology lies on the border between Biology and**

Paleontology as a science

Use of Paleontology?

1. **Origin of life**
2. **Curiosity about different worlds**
3. **Climate and biodiversity change**
4. **The shape of**

Paleontology as a science

Use of Paleontology?

5. **Extinction.**
6. **Dating rocks.**

END

Paleontology as a science

Topic 2

What is science?

Paleontology as a science

What is science?

- **Science is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the**

Paleontology as a science

What is science?

- **From Latin scientia, meaning "knowledge"**
- **Science is supposed to be about reality, about hard facts, calculations and**

Paleontology as a science

What is science?

- **In mathematics, and many areas of physics, this might be true.**
- **In natural sciences, there have been two main approaches**

1. **Induction**
2. **deduction**

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Induction

- **Sir Francis Bacon**
- **The enquirer might hope to see common patterns among the observations, and these common patterns would**

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Deduction

- **Aristotle**
- **A series of observations point to an inevitable Outcome**
- **“All *men are mortal. Socrates is a man. Therefore Socrates is mortal.*”**

Paleontology as a science

Hypotheticodeductive method

- **Karl Popper**
- **"Proof is impossible"**
- **Scientists set up the hypotheses**
- **hypothesis testing;**
- **They seek to refute, or disprove**

Paleontology as a science

Paradigm shifts

- **Thomas Kuhn**
- **science shuttles between so-called times of normal science and times of scientific revolution.**
- **Scientific revolutions, or paradigm shifts, are when a whole new idea invades**

Paleontology as a science

An Example of Paradigm shift

- **The paper by Luis Alvarez and colleagues (1980)**
- **The Earth had been hit by a meteorite 65 million years ago,**
- **Caused the extinction of the**

Paleontology as a science

A good Hypothesis

1. **hypotheses should be sensible and testable**
2. **Speculation vs. "Informed deduction"**
3. **Should be based on observable facts, not the**

Paleontology as a science

Paleontology rendition in Popular culture

- **Jurassic Park and Walking with Dinosaurs**
- **The slow evolution of reconstructions of ancient life over the centuries reflects the growth of**

Paleontology as a science

Topic 3

Steps to understanding Paleontology

Paleontology as a science

STEPS TO UNDERSTANDING

1. **Earliest fossil finds**
2. **Fossils as magical stones.**
3. **Fossils as fossils**
4. **The idea of extinction**
5. **The vastness of geological time**

Paleontology as a science

Earliest fossil finds

- **Prehistoric**
- **peoples picked up and used them as Ornaments**
- **Early Greeks, Xenophanes (576–480 bce) and Herodotus(484–426)**

Paleontology as a science

Fossils as magical stones

- **Roman and medieval times**
- **Fossil sharks' teeth were known as *glossopetrae* worn as amulets**
- **The idea of *vis plastica***
- **The work of Johann Beringer**

Paleontology as a science

Fossils as fossils

- **The genius of Leonardo da Vinci**
- **Nicolaus Steno, true nature of *glossopetrae***
- **Robert Hooke, descriptions of Fossils using a crude microscope**
- **Magical explanations of fossils were**

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The idea of extinction

- **Robert Hooke was one of the first to hint at the idea of extinction**
- **William Hunter (1768): "American incognitum"**
- **Reality of extinction: French natural scientist Georges Cuvier**
- **Cuvier : father of**

Paleontology as a science

The vastness of geological time

- **Sedimentary rocks and their contained fossils document the history of long spans of time.**
- **Naming of the geological periods and eras : 1820s and 1830s**
- **Stratigraphy is an understanding of**

Paleontology as a science

FOSSILS AND EVOLUTION

Paleontology as a science

FOSSILS AND EVOLUTION

1. **Progressionism and Evolution**
2. **Darwinian evolution**

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Progressionism and Evolution

- **Limited Knowledge of the fossil record in the 1820s and 1830s**
- **Paleontologists debated whether there was a progression from simple organisms in the most ancient rocks to**

Paleontology as a science

Progressionism and Evolution

- **Charles Lyell (1797–1875), was an antiprogressionist**
- **Progressionism (Orthogenesis) was linked to the idea of evolution.**
- **The work of Comte de Buffon (1707–1788) and**

Paleontology as a science

Progressionism and Evolution

- **Lamarck s' idea of "Great Chain of Being" or the *Scala naturae*.**
- **"All organisms were linked in time by a unidirectional ladder, from simplest at the bottom to most**

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Darwinian evolution

- **Charles Darwin (1809–1882)**
- **Developed the theory of evolution by natural selection in the 1830s**
- **Abandoning the usual belief that species were**

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Darwinian evolution

- **Idea of evolution by common descent, that all species today had evolved from other species in the past.**
- **The problem: how the variation within species could be harnessed to**

Paleontology as a science

Darwinian evolution

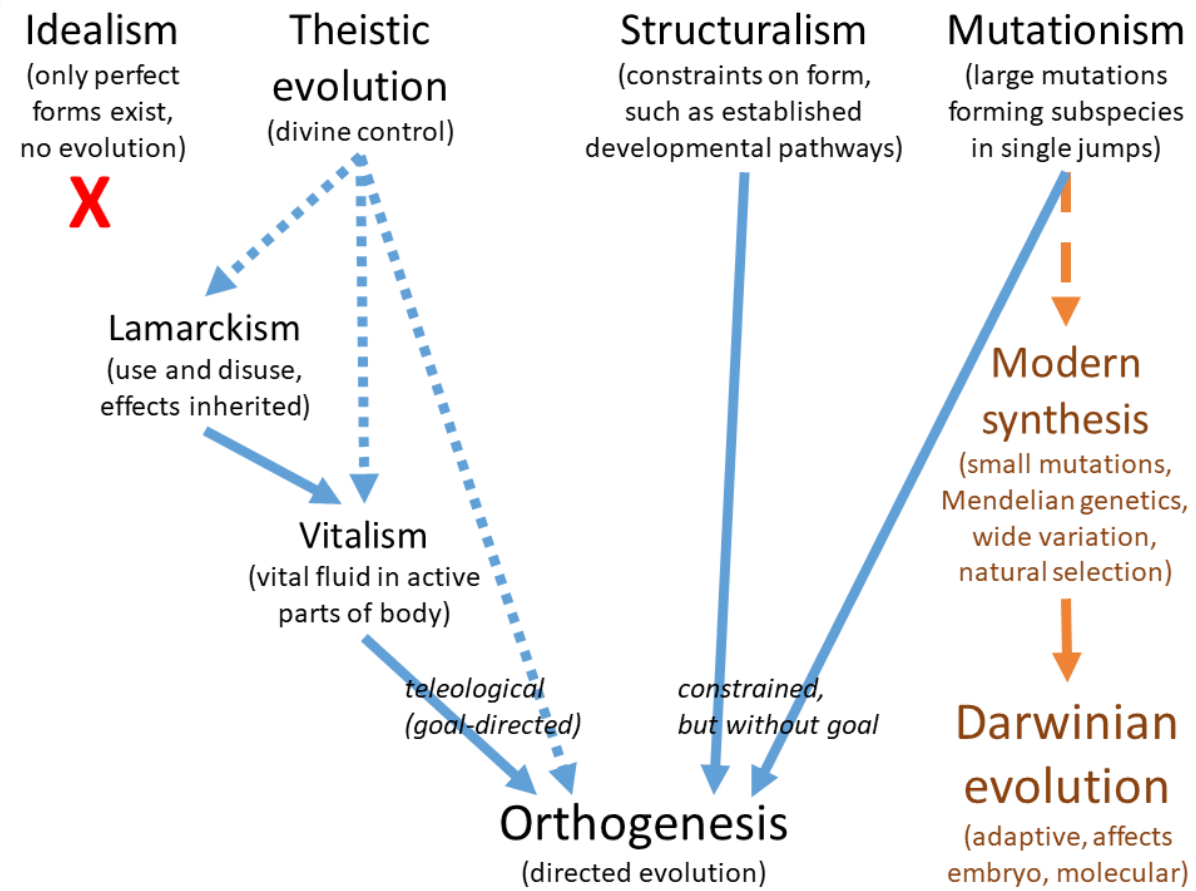
- **Ideas of Thomas Malthus (1766–1834)**
- **Survival of the fittest through adaptations**
- **Book "On the Origin of Species**

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Darwinian evolution

- "**Modern synthesis**"
- **Modern genetics early in the 20th century**
- **Amalgamation of Genetics with "natural history" (systematics, ecology, paleontology)**
- **Establishment of**

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https://en.wikipedia.org/wiki/Orthogenesis#/media/File:Alternatives_to_Darwinism.png

Paleontology as a science

PALEONTOLOY TODAY

Paleontology as a science

PALEONTOLOGY TODAY

1. **Dinosaurs and fossil humans**
2. **Evidence of earliest life**
3. **Macroevolution**
4. **Paleontological research**

Paleontology as a science

Dinosaurs and fossil humans

- **19th century paleontology**
- **“Archaeopteryx”, true “missing link” predicted by Darwin only 2 years before.**
- **Incomplete remains of Neandertal man in 1856**

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Archaeopteryx

- ***Archaeopteryx* lithographica,**
- **Specimen displayed at the Museum für Naturkunde in Berlin**

https://en.wikipedia.org/wiki/File:Archaeopteryx_lithographica_(Berlin_specimen).jpg

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Evidence of earliest life

- **Extraordinary progress in understanding the earliest stages in the evolution of life**
- **Cambrian fossils**
- **Precambrian fossils**
- **In 1947, the first soft-bodied Ediacaran fossils**

Paleontology as a science

Macroevolution

- **Rates of evolution,**
- **The nature of speciation**
- **The timing and extent of mass extinctions**
- **The diversification of life**
- **other topics that involve long time**

Paleontology as a science

END

Paleontological research

- **Done by paid professionals**
- **By amateur enthusiasts**
- **Amateurs are not paid to work as paleontologists**
- **Collaborations between different sciences is the key**

Fossils in Time and Space

Fossils in time and space

Fossils in Time and Space

Fossils in Time and Space

- **The Earth is old, and the distribution of continents and oceans has changed radically over time.**
- **Past: History of life into a**

Fossils in Time and Space

Life on Earth

- **Evolving for up to 4 billion years**
- **Complex story of fossil groups coming and going**
- **Continents moving from place to place**

Fossils in Time and Space

How to Study fossils in time and space

- **Development of geographic and temporal frameworks**
- **Accurate and reliable enough to chart the distributions of fossil organisms**

Fossils in Time and Space

How to Study fossils in time and space

- **Paleogeographers and Stratigraphers are equipped with a range of computer-based high-tech methods.**

Fossils in Time and Space

How to Study fossils in time and space

- **Models describing the distributions of the continents, oceans and their biotas throughout geological time**

Fossils in Time and Space

Use of Fossils information

- **Fossils information is also useful in Geology**
- **Allows the tectonic history of mountain ranges to be reconstructed**

Fossils in Time and Space

Use of Fossils information

- **Helps in identifying the levels of thermal maturity of rocks**
- **The gas and oil windows in hydrocarbon exploration**

END

Fossils in time and space

Frameworks

Fossils in time and space

Rock stratigraphy

- **A rock stratigraphy is the essential framework that paleontologists use to accurately locate fossil collections in both temporal and spatial**

Fossils in time and space

Leonardo's legacy

- **The origin of modern stratigraphy: Leonardo da Vinci and his drawings**
- **da Vinci portrayed a clear sequence of laterally continuous, horizontal**

Fossils in time and space

Steno's Work

- **Nicolaus Steno: established the simple fact that older rocks are overlain by younger rocks if the sequence has not been inverted**
- **law of superposition of**

Fossils in time and space

Steno's Work

- **The principle of original horizontality: "Strata either perpendicular to the horizon or inclined to the horizon were at one time parallel to the**

Fossils in time and space

Steno's Work

- **The principle of lateral continuity:**
  "Material forming any stratum were continuous over the surface of the Earth unless some other solid bodies stood in

Fossils in time and space

Steno's Work

- **The principle of cross-cutting relationships:**
- **"If a body or discontinuity cuts across a stratum, it must have formed after that stratum.**

Fossils in time and space

Types of Stratigraphy

1. **Lithology (Lithostratigraphy)**
2. **Fossils (Biostratigraphy)**
3. **Tectonic units, such as thrust sheets (Tectonostratigraphy)**
4. **Magnetic polarity**

Fossils in time and space

Types of Stratigraphy

5. **Chemical compositions (Chemostratigraphy)**
6. **Discontinuities (Allostratigraphy),**
7. **Seismic data (Seismic stratigraphy)**
8. **Depositional trends (Cyclo-**

END

Fossils in time and space

Lithostratigraph
y

Fossils in time and space

Early geologists

- **Early geologists thought the Earth was very young**
- **Scottish scientist James Hutton (1726–1797) chellenged**
- **“no vestige of a beginning,– no prospect of an end”.**
- **“ruins of an**

Fossils in time and space

Gaia hypothesis and Modern Concept

- **Gaia hypothesis: Earth as a living organism in equilibrium with its biosphere.**
- **Modern Concept: Earth as a dynamic and changing system**

Fossils in time and space

Lithostratigraphy

- **All aspects of stratigraphy start from the rocks themselves**
- **The order and succession of rocks is called lithostratigraphy**

Fossils in time and space

Lithostratigraphy

- **Building blocks for any study of biological and geological change through time.**
- **Successions of rock are often divided by gaps or unconformities.**

Fossils in time and space

Lithostratigraphy

- **A stratigraphy is required to monitor biological and geological changes through time and underpins the whole basis of Earth**

Fossils in time and space



The Permian through Jurassic strata of the Colorado Plateau area of southeastern Utah demonstrate the principles of stratigraphy

https://en.wikipedia.org/wiki/Stratigraphy#/media/File:SEUtahStrat.JPG

Fossils in time and space

Stratigraphic unit

- **A stratigraphic unit is a volume of rock of identifiable origin and relative age range that is defined by the distinctive and dominant, paleontologic features**

Fossils in time and space

Lithostratigraphic units

1. **A bed, is a lithologically distinct layer within a member or formation and is the smallest recognizable stratigraphic unit.**
2. **A member is a more local lithologic**

Fossils in time and space

Lithostratigraphic units

3. **The formation, a rock unit that can be mapped and recognized across country**
4. **A succession of contiguous formations with common characteristics is called a group**

Fossils in time and space

Lithostratigraphic units

5. **Groups themselves may comprise a supergroup.**

END

Fossils in time and space

Use of fossils: Discovery of Biostratigraphy (Part 1)

Fossils in time and space

Early Palaeontologists

- **Work of William Smith in Britain**
- **"Assemblages of fossils in different layers"**
- **Georges Cuvier (Anatomist) and Alexandre Brongniart in France (Mollusck expert)**

Fossils in time and space

Early Palaeontologists

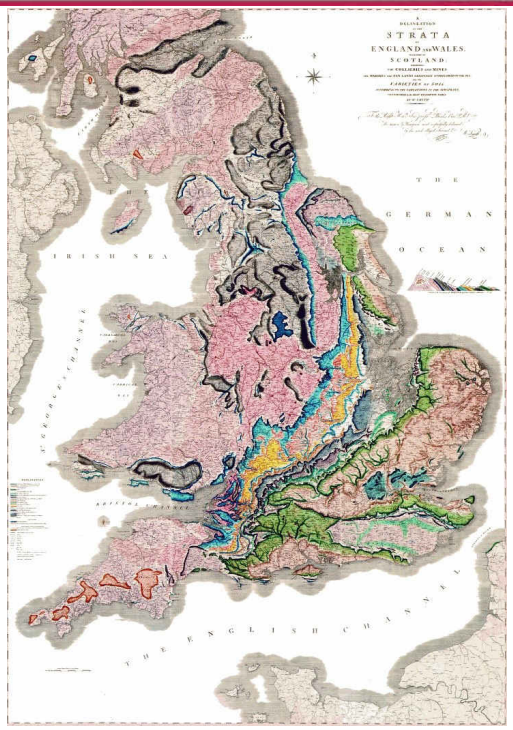
- **William Smith: Trilobite-Dominated assemblages in England and Wales area.**
- **Cuvier and Brongniart: Comparison of different strata in Paris basin and**

Fossils in time and space



A Trilobite Fossil

https://en.wikipedia.org/wiki/Trilobite#/media/File:Cambrian_Trilobite_Olenoides_Mt._Stephen.jpg



Smith's famous 1815 geological map

https://en.wikipedia.org/wiki/William_Smith_(geologist)#/media/File:Geological_map_Britain_William_Smith_1815.jpg

Fossils in time and space

The Work of John Phillips

- **Formally defined the three great eras**
- **Paleozoic (“ancient life”)**
- **Mesozoic (“middle life”)**
- **Cenozoic (“recent life”)**
- **separated by extinction events**

Fossils in time and space

The Work of John Phillips

- **Precise biotic and morphological changes along phylogenetic lineages**
- **Accurate correlation using a wide variety of fossil organisms**

Fossils in time and space

Biostratigraphy: the means of correlation

- **Biostratigraphy is the establishment of fossil based successions and their use in stratigraphic correlation**
- **Biozones: The main operational units of a biostratigraphy.**

Fossils in time and space

Biostratigraphy: the means of correlation

- **Measurements of the stratigraphic ranges of fossils, or assemblages of fossils, form the basis for the definition of biozones**

Fossils in time and space

Biostratigraphy: the means of correlation

- **The known range of a zone fossil is the time between its first and last appearances in a specific rock section,**
- **First appearance datum (FAD)**
- **Last appearance datum (LAD)**

Fossils in time and space

Biostratigraphy: the means of correlation

- **Establishment of biozones**
- **Quantitative techniques to understand the relationships between rock thickness and time, and to make links from locality to locality**

END

Fossils in time and space

Use of fossils: Discovery of Biostratigraphy (Part 2)

Fossils in time and space

Biostratigraphy: the means of correlation

- **The fossil record is rarely complete.**
- **Only a small percentage of potential fossils are ever preserved.**
- **Stratigraphic ranges can also be influenced by**

Fossils in time and space

Biostratigraphy: the means of correlation

- **Signor–Lipps effect**
- **“Since the fossil record of organisms is never complete, neither the first nor the last organism in a given taxon will be recorded as**

Fossils in time and space

Biostratigraphy: the means of correlation

- **Many different animal and plants are used in biostratigraphic correlation**
- **Graptolites (1 myr) and Ammonites (25 kyr) are the best known and most reliable zone**

Fossils in time and space

Biostratigraphy: the means of correlation

- **Microfossil groups: conodonts, dinoflagellates, foraminiferans and plant spores used in petroleum exploration**
- **Comprise of small samples, drill**

Fossils in time and space

Biostratigraphy: the means of correlation

- **Microfossil groups**
- **many groups are widespread and rapidly evolving.**
- **Drawback: Techniques used to extract them from rocks are specialized, like acid digestion and thin sections.**

Fossils in time and space

Chronostratigraphy

- **Dividing up geological time**
- **Chronostratigraphy or global standard stratigraphy**
- **Most fundamental of all stratigraphic concepts**

Fossils in time and space

Chronostratigraphy

- **“The branch of geology concerned with establishing the absolute ages of strata.”**

Fossils in time and space

Sequence stratigraphy

- **“Sequence Stratigraphy is a branch of geology that attempts to subdivide and link sedimentary deposits into unconformity bound units on a variety of**

Fossils in time and space

Cyclostratigraphy:

- **Finding the rhythm**
- **Cyclostratigraphy is the study of astronomically forced climate cycles within sedimentary successions**

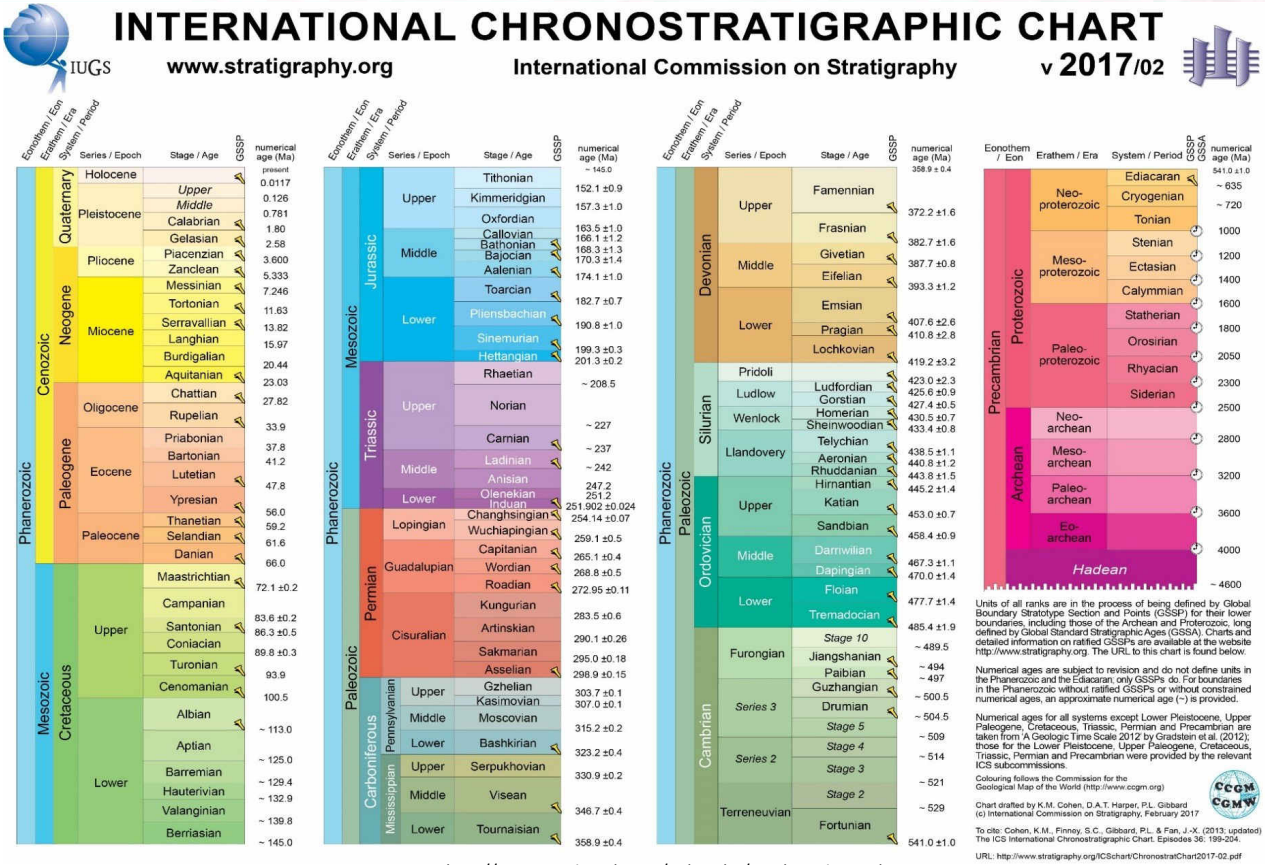
Fossils in time and space

Geologic time scale

- **System of chronological dating that relates geological strata (stratigraphy) to time**
- **Used to describe the timing and relationships of events that have occurred during**

END

Fossils in time and space



http://www.stratigraphy.org/index.php/ics-chart-timescale

Fossils in time and space

Paleobiogeography

Fossils in time and space

Paleobiogeography

- **All living organisms have a defined geographic range**
- **The ranges may be large or small, and controlled by a variety of factors including climate and**

Fossils in time and space

Early Biogeographists

- **Charles Darwin (Galápagos islands) and Alfred Russel Wallace (East Indies)**
- **Recognized the reality of biogeographic provinces.**

Fossils in time and space

Early Biogeographists

- **Philip Sclater and Alfred Russel Wallace**
- **The Earth today can be divided into six main provinces**
- **Nearctic, Palearctic, Neotropical,**

Fossils in time and space



Six Biogeographic Realms according to the WWF

https://en.wikipedia.org/wiki/Biogeographic_realm#/media/File:Ecozones.svg

Fossils in time and space

Early Biogeographists

- **Early 1900s, the German scientist Alfred Wegener suggested that the continents moved across the Earth's surface on a liquid core, suggesting that continents could in fact drift.**

Fossils in time and space

Computerized paleogeographic systems

- **Our understanding of plate movements has been greatly advanced**
- **Paleomap Project**
- **taking the Earth far into the future as well as**

Fossils in time and space

Faunal and floral barriers

- **Barriers of various types have partitioned biogeographic provinces through time.**

Fossils in time and space

The work of Gaylord Simpson

- **George G. Simpson Three passages**
- **Corridors (open at all times)**
- **Filters (allowed restricted**
- **Access)**
- **Sweepstake routes (opened only**

Fossils in time and space

Barriers

- **Continental settings: mountain ranges, inland seas or even rain forests.**
- **Marine faunas: wide expanses of deep ocean, swift ocean currents or land**

Fossils in time and space

Isthmus of Panama

- **Barrier for some organisms may provide a corridor for others.**
- **The emergence of the Isthmus of Panama (3 Mya)**
- **Connected North and South America**
- **Separated the**

END

Fossils in time and space



The isthmus of Panama

https://eoimages.gsfc.nasa.gov/images/imagerecords/4000/4073/Panama_SRTM_lrg.jpg

Fossils in time and space

Island
Paleobiogeography

Fossils in time and space

Island biogeography

- **Modern oceans are littered with islands.**
- **The biogeography of modern islands is complex and it is hard to apply models based on modern islands**

Fossils in time and space

Island biogeography

- **Island biogeography is the study of the species composition and species richness on islands.**

Fossils in time and space

Island biogeography

- **Island biogeography is a study aimed at establishing and explaining the factors that affect species diversity of a specific community.**

Fossils in time and space

Island biogeography

- **Most islands are isolated from the mainland, and they are important powerhouses of speciation**

Fossils in time and space

Island biogeography

- **Moving island complexes: the cross-latitude transfer of evolving animals and plants may have acted as "Noah's arks".**
- **Example: The transit of India from Gondwana to**

Fossils in time and space

Island biogeography

- **Island biotas (faunas and floras) are often diverse, with many endemic species and commonly with evidence that these species came originally from one or more**

Fossils in time and space

Island biogeography

- **Galápagos, or Aldabra, have become important sites for biologists to watch “evolution in action”.**
- **It is difficult to understand the role of such islands through**

Fossils in time and space

Island biogeography

- **By their very nature, being short lived and located in tectonically active areas**
- **They are quickly lost and often destroyed.**

END

Fossils in time and space

FOSSILS IN FOLD BELTS

Fossils in time and space

FOSSILS IN FOLD BELTS

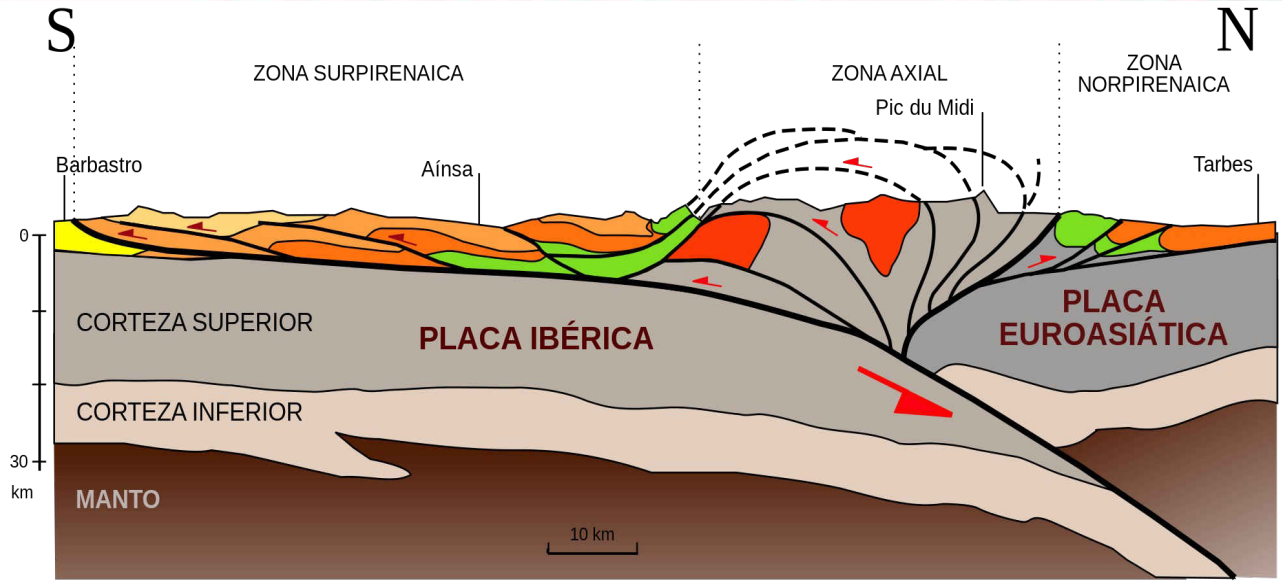
- **“One bad fossil is worth a good working hypothesis”**
- **Rudolf Trümpy, an eminent Alpine geologist.**

Fossils in time and space

FOLD BELTS

- **A fold and thrust belt is a series of mountainous foothills adjacent to an orogenic belt, which forms due to contractional**

Fossils in time and space



Profile through the Pyrenees. In the south a fold and thrust belt exists as sediments are folded and stacked (thrusted) on top of the other. WF

https://en.wikipedia.org/wiki/Fold_and_thrust_belt#/media/File:Profile_through_the_Pyrenees_ES.svg

Fossils in time and space

FOSSILS IN FOLD BELTS

- **Fossils from the deformed zones of mountain belts**
- **They are usually poorly preserved**

Fossils in time and space

FOSSILS IN FOLD BELTS

- **We can reassemble ancient mountain belts and trace the origins of their jumbled structure using**

Fossils in time and space

FOSSILS IN FOLD BELTS

- **Fossils in fold belts can be of great value to structural geologists in understanding the rates and timing of tectonic events**

Fossils in time and space

FOSSILS IN FOLD BELTS

- **A fossil that was originally symmetric, but now squeezed, or stretched**

- **The precise evidence of the magnitude of the tectonic forces on it**

Fossils in time and space

FOSSILS IN FOLD BELTS

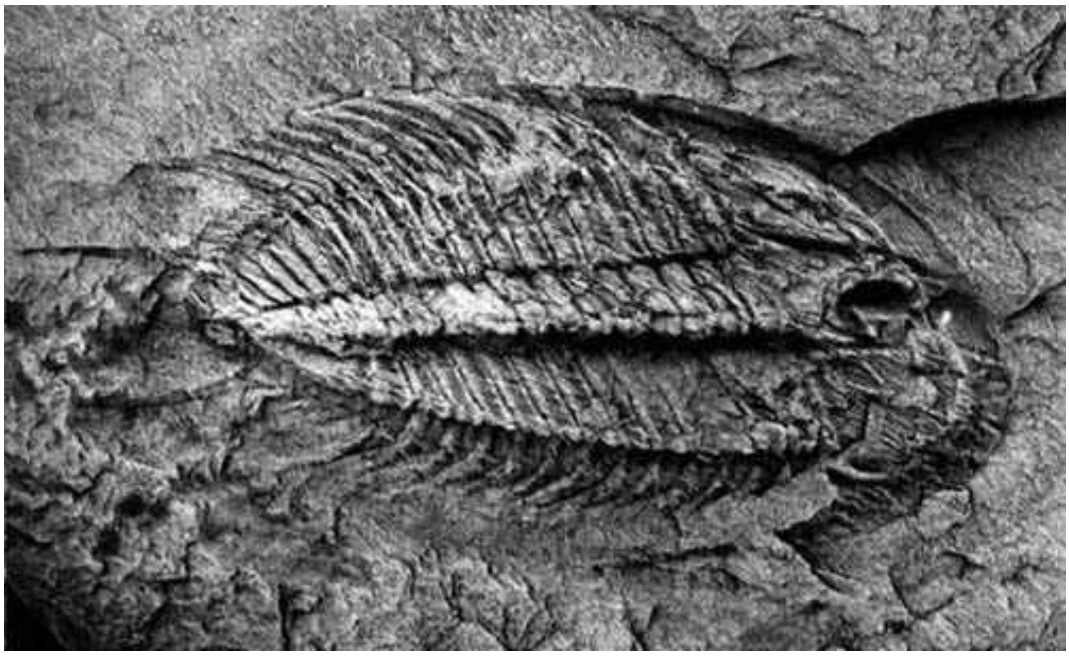
- **Example is the "Delabole butterfly"**
- **In fact, the wide-hinged fossils are "Spiriferide brachiopods"**

Fossils in time and space

FOSSILS IN FOLD BELTS

- **Hughes and Jell (1992)**
- **Techniques to unstrain Cambrian trilobites from Kashmir**
- **distorted by earth movements during the uplift of the**

Fossils in time and space



Strained Cambrian trilobites from Himalaya.

(Courtesy of Nigel Hughes.)

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=02&fig=Fig2-19&img=c02f019

Fossils in time and space

END

FOSSILS IN FOLD BELTS

- **The investigation of thermal maturation is now a routine petroleum exploration technique.**
- **A number of groups of microfossils change color**

Taphonomy and fossil record

Taphonomy and Fossil record

Taphonomy and fossil record

Taphonomy

- **“Taphonomy is the paleontological study includes all the processes that occur after the death of an organism and before its fossilization in**

Taphonomy and fossil record

Taphonomy

- **Plants and animals with hard tissues are most frequently preserved in the fossil record.**
- **Soft tissues usually decay rapidly, but rapid burial or early**

Taphonomy and fossil record

Taphonomy

- **Physical and chemical processes during transport and compaction damage hard tissues**
- **Plants preserve as permineralized tissues, coalified**

Taphonomy and fossil record

Taphonomy

- **Many of the analytic approaches used by taphonomists are also used by forensic scientists.**
- **Both observe the state of decay of remains**
- **Measurement**

Taphonomy and fossil record

Taphonomy

- **Assessment of the rare earth elements (scandium, yttrium and the 15 lanthanides) to help pinpoint the time of death**
- **Archeologist and**

Taphonomy and fossil record

Fossil Record

- **Quality of the fossil record?**
- **Fidelity and quality of the fossil record.**
- **Can paleontologists trust their patchy fossil finds to understand large-scale patterns of**

Taphonomy and fossil record

Fossil Record

- **Paleontologists should be careful when they attempt to reconstruct a whole plant or animal, and try to understand its biomechanics, when they have just a few**

Taphonomy and fossil record

Fossil Record

- **Care is required in seeking to understand patterns of diversity change and evolution when many fossil species are missing.**
- **Diverse opinions and arguments in**

END

Taphonomy and fossil record

Fossil Preservation (Part 1)

Taphonomy and fossil record

Fossilization

- **Sometimes a plant or an animal dies ends up as a fossil.**
- **There are several stages that normally occur in the transition from a dead**

Taphonomy and fossil record

Transition to fossil

1. **Decay of the soft tissues of the plant or animal.**
2. **Transport and breakage of hard tissues.**
3. **Burial and modification of the hard tissues.**

Taphonomy and fossil record

Fossilization

- **In rare cases, soft parts may be preserved, and these examples of exceptional preservation are crucially important in reconstructing past life.**
- **"Lagerstätten"**

Taphonomy and fossil record

Two kinds of fossils

1. **Body fossils: the partial or complete remains of plants or animals**
2. **Trace fossils: the remains of the activity of ancient organisms, such as**

Taphonomy and fossil record

Decay

- **When large animals feed on dead plant or animal tissues, the process is termed scavenging**
- **When microbes, such as fungi or bacteria, transform tissues of the dead organism, the process is**

Taphonomy and fossil record

Factors controlling Decay

- **Oxygen**
- **Microbial nutrients**
- **Temperature**
- **pH**

- **Example of Neolithic and younger “bog bodies” of northern Europe**

Taphonomy and fossil record

Volatiles and Refractories

- **Soft parts of animals are made from volatiles, forms of carbon that break down readily.**
- **Refractories are the organic carbons much less liable to**

Taphonomy and fossil record

Mineralization

- **Early mineralization of soft tissues depends on three factors:**
  1. **Rate of burial**
  2. **Organic content**
  3. **Salinity**
- **Physical and chemical effects occurring after burial, are termed as**

Taphonomy and fossil record

Conservation traps

- **Obrution deposits: sedimentation rates are so rapid that carcasses are buried virtually instantly**
- **Amber: fossilised resin**

Taphonomy and fossil record

Mineralization Types

- **Mineralization of soft tissues occurs in three ways**

1. **Permineralization**
2. **Formation of mineral coats**
3. **Formation of tissue casts and shells**

END

Taphonomy and fossil record

Fossil Preservation (Part 2)

Taphonomy and fossil record

Breakage and transport

- **Several processes of breakage**
- **Physical: disarticulation, fragmentation, abrasion**
- **Chemical: bioerosion, corrosion, dissolution**

Taphonomy and fossil record

Breakage and transport

- **Disarticulation: Skeletons that are made from several parts may become disarticulated, separated into their component parts.**
- **After scavenging or decay of connective tissue**

Taphonomy and fossil record

Breakage and transport

- **Fragmentation: Skeletons may also become fragmented**
- **Individual shells, bones or pieces of woody tissue break up into smaller pieces usually along lines of**

Taphonomy and fossil record

Breakage and transport

- **Abrasion:**
  Shells, bones and wood may be abraded by physical grinding and polishing against each other and against other sedimentary grains

Taphonomy and fossil record

Breakage and transport

- **Bioerosion:**
- **The removal of skeletal materials by boring organisms such as sponges, algae and bivalves**
- **Shells, bones and wood may**

Taphonomy and fossil record

Breakage and transport

- **Corrosion and Dissolution**
- **Before and after burial, skeletal materials are commonly corroded and dissolved by chemical action, i.e. by weak acidic**

Taphonomy and fossil record

Burial and Modifications

- **The remains are typically buried after scavenging, decay, breakage and transport.**
- **Sediment is washed or blown over the remains, and the specimen**

Taphonomy and fossil record

Burial and Modifications

- **During and after burial, the specimen may undergo physical and chemical change**
- **Addition of $CaCO_3$ is called Carbonate concretion**
- **Coprolites are**

Taphonomy and fossil record

Plant Preservation

- **Through petrification or cellular permineralization**

1. **Coal balls**
2. **Coalified compression**
3. **Cementation**
4. **Direct preservation**

END

Taphonomy and fossil record

QUALITY OF THE FOSSIL RECORD

Taphonomy and fossil record

Incompleteness of the fossil record

- **Charles Darwin "imperfection of the geological record"**
- **in 1972, David Raup explained all the factors that make the fossil record**

Taphonomy and fossil record

Anatomic filters

- **Organisms are likely to be preserved only if they have hard parts, a skeleton of some kind.**
- **Entirely soft-bodied organisms, such as worms and jellyfish, are only**

Taphonomy and fossil record

Biological filters

- **Behavior and population size matter**
- **Common organisms such as rats are more likely to be fossilized than rare ones such as pandas**
- **Shorter life span of rats**

Taphonomy and fossil record

Ecological filters

- **Where an organism lives matters.**
- **Animals that live in shallow seas, or plants that live around lakes and rivers, are more likely to be buried under**

Taphonomy and fossil record

Sedimentary filters

- **Some environments are typically sites of deposition, and organisms are more likely to be buried there.**
- **Mountainside or a beach VS a shallow**

Taphonomy and fossil record

Preservation filters

- **Once the organism is buried in sediment, the chemical conditions must be right for the hard parts to survive.**
- **The destruction of bones or shells by acidic waters. worn and damaged**

Taphonomy and fossil record

Diagenetic filters

- **After a rock has formed, the rock may be transformed by the passage of mineralizing waters**
- **Either enhancing the fossils, by replacing biomolecules with mineral**

Taphonomy and fossil record

Metamorphic filters

- **Over millions of years, the fossiliferous rock might be baked or subjected to high pressure.**
- **In these kinds of metamorphic fossils may survive these terrible indignities, or**

Taphonomy and fossil record

Vertical movement filters

- **Burial means the rock has been covered by younger rock**
- **Tectonic movements must subsequently raise the fossiliferous rock to the Earth's surface, or the fossil**

Taphonomy and fossil record

Human filters:

- **Fossils are seen and collected by a human being**
- **The fossil has to be registered in a museum as part of collective human paleontological knowledge**

Taphonomy and fossil record

Sampling and reality

- **The fossil record give us a good outline of the key events in the history of life.**
- **Understanding the history of life with the help of the fossils (small remnant of what once existed)is a big**

END

Paleoecology and Paleoclimates

Paleoecology and Paleoclimates

Paleoecology and Paleoclimates

Importance of Fossils

- **Fossil organisms provide fundamental evidence of evolution**
- **They also allow the reconstruction of ancient animal and**

Paleoecology and Paleoclimates

Paleoecologists

- **The functions of single fossil organisms (paleoautecology)**
- **The composition and structure of fossil communities**

Paleoecology and Paleoclimates

The Paleoecology of fossil organisms

- **described in terms of life strategies and trophic modes together with their habitats**
- **All fossil organisms interacted with other fossil**

Paleoecology and Paleoclimates

The Paleoecology of fossil organisms

- **Described in terms of life strategies and trophic modes together with their habitats**
- **All fossil organisms interacted with other fossil organisms**

Paleoecology and Paleoclimates

The Paleoecology Analysis

- **Populations and paleocommunities may be analyzed with a range of statistical techniques.**

Paleoecology and Paleoclimates

Evolutionary Paleoecology

- **Charts the changing structure and composition of Paleocommunities through time**
- **Ecological events can be ranked in**

Paleoecology and Paleoclimates

Evolutionary Paleoecology

- **Charts the changing structure and composition of Paleocommunities through time**
- **Ecological events can be ranked in importance.**

Paleoecology and Paleoclimates

Paleoclimates

- **Described on the basis of climatically-sensitive biotas and sediments together with stable isotopes.**
- **Climate has been an important factor in driving evolutionary change at a**

Paleoecology and Paleoclimates

Paleoclimates

- **Described on the basis of climatically-sensitive biotas and sediments together with stable isotopes.**
- **Climate has been an important factor in driving evolutionary change at a**

Paleoecology and Paleoclimates

Feedback loops and Gaia Hypothesis

- **Feedback loops between organisms and their environments indicate that the Gaia hypothesis is a useful model for some of geological time**

END

Paleoecology and Paleoclimates

Paleoecology (Part 1)

Paleoecology and Paleoclimates

Paleoecology

- **Study of the life and times of fossil organisms, the lifestyles of individual animals and plants together with their relationships to each other and their**

Paleoecology and Paleoclimates

Speculation

- **Element of speculation has prompted some paleontologists to exclude paleoecology from mainstream science**

Paleoecology and Paleoclimates

Solution

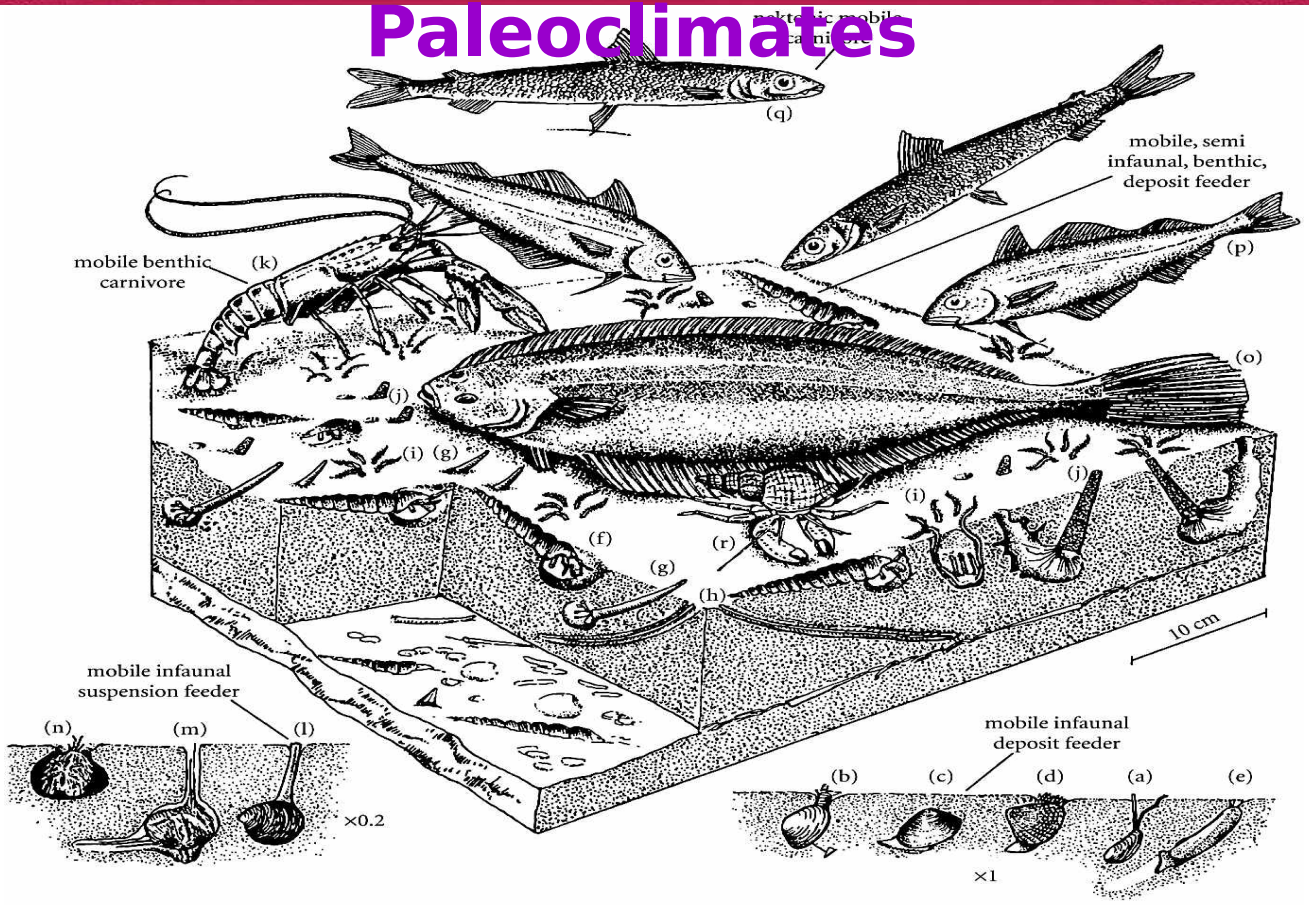
- **Emerging numerical and statistical techniques can help us frame and test hypotheses**
- **Paleoecology is actually not very different**

Paleoecology and Paleoclimates

Two main areas

- **Paleoautecology is the study of the ecology of a single organism**
- **Paleosynecology looks at communities or**

Paleoecology and Paleoclimates



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Paleoecology and Paleoclimates

Fidelity

- **The similarity of a death assemblage to its living counterpart, its fidelity**
- **Measurements of biomass and taxonomic composition**

Paleoecology and Paleoclimates

Structure of Community

- **Numerical abundance and diversity are not the best estimates**
- **Counts of stable adult populations are the most realistic monitors of community**

Paleoecology and Paleoclimates

Structure of Community

- **A census of an extraordinarily preserved Lagerstätte deposit can help in the estimation of the Taphonomic**

Paleoecology and Paleoclimates

Structure of Community

- **The degree of breakage with the attitude of fossils in sediments is useful to separate autochthonous (in place) from allochthonous**

Paleoecology and Paleoclimates

The -Coenoses

- **The living assemblage, or biocoenosis, is transformed into a thanetocoenosis after death and decay.**
- **Taphocoenosis is the end product that is finally**

END

Paleoecology and Paleoclimates

Paleoecology
Part 2

Paleoecology and Paleoclimates

Population

- **Populations are the building blocks of communities**
- **A population is a naturally occurring assemblage of plants and animals that live in the same place at the**

Paleoecology and Paleoclimates

Ecosystem

- **“All the populations of species living in association”**
- **Keystone species help shape the ecosystem and that can trigger large-scale changes if they disappear.**
- **A classic**

Paleoecology and Paleoclimates

Incumbent Species

- **Incumbent species can occupy the same ecological niche for many millions of years, adding stability to many ecosystems.**

Paleoecology and Paleoclimates

Habitat and Niche

- **Fossil organisms can be classified in terms of**
- **Habitat, where they live.(their address)**
- **Niche, their lifestyle (their occupation).**

Paleoecology and Paleoclimates

Marine Sediments

- **The majority of fossil animals have been found in marine sediments**
- **Occupy a wide range of depths and conditions.**
- **Photic zone is the depth of**

Paleoecology and Paleoclimates

Marine Variety of Life

- **Marine environments host a variety of lifestyles**
- **The upper surface waters are rich in floating plankton, and nektonic organisms swim at**

Paleoecology and Paleoclimates

Marine Sediments

- **Benthos are the beasts that**
- **live in or on the seabed**
- **Mobile nektobenthos, scuttle across the seafloor**
- **the fixed or sessile benthos are**

Paleoecology and Paleoclimates

Marine Sediments

- **Infaunal organisms live beneath the sediment–water interface**
- **Epifaunal organisms live above it The sediment–water**

Paleoecology and Paleoclimates

Guilds

- **Guilds are groups of functionally similar organisms occurring together in a community.**

Paleoecology and Paleoclimates

END

Megaguild

- **Megaguilds are a range of adaptive strategies based on a combination of life position (e.g. shallow, active, infaunal**

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PPT Slides 01 TO 180

Regards : Zarva Chaudhary

Merged File date 08/07/2021

Admin:

* Zarva Chaudhary *

Chaudhary Moazzam

* Laiba Mahi *

Paleoecology and Paleoclimates

Paleoclimates

Paleoecology and Paleoclimates

Paleoclimatology

- **The study of changes in climate taken on the scale of the entire history of Earth.**
- **Uses the methods from the Earth and life**

Paleoecology and Paleoclimates

Paleoclimatology

- **It obtains data from previously preserved things such as rocks, sediments, ice sheets, tree rings, corals, shells, and microfossils**

Paleoecology and Paleoclimates

The Climate change in life history

- **Last 600 million years**
- **Earth has oscillated at least five times between icehouse and greenhouse conditions**
- **Spending most of the time in greenhouse climates**

Paleoecology and Paleoclimates

Five climate zones

1. **Humid Tropical (no winters and average temperatures above 18°C)**

2. **Dry subtropical (evaporation exceeds**

Paleoecology and Paleoclimates

Five climate zones

3. **Warm temperate (mild winters)**

4. **Cool temperate (severe winters)**

5. **Polar (no summers and**

Paleoecology and Paleoclimates

A big Question

- **Can these zones be recognized through deep time and be used to develop models for both short- and long-term climate**

Paleoecology and Paleoclimates

Identification of climate zones

- **A range of geological and paleontological criteria has helped identify climatic zones through time.**

Paleoecology and Paleoclimates

Identification of climate zones

- **calcretes (soils rich in calcium carbonate) and evaporites (evaporated salts) help identify dry,**

Paleoecology and Paleoclimates

Identification of climate zones

- **Dropstones (stones that plummet from the bottoms of melting icebergs into seabed sediments) and Tillites (rocks and sand left behind by an advancing**

Paleoecology and Paleoclimates

Trends of climate change

- **Short term trends**
- **Long term trends**
- **Consequences for evolution**
- **Biological Feedback and Gaia**

END

Macroevolution & The Tree of Life

Macroevolution and the Tree of Life

Macroevolution & The Tree of Life

Evolution by natural selection

- **Evolution by natural selection is a core scientific model that was set out by Darwin**
- **It has been confirmed again and again in every**

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Intelligent design

- **Creationists attempts to promote their religious beliefs, such as "intelligent design" or belief in a flat Earth, are not testable and therefore are not science.**

Macroevolution & The Tree of Life

Speciation

- **Speciation often occurs by the establishment of a barrier, and the isolation of part of a previously interbreeding**

Macroevolution & The Tree of Life

Evolution

- **Evolution takes place both within**
- **Species lineages (phyletic gradualism)**
- **at the time of speciation (punctuated**

Macroevolution & The Tree of Life

Tree of Life

- **The evolution of life may be represented by a single branching phylogenetic tree.**
- **Cladistics is a method of reconstructing phylogeny based on the identification of shared derived characters**

Macroevolution & The Tree of Life

Evolution

- **Molecular sequencing provides additional evidence for reconstructing and dating the tree of life.**

END

- **DNA has been extracted from fossils such as woolly mammoths, but**

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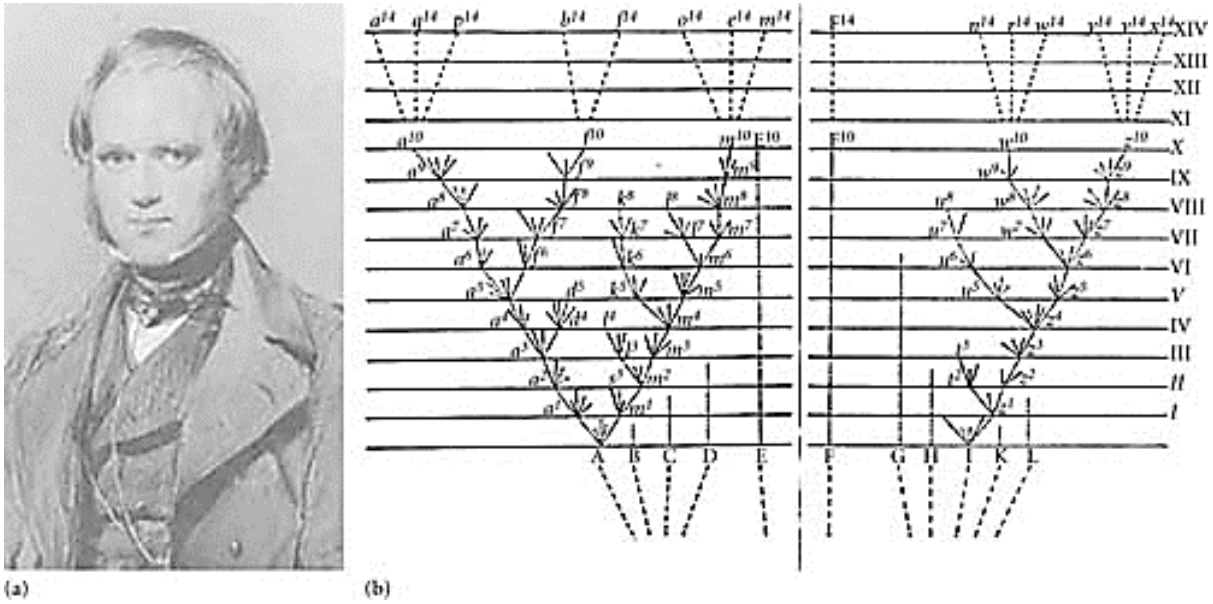
Evolution by Natural Selection

Macroevolution & The Tree of Life

Early Evolutionists

- **Darwin laid the framework for Evolutionary Biology 150 years ago.**
- **No one has yet falsified Darwin's theory of evolution by natural selection**
- **On The Origins**

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(a) Charles Darwin. (b) Branching diagram of phylogeny, the only illustration in On the Origin of Species (1859). It shows how two species, A and I, branch and radiate through time. The units I–XIV are time intervals of variable length, and the lower case letters (a, b, c) represent new species.

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Tree of Life

- **Darwin: life had diversified to millions of species by the continued splitting of species from a common stem**
- **Explained for the first time the meaning of the natural hierarchy of**

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Macroevolution

- **Paleontological aspects of evolution, such as the tree of life and studies of processes over thousands and millions of years, are sometimes called macroevolution (“big**

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Microevolution

- **Microevolution (“small evolution”) are all the smaller-scale and shorter-term processes studied by biologists and geneticists in the laboratory**

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Darwin's Quest of the Truth

- **The Voyage of *HMS Beagle***
- **Observation of Diversity of life**
- **Evidence for relationship in time and space**
- **Awareness of Fossil record**
- **Malthus' work**

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Principle of Natural Selection

- ***"Only the organisms best adapted to their environment tend to survive and transmit their genetic characteristics in increasing numbers to succeeding generations while those less***

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Natural Selection

1. **Nearly all species produce far more young than can survive to adulthood (Malthus'principle)**
2. **The young that survive tend to be those best**

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Natural Selection

3. **Characters are inherited from parent to offspring, so the characters that ensure survival will tend to be passed on.**
4. **These survival characteristics will increase**

END

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Evolution and
The Fossil record

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Species

- **Species consist of many highly variable individuals, often divided into geographically restricted populations and races.**
- ***Homo sapiens:***

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Biological Species' Concept

- ***"A species consists of all individuals that naturally breed together and that produce viable offspring"***
- **Humans**
- **Wolves and**

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Gene pool of Local populations

- **Local populations may be isolated from other populations of the same species, and with a subtly different gene pool, the overall array of genetic material in all**

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Gene flow

- **The cohesion of a species is maintained over its natural range by processes of gene flow.**
- **Gene flow: interbreeding with members of neighboring**

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Speciation

- ***"The process of splitting of a population to form two species is speciation".***
- **The allopatric**
- **("other homeland") model**
- **The geographic model (based on the**

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The Reasons for Speciation

1. **Each population, or set of populations, would start out with a different gene pool.**
2. **Selection pressures would be different**

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Models of Speciation

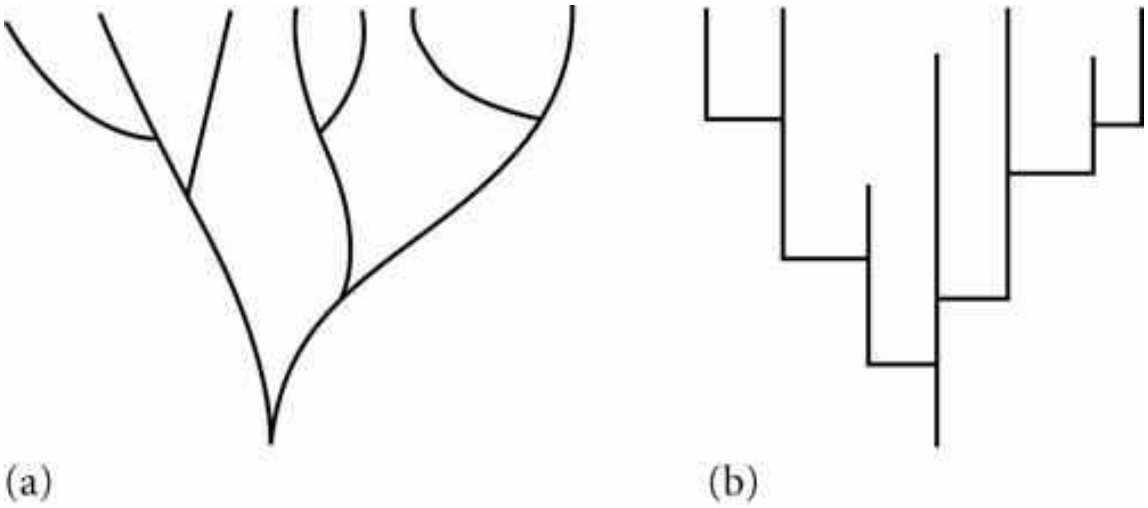
1. **The Phyletic Gradualism Model: Phyletic gradualism, where evolution takes place in the lineages, and speciation is a side effect of that evolution**

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Models of Speciation

2. **Punctuated Equilibrium Model: Where most evolution is associated with speciation events, and lineages show little evolution (stasis).**

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Two models of speciation and lineage evolution. (a). (b) Punctuated equilibrium, where most evolution is associated with speciation events, and lineages show little evolution (stasis)

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Macroevolution & The Tree of Life

The Tree of Life

Macroevolution & The Tree of Life

Tree Thinking

- **Darwin was the first to picture evolution as a great branching tree.**
- **"Which species of ape is closest to humans – the gorilla or chimp?"**
- **Putting**

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Tree Thinking

- **Scala Naturae: the ladder of life.**
- **Ladder go from lower to higher, simple to complex**
- **Tree of life: Splits and Branches**
- **Tree is a better analogy for life**

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Cladistics

- **In Cladistics, we reconstruct the Life's Hierarchy.**
- **The true patterns of Relationship among the organisms.**
- **Similarities and Differences**

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Phylogenetically informative characters

- **Good characters are phylogeneticall y informative, that is, indicative of the true phylogeny.**
- **These characters**

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Phylogenetically uninformative characters

- **Phylogeneticall y uninformative characters fall into two main categories:**
- **Convergences**
- **Plesiomorphies**

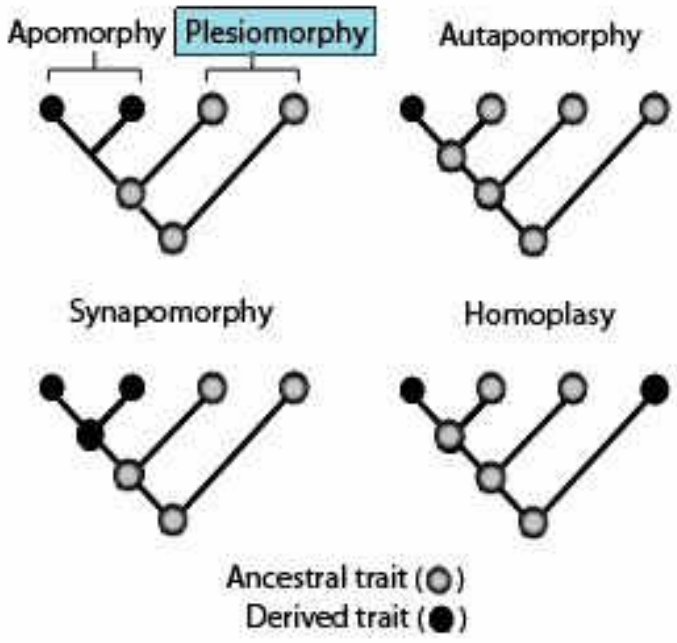
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Convergence

- **Convergence in evolution is when features, or organisms, evolve to look the same perhaps because they live the same way.**

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Plesiomorphies



https://upload.wikimedia.org/wikipedia/commons/1/1b/Plesiomorphy.jpg

- **Plesiomorphies are characters that are shared by the organisms of interest, but also by other groups.**

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Monophyletic Groups

- **These are groups that had a single origin and include all the descendants of that common ancestor.**
- **Psittaciformes, the parrots, long been identified as real and distinct**

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Non Natural Groups

- **Clades are distinguished from two kinds of non-natural groups:**

- **Paraphyletic groups**
- **Polyphyletic groups**

END

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Cladistics

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Early Scientists

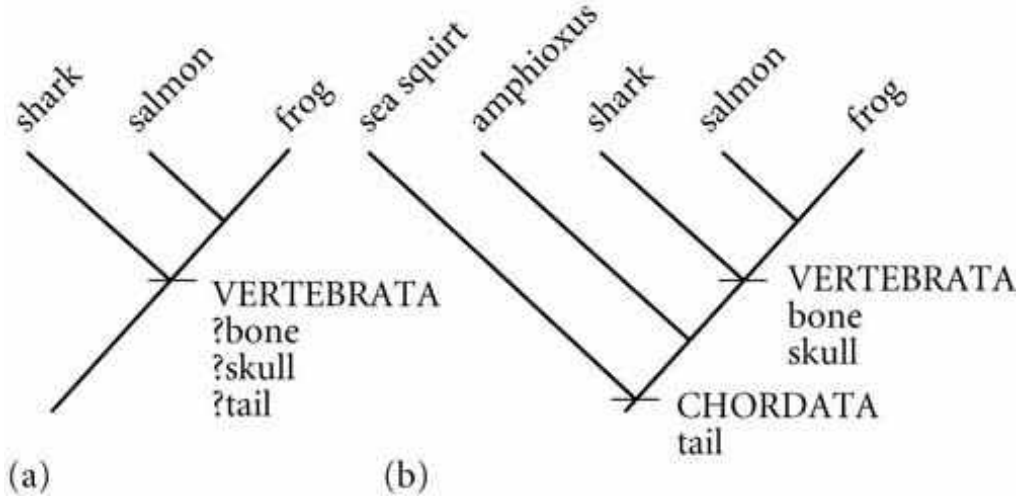
- **Willi Hennig (1913–1976), an eminent German entomologist, stressed the need to develop a new, more objective method in systematics,**

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Cladistics

- **The fundamental aim of cladistics is to identify clades, and so to discover, or reconstruct, the tree of life.**
- **Patterns of relationships are shown as branching**

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Reconstructing the phylogeny of vertebrates by cladistic methods. (a) Are the defining features of vertebrates the possession of bone, a skull and a tail? (b) The tail is found in a wider group, termed the Chordata, but the skull and bone define the Vertebrata

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Nodes

- **The most closely related species are joined most closely.**
- **The branches in the cladogram join at branching points, or**

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Apomorphies

- **Hennig called the phylogenetically informative characters "Apomorphies" or derived characters**
- **Apomorphies are features that arose**

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Synapomorphies

- **"Apomorphies" shared by two or more species are termed synapomorphies**
- **Synapomorphies of Order Psittaciformes include the deep, hooked**

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Older distinctions

- **"Homology" and "Analogy"**
- **Vertebrate Limbs**
- **Wing of bird, paddle of whale arm of human are the same. Homologs.**
- **Peddles of**

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Molecular Revolution

- **Birth of Molecular Biology 1950s and 1960s**
- **Comparisons of molecules allow analysts to do two things:**

1. **To draw up trees of**

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Dendrograms

- **Trees of relationships can be based on a comparison of the amount of difference between protein sequences, and a best-fitting dendrogram,**

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Molecular Clocks

- **Time estimation comes from the concept of the molecular clock.**
- **The amount of difference in the fine structure of a protein is proportional to the time since**

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Nucleic Acids

- **The nucleic acid sequences must be aligned, that is matched, so that the code of a particular gene in one species is lined up with the same sequence in**

END

Fossils form and function

Fossil form and Function

Fossils form and function

Fossil species

- **Fossil species are identified according to their external form; this is termed the morphological species concept.**
- **Variations in form include normal levels of**

Fossils form and function

Fossil species

- **The other types of variations in the forms of the fossils include**
- **Geographic distribution**
- **Sexual dimorphism**
- **Different growth stages**
- **ecophenotypic variation**

Fossils form and function

Allometry

- **Fossil species may show allometry, or changes in relative proportions during growth;**
- **Specific organs may show positive (grow faster) or negative (grow**

Fossils form and function

Development and Phylogeny

- **The development of an organism may give some evidence about phylogeny.**
- **Changes in developmental rates and timing (heterochrony)**

Fossils form and function

The New "Evo-Devo" Perspective

- **shows how certain developmental genes control fundamental aspects of form**
  - **Symmetry**
  - **Front–back orientation**
  - **Segmentation**

Fossils form and function

Inferring function from ancient organisms

- **Is difficult**
- **Various methods of doing this:**
- **Comparison with modern analogs**
- **Biomechanical testing**
- **Circumstantial**

Fossils form and function

Modern analogs

- **Modern analogs may provide exact parallels with some fossil organisms**

- **More often they provide only principles or**

Fossils form and function

Biomechanical models

- **May be used to assess how the design of an ancient organism matches the hypothetical forces acting on it**

Fossils form and function

Biomechanical models

- **May be used to assess how the design of an ancient organism matches the hypothetical forces acting on it**
- **Models of locomotion**

Fossils form and function

Biomechanical models

- **Circumstantial evidence, such as**

1. **The enclosing rocks**
2. **Associated fossils**
3. **Trace fossils and**
4. **Close study of the fossils themselves**

END

Fossils form and function

Growth and Form

Fossils form and function

Evolution and Form:

- **Darwin gave us an evolutionary view of form.**
- **He was astonished by**
- **The variety of external appearances**
- **By their wonderful adaptations**

Fossils form and function

Form

- **The form, or external appearance, of any microbe, plant or animal is shaped by evolution.**
- **Wings for flight**
- **Longs beak**

Fossils form and function

Sexual Selection

- **Sexual selection is the set of evolutionary processes that depend on interactions between the sexes.**
- **Example: The astonishing tails and colors of male birds**

Fossils form and function

Adaptations

- **Plants and animals have adaptations that function in the context of both natural and sexual selection**
- ***An adaptation is an aspect of form that performs a physical or***

Fossils form and function

Importance of Form

- **The form of fossils is important for three reasons**
  1. **Form is the only evidence we have in fossils for identifying species and wider relationships**

Fossils form and function

Importance of Form

2. **Form can tell us about behavior and ecology**

3. **The study of changes in form through time informs us about evolution**

Fossils form and function

Recognizing ancient species

- **Paleontologists use the morphological species concept**
- **Statistical observations define the mean or average characteristics in a specie**

END

Fossils form and function

Growth and Form (Continued)

Fossils form and function

Variations Within the Species

- **Within a species, there may be a range of morphologies**
  - **Individual variation**
  - **The stuff of natural selection, as Darwin**

Fossils form and function

Variations Within the Species

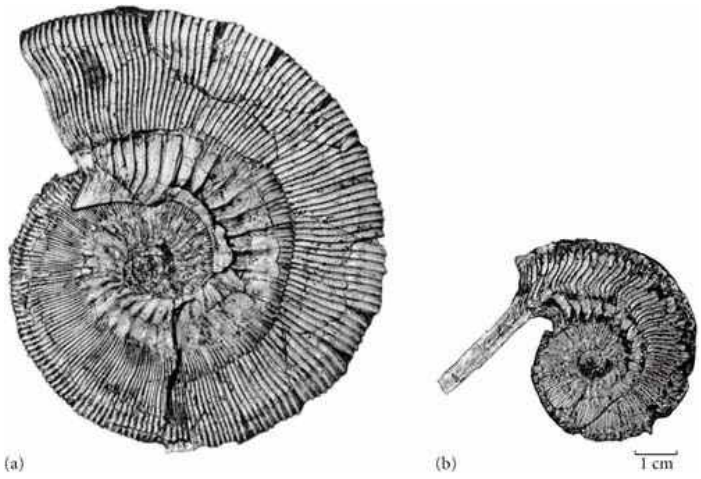
- **Geographic variation and physical differences between populations or subspecies in different parts of the overall species**

Fossils form and function

Variations Within the Species

- **Sexual dimorphism, in which males and females may show different sizes, and different specialized features (horns, antlers, tail feathers)**

Fossils form and function



Sexual dimorphism in ammonites, the Jurassic Kosmoceras. The larger shell (a) was probably the female, the smaller (b) the male. (Courtesy of Jim Kennedy and Peter Skelton.)

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Fossils form and function

Variations Within the Species

- **Growth stages, where there may be quite different larval and adult stages, or where body form alters during growth**

Fossils form and function

Variations Within the Species

- **Ecophenotypic effects,**
- **Where local ecological conditions affect the form of an organism during its lifetime**

Fossils form and function

Allometry

- **Changes in form during growth are common.**
- **Think of human growth: babies have relatively large heads and eyes, and small limbs**

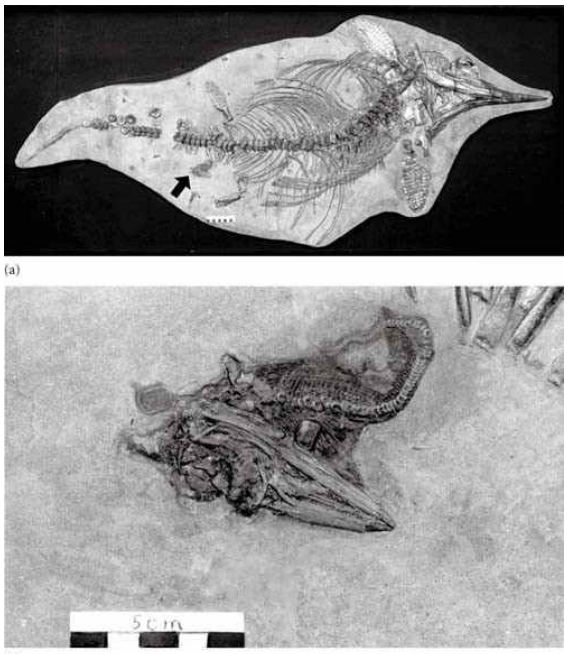
Fossils form and function

Allometry

- **If measurements of the variable parts are scaled against a standard measure of the animal, it is evident that the proportions change as the**

Fossils form and function

Adult female Ichthyosaurus (a) from the Lower Jurassic of Somerset, England, showing an embryo that has just been born (arrow), and detail of the curled embryo (b). (Courtesy of Makoto Manabe.)



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Fossils form and function

Allometric Growth

- **The ratio of eye diameter to body length diminishes as the animal approaches adulthood.**
- **This is an example of allometric ("different**

Fossils form and function

Isometric Growth

- **If there is no change in proportions during growth, the feature is said to show isometric (“same measure”)**

Fossils form and function

Biological Scaling Principle

- **Some organs and functions relate to the mass of an animal (a three-dimensional measure)**
- **others relate to body length or body outline (one- and two-dimensional**

END

Fossils form and function

Evolution and Development

Fossils form and function

Ontogeny and Phylogeny

- **Biologists have long sought a link between ontogeny (development) and phylogeny (evolutionary history)**

Fossils form and function

Biogenetic Law

- **In 1866, Ernst Haeckel, a German evolutionist, announced his Biogenetic Law, that "ontogeny recapitulates phylogeny".**

Fossils form and function

Biogenetic Law

- **Ernst Haeckel's idea was that the sequence of embryonic stages mimicked the past evolutionary history of an**

Fossils form and function

Von Baer's Law

- **A parallel between the sequence of development, and a cladogram.**
- **In human development embryo passes through the major nodes of the cladogram of vertebrates.**

Fossils form and function

Von Baer's Law

- **The synapomorphies of vertebrates appear first, then those of tetrapods, then those of amniotes, then those of mammals, of primates, and of the species**

Fossils form and function

Development and Phylogeny

- **Three other aspects of development throw light on phylogeny**
- **Atavisms**
- **Vestigial structures**
- **Patterns of Development**

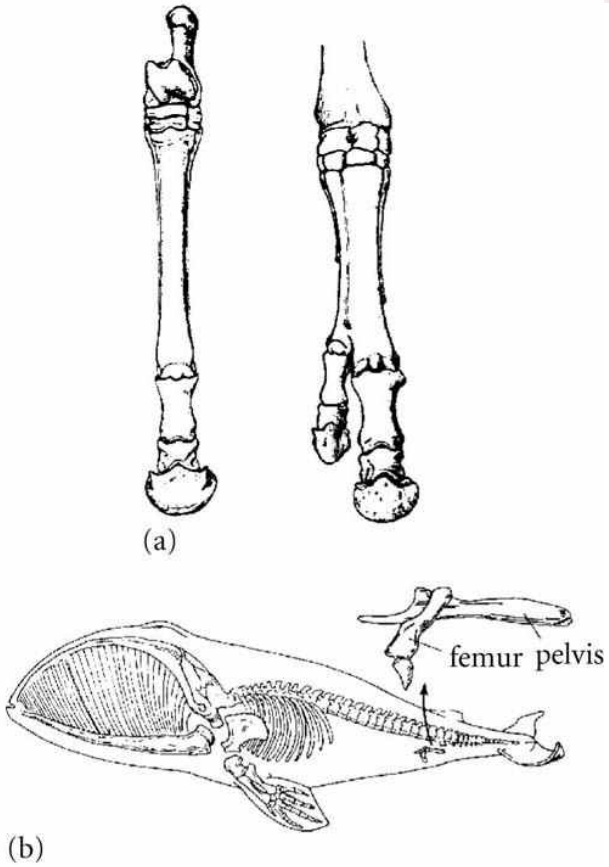
Fossils form and function

Atavisms

- **Certain developmental abnormalities called atavisms, or throwbacks, show former stages of evolution, such as human babies with small tails or**

Fossils form and function

Hints of ancestry in modern animals. (a) Extra toes in a horse; normal horse leg (left), extra toes (right). (b) The vestigial hip girdle and hindlimb of a whale; the rudimentary limb is the rudiment of a hindlimb that functioned



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Fossils form and function

Developmental Genes

- **Widely shared among organisms**
- **Determine aspects of form**
- **Symmetry**
- **Anteroposterior orientation**
- **Limb differentiatio**

Fossils form and function

END

Developmental Genes

- **Since the 1980s a major new research field “evodevo” (short for evolution–development)**
- **Most famous developmental genes are**

Mass extinctions and biodiversity loss

Introduction

Mass extinctions and biodiversity loss

Mass Extinctions

- **During mass extinctions, 20–90% of species were wiped out; these include a broad range of organisms, and the events appear to have happened rapidly.**

Mass extinctions and biodiversity loss

Mass Extinctions

- **It is difficult to study mass extinctions in the Precambrian**
- **There have been a Neoproterozoic event between the Ediacaran and Early Cambrian**

Mass extinctions and biodiversity loss

Mass Extinctions

- **The "big five" Phanerozoic mass extinctions occurred in the**
- **End-Ordovician**
- **Late Devonian**
- **End-Permian**
- **End-Triassic**
- **End-Cretaceous**

Mass extinctions and biodiversity loss

Mass Extinctions

- **The end-Permian mass extinction was the largest of all time**
- **Probably caused massive volcanic eruptions, leading to acid rain and global anoxia**

Mass extinctions and biodiversity loss

Mass Extinctions

- **The end-Cretaceous mass extinction has been most studied, and it was probably caused by a major impact on the Earth.**

Mass extinctions and biodiversity loss

Mass Extinctions

- **Smaller-scale extinction events include the loss of mammals at the end of the Pleistocene, perhaps the result of climate change and human hunting.**

Mass extinctions and biodiversity loss

Recovery from Mass Extinctions

- **Takes a long time**
- **First, some unusual disaster taxa that cope well in harsh conditions**
- **Gives way to the longer-lived taxa that**

Mass extinctions and biodiversity loss

Major Concern Today

- **Calculated species loss as high as during any mass extinction of the past.**
- **The severity of the current extinction episode is still debated.**

END

Mass extinctions and biodiversity loss

Mass Extinctions

Mass extinctions and biodiversity loss

Extinction

- **Extinction, is now a key theme in discussions about the future**
- **The dodo is perhaps the most iconic of icons**
- **An icon of human**

Mass extinctions and biodiversity loss

An image of a dodo from another era. Lewis Carroll introduced the dodo as a kindly and wise old gentleman in Alice Through the Looking Glass, although at the time most people probably regarded the dodo as rather foolish. Driven to extinction in the 17th century by overhunting, the dodo is now an image of human



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Mass extinctions and biodiversity loss

Mass Extinctions

- **The most spectacular extinctions are known as mass extinctions**
- **Times when a large cross-section of species died out rather rapidly.**

Mass extinctions and biodiversity loss

Extinctions Events

- **There may have been only five or six mass extinctions throughout the known history of life, although there were many extinction events,**

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Study of Mass Extinctions

- **From the 1980s**
- **Wide interdisciplinary links**
- **Stratigraphy**
- **Geochemistry**
- **Climate modeling**
- **Ecology**
- **Conservation**
- **Astronomy**

Mass extinctions and biodiversity loss

Study of Mass Extinctions

- **The study of mass extinctions involves careful hypothesis testing at all levels, from the broadest scale to the narrowest**

Mass extinctions and biodiversity loss

Back ground Extinctions

- **Extinction happens all the time**
- **Species have a natural duration of few million years and so they live for a time and then disappear**

Mass extinctions and biodiversity loss

Features of Mass Extinction

- **More than 30% of plants and animals of the time.**
- **The extinct organisms spanned a broad range of ecologies**

Mass extinctions and biodiversity loss

Features of Mass Extinction

- **The extinctions were worldwide covering most continents and ocean basins.**
- **The extinctions all happened within a relatively short time**

Mass extinctions and biodiversity loss

Features of Mass Extinction

- **The level of extinction stands out as considerably higher than the background extinction level.**

END

Mass extinctions and biodiversity loss

Mass Extinctions (Continued)

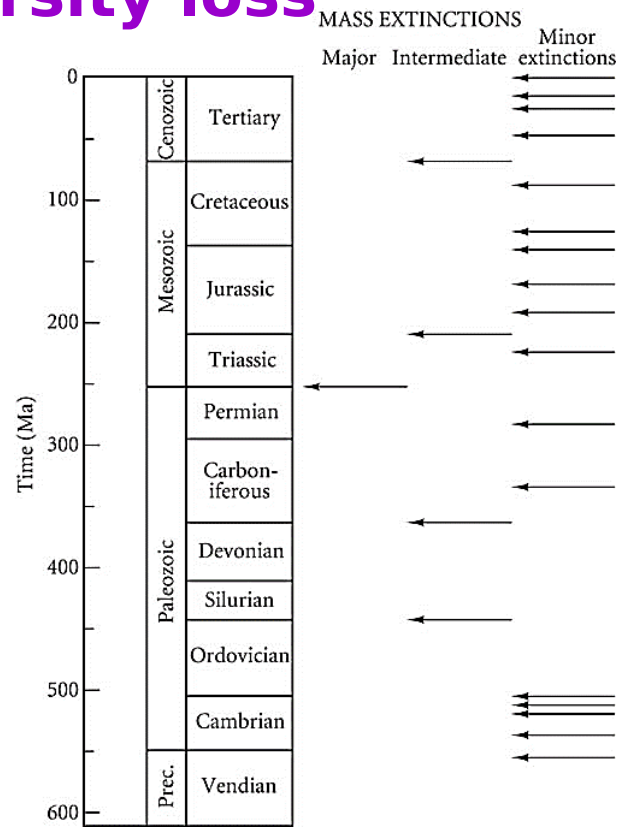
Mass extinctions and biodiversity loss

Mass Extinctions

- **Paleontologists talk about the “big five” mass extinctions of the last 540 myr**
- **The Phanerozoic, and the current extinction crisis is**

Mass extinctions and biodiversity loss

Mass extinctions through the past 600 myr.
Major: 50% of families and up to 96% of species
Intermediate: global in extent, and involved losses of 20% of families and 75–85% of species. Minor mass extinctions: causing losses of 10% of families and up to 50% of species



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Mass extinctions and biodiversity loss

Patterns and Timings

- **Good-quality fossil records indicate a variety of patterns of extinction**
- **The rock record can be misleading**
- **Gradual extinctions**

Mass extinctions and biodiversity loss

Signor–Lipps effect

- **Paleontologists will never find the very last fossil of a species.**
- **Signor and Lipps showed how this backward smearing now termed the Signor–Lipps**

Mass extinctions and biodiversity loss

Selectivity and mass extinctions

- **The second defining character of mass extinctions was that they should be ecologically catholic**
- **There should be little**

Mass extinctions and biodiversity loss

Periodicity of mass extinctions

- **Fundamental debate has been whether each event had its own unique causes, or whether a unifying principle linking all mass extinctions**

Mass extinctions and biodiversity loss

Periodicity of mass extinctions

- **The idea of periodicity of impacts was reawakened by Rohde and Muller (2005) who argued for a 62 myr periodicity in mass extinction**

END

Mass extinctions and biodiversity loss

The “Big Five” Mass Extinction Events

Mass extinctions and biodiversity loss

The “big five” or the “big three”?

- **There is some debate about whether there were five or three mass extinctions**
- **Key points about three of the five**

Mass extinctions and biodiversity loss

End-Ordovician mass extinction

- **445 Ma**
- **Substantial turnovers occurred among marine faunas**
- **Reef-building animals, brachiopods, echinoderms, ostracodes trilobites died out**

Mass extinctions and biodiversity loss

End-Ordovician mass extinction

- **Major Climatic changes**
- **Tropical-type reefs and their rich faunas lived around the shores of North America that then lay around the equator**
- **Southern glaciation and**

Mass extinctions and biodiversity loss

Late Devonian mass extinction

- **A succession of extinction pulses 380 to 360 Ma**
- **The cephalopods were decimated**
- **Causes: A major cooling phase associated with anoxia or an extraterrestrial impact**

Mass extinctions and biodiversity loss

The end-Triassic mass extinction

- **The fourth of the big five mass extinctions**
- **A marine mass extinction event at, or close to, the Triassic-Jurassic boundary, 200 Ma**
- **Anoxia and global warming**

Mass extinctions and biodiversity loss

Rest of Mass Extinctions

- **The third and fifth of the "big five" were the**
- **Permo-Triassic (PT)**
- **Cretaceous-Tertiary (KT) events**

Mass extinctions and biodiversity loss

The Permo-Triassic event

- **The end-Permian, or Permo-Triassic, extinction was the most devastating of all time**
- **Less understood than KT event**

Mass extinctions and biodiversity loss

The Permo-Triassic event

- **The peak of eruptions by the Siberian Traps was dated at 251 Ma, matching precisely the date of the PT boundary**
- **Environmental changes**

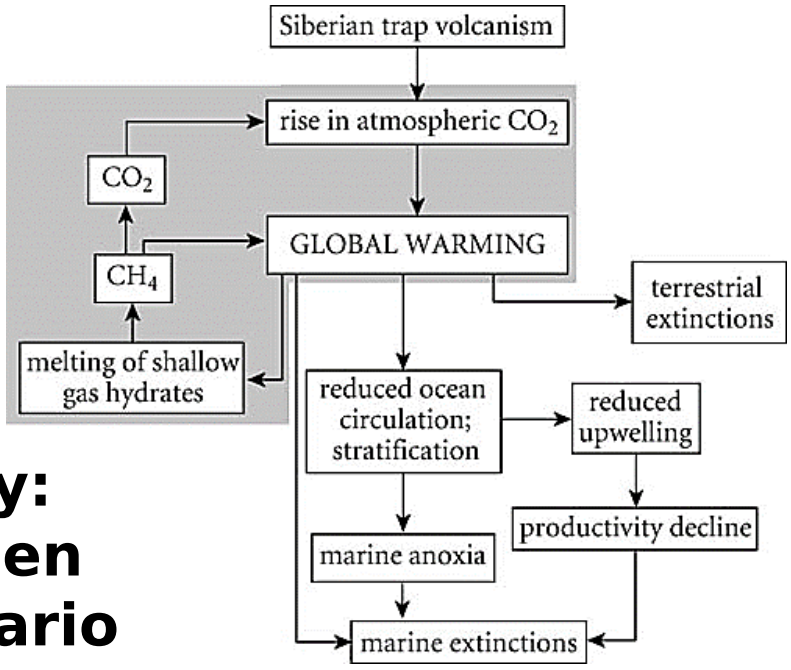
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The Permo-Triassic event

- **studies of stable isotopes (oxygen, carbon) in those rock sections revealed a common story of environmental**

Mass extinctions and biodiversity loss

The possible chain of events following the eruption of the Siberian Traps



Shaded Grey: Runway Green House Scenario

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Mass extinctions and biodiversity loss

The Cretaceous-Tertiary event

Mass extinctions and biodiversity loss

The KT event

- **Intense scrutiny since 1980**
- **Reasonable theories (global climate change, change in plants, impact, plate tectonic**

Mass extinctions and biodiversity loss

The KT event

- **June 1980, paper in Science by Luis Alvarez and colleagues**
- **10 km meteorite (asteroid) had hit the Earth**
- **The impact threw up a great cloud of**

Mass extinctions and biodiversity loss

The KT event

- **An unusual clay band right at the KT boundary, within a succession of marine limestones**
- **Iridium spike: where the iridium content shot**

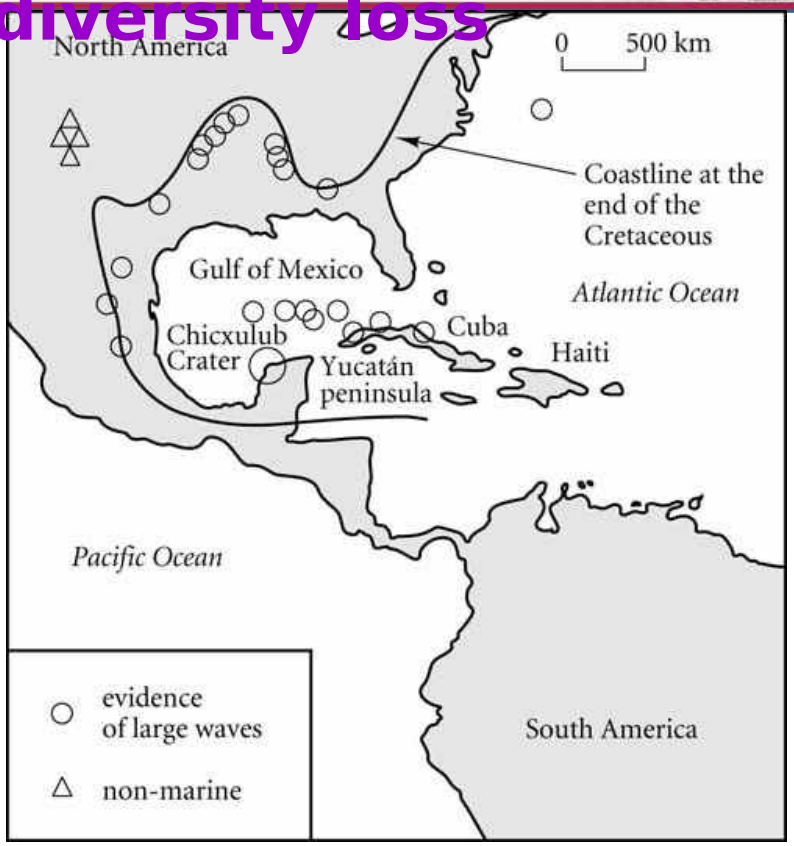
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The KT event

- **Alvarez Predictions: 150KM crater, 10 KM Diameter of Meteorite**
- **1991, Crater was identified in Chicxulub in Mexico**

Mass extinctions and biodiversity loss

The KT impact site identified. Location of the Chicxulub Crater on the Yucatán peninsula



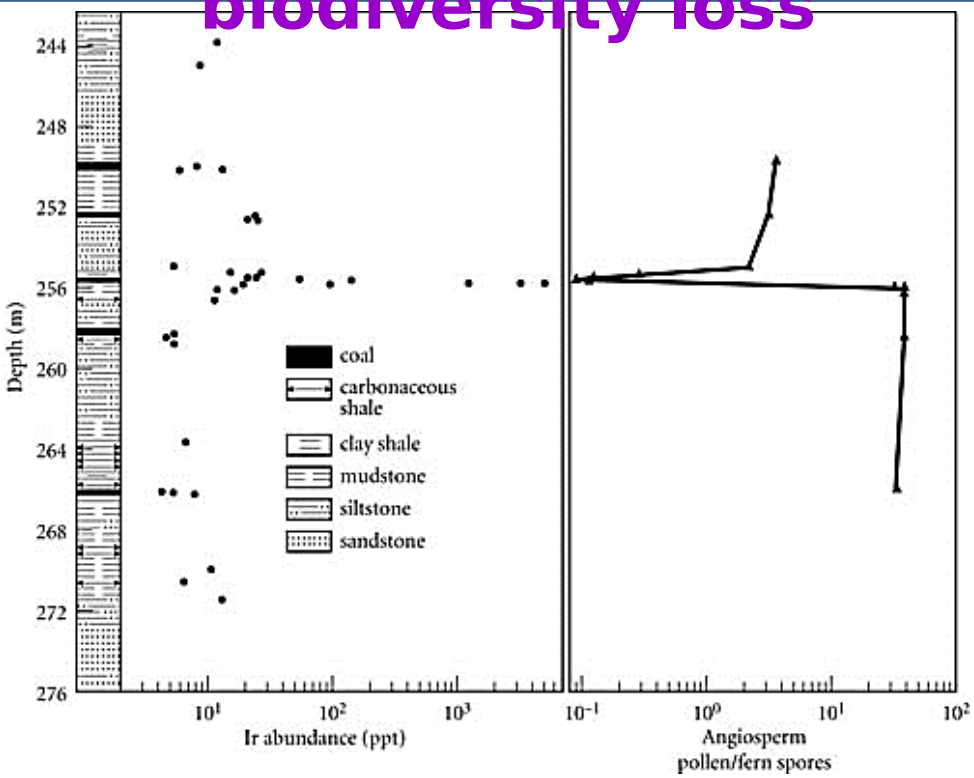
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Mass extinctions and biodiversity loss

The KT event

- **Catastrophic Extinction in plants, lower level of pollens, sudden loss of angiosperms and replacement with ferns**
- **Progressive return to**

Mass extinctions and biodiversity loss



The Iridium (Ir) spike and Fern spike

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Mass extinctions and biodiversity loss

Another Alternative

- **The gradualist model**
- **Extinctions occurred over long intervals of time as a result of climatic changes**

Mass extinctions and biodiversity loss

Another Alternative

- **On land, subtropical lush habitats with dinosaurs gave way to strongly seasonal, temperate, conifer-dominated habitats with**

Mass extinctions and biodiversity loss

Third school of Thought

- **Volcanic activity**
- **The Deccan Traps in India represent a vast outpouring of lava that occurred over the 2–3 myr**

END

The Origin of Life

Introduction

The Origin of Life

RNA world

- **By fusion of organic molecules in the first billion years after the formation of the Earth**
- **Self-replicating RNA "RNA**

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The Origin of Life

- **Photosynthesis by a group of bacteria, called cyanobacteria, generated molecular oxygen (O2)**
- **The atmosphere became oxygenated**

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Three great domains

- **By gene sequencing of modern organisms,**
- **Bacteria, Archaea and Eucarya**
- **The first two are prokaryotes, the last**

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The Earliest Fossils

- **Bacteria in rocks up to 3.2 Ga, indicated by stromatolites**
- **Structures built by alternating algal mats and sediment**

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Cellular Organism

- **Cellular fossils 3.5 Ga are highly controversial**
- **The first widely accepted cellular fossils date**

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Origin of Eukarya

- **Lipids Biomarkers, evidence for cyanobacteria and eukaryotes 2.7 Ga**
- **The oldest eukaryotes, 1.9 Ga**

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Origin of Sexes

- **Red algae from 1.2 Ga show that sex had originated**
- **They show mitosis, but also meiosis, which is unique to sexual**

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Origin of Multicellularity

- **Together with sex came multicellularity**
- **The possession of many, often specialized,**

END

The Origin of Life

Scientific Methods

The Origin of Life

Scientific models

- **Some of them now rejected by the evidence**
- **Others still available as potentially valid hypotheses:**

1. **Spontaneous generation**
2. **Inorganic**

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Scientific models

3. **Extraterrestrial origins**
4. **Biochemical model**
5. **Hydrothermal model**

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Spontaneous generation

- **Medieval scholars**
- **Organisms sprang into life directly from nonliving matter**
- **Pasteur, 1861**
- **Meat in airtight containers: maggots did**

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The inorganic model

- **Complex organic molecules arose gradually on a pre-existing, non-organic replication platform**
- **Silicate crystals**
- **Graham Cairns-Smith of**

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Extraterrestrial Model

- **The building blocks for life were seeded on Earth from outer space**
- **Simple organic molecules in meteorites called carbonaceous chondrites**
- **Panspermia**

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Biochemical Model

- **1920s, independently**
- **Russian biochemist, A. I. Oparin**
- **British evolutionary biologist, J. B. S. Haldane**

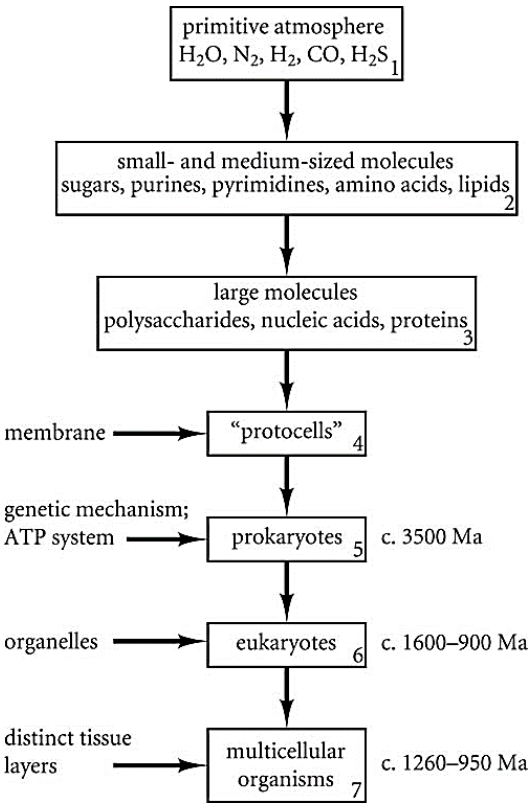
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Biochemical Model

- **Life could have arisen through a series of organic chemical reactions that produced ever more complex biochemical structures**
- **Biochemical theory of**

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The biochemical theory for the origin of life, as proposed by Oparin and Haldane in the 1920s. Biochemists have achieved steps 1–3 in the laboratory, but scientists have so far failed to create life



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Hydrothermal Model

- **Modification to the Oparin–Haldane biochemical model**
- **The last universal common ancestor of life (LUCA) was a hyperthermophile, a simple organism that**

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Hydrothermal Model

- **Seawater mixes with molten magma and emerges as superheated steam, with the sulfur in it now concentrated as sulfide**
- **Emerging hot-water plume black**

END

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Testing the Biochemical Model

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Stanley Miller

- **In 1953, then a student at the University of Chicago, made a model of the Precambrian atmosphere and ocean in a laboratory glass vessel**

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Stanley Miller

- **Exposed a mixture of water, nitrogen, carbon monoxide and nitrogen to electric sparks, to mimic lightning,**
- **Found a**

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Brownish Sludge

- **Contained sugars, amino acids and nucleotides**
- **Researchers consider the mixture of gases that Miller used was strongly chemically reducing**

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Further Experiments

- **in1950s and 1960s led to the production of polypeptides, polysaccharides and other larger organic molecules**

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Protocells of Sidney Fox

- **FSU, Succeeded in creating cell-like structures, in which a soup of organic molecules became enclosed in a membrane**
- **Didn't survive**

END

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RNA World

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Precellular Life

- **The transition from non-living to living**
- **No a single Step**
- **What then could have been the transitional form of “precellular” life?**
- **widely**

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RNA

- **RNA, or ribonucleic acid, is one of the nucleic acids and it has key roles in protein synthesis**
- **The genetic code**
- **There are several**

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RNA the Precursor

- **In 1968, Francis Crick suggested that RNA was the first genetic molecule**
- **RNA has unique property of acting both as a gene and an**

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RNA World

- **Walter Gilbert first used the term “RNA world” in 1986**
- **The first evidence**
- **Sidney Altman and Thomas Cech**

The Origin of Life

Ribozyme

- **An RNA that could edit out unnecessary parts of the message it carried before delivering it to the ribosome.**
- **Cech called his discovery a ribozyme**

The Origin of Life

Ribozyme

- **An RNA that could edit out unnecessary parts of the message it carried before delivering it to the ribosome.**
- **Cech called his discovery a ribozyme**

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Chasing Evidence

- **Since 1990,**
- **Jack Szostak and colleagues argued that the first RNA molecules on the prebiotic ("before life") Earth were assembled from nucleotides**

The Origin of Life

Chasing Evidence

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- **Jack Szostak and colleagues argued that the first RNA molecules on the prebiotic ("before life") Earth were assembled from nucleotides**

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RNA Replicase

- **One RNA acted as a Template and another Enzyme**
- **Combine as an RNA replicase**
- **Szostak and colleagues proposed a second precellular structure, "A**

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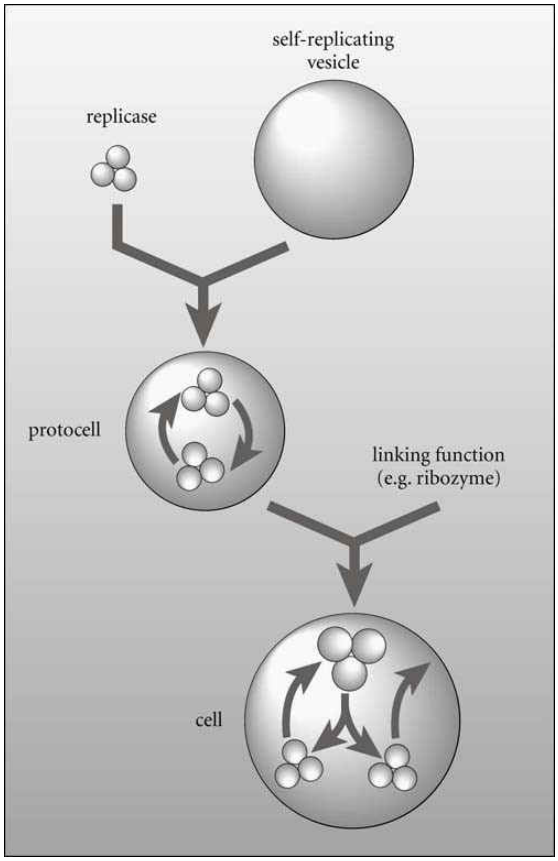
Protocell

- **A membrane-bound structure composed mainly of lipids that self-replicates**
- **The RNA replicase entered a self-replicating vesicle**

END

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The model behind "RNA world", where an RNA replicase and a self-replicating membrane-bound vesicle combine to form a protocell



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Evidence for the Origin of Life

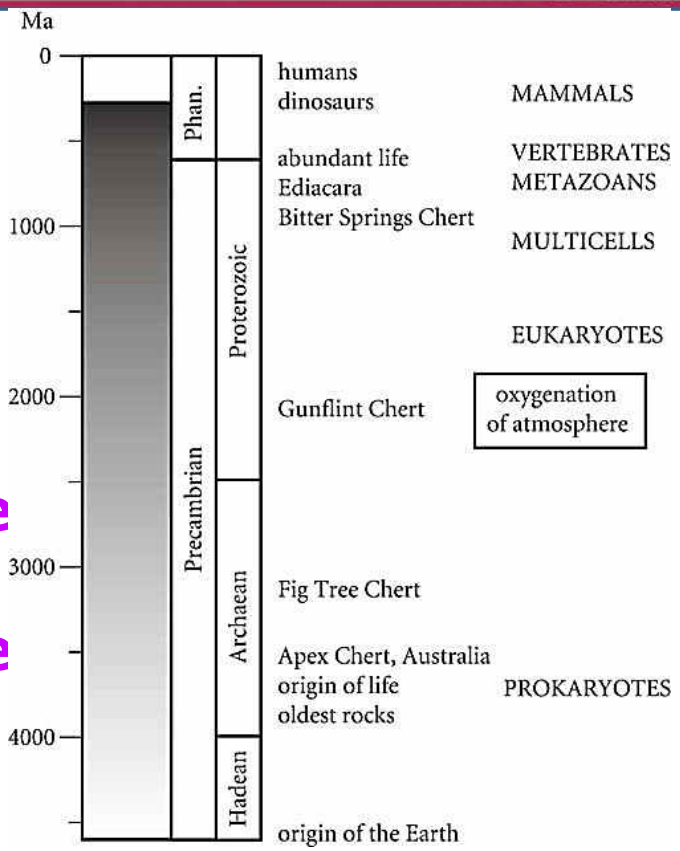
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The Early Precambrian world

- **The Precambrian is divided into**
- **Hadean eon**
- **Archaean eon**
- **Proterozoic eon**
- **Hadean Eon spans from the origin of the Earth, 4.57 to about**

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Time scale showing major events in the history of the Earth and of life. Most of the time scale is occupied by the Precambrian



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Precambrian world

- **Beginning of the Hadean**
- **Temperatures on surface were too high**
- **The crust was too unstable for any form of carbon-based life to exist.**

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Cooling of Earth

- **As the Earth's surface cooled, the lithosphere, its rocky crust, began to differentiate as a cooler upper layer above the**

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Oldest Rocks

- **The oldest rocks are from Canada and are dated at 3.8–4 Ga, and some mineral grains from Australia have even been dated to 4.4 Ga**

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The Archaean Eon

- **Lasted from about 4 to 2.5 Ga.**
- **The oldest sedimentary rocks from the Isua Group in Greenland, dated at 3.8–3.7 Ga**

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The Archaean Eon

- **Rosing and Frei (2004)**
- **Reported values of δ13C in organic matter from the Isua Group rocks that match those of modern living**

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The Great Oxygenation Event

- **The Proterozoic Eon, from 2.5 Ga to 542 Ma**
- **2.4 Ga, atm oxygen levels rose to one-hundredth or one-tenth of modern levels**

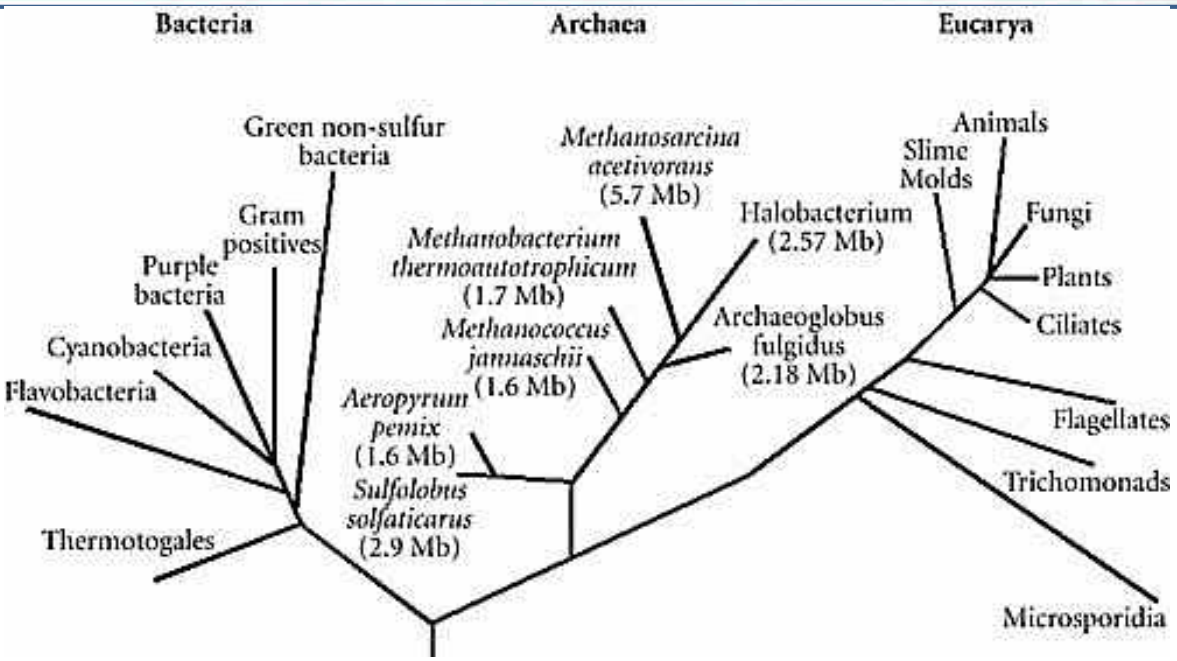
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A Second Rise of Oxygen

- **around 0.8–0.6 Ga is indicated by increased levels of marine sulfate**
- **The two rises in oxygen levels, at the beginning**

END

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The Universal Tree of Life based on molecular phylogenetic work.

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Life Diversifies: Eukaryotes

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Eukaryote Characters

- **Evidence about the earliest evolution of the three domains is scant**
- **Nucleus: DNA in chromosomes**
- **Cell**

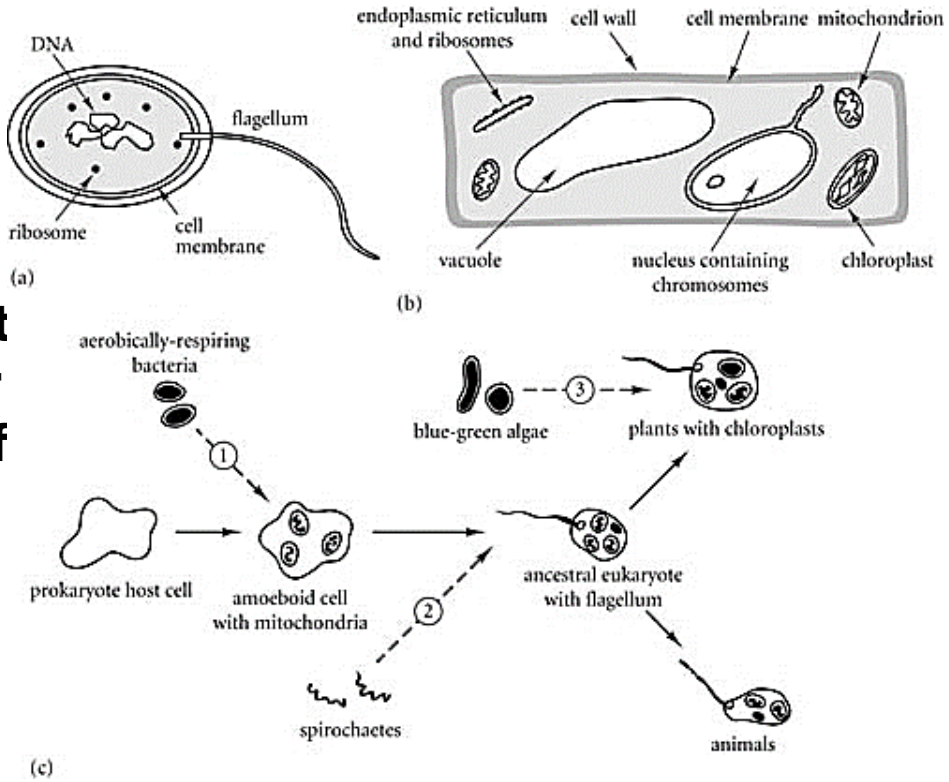
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Endosymbiotic Theory

- **Margulis: 1970s.**
- **Prokaryote consumed, or was invaded by, prokaryotes**
- **Two species evolved together in a mutually beneficial**

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The Endosymbiotic Theory for the Origin of Eukaryotes



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The Origin of Life

Basal Eukaryotes

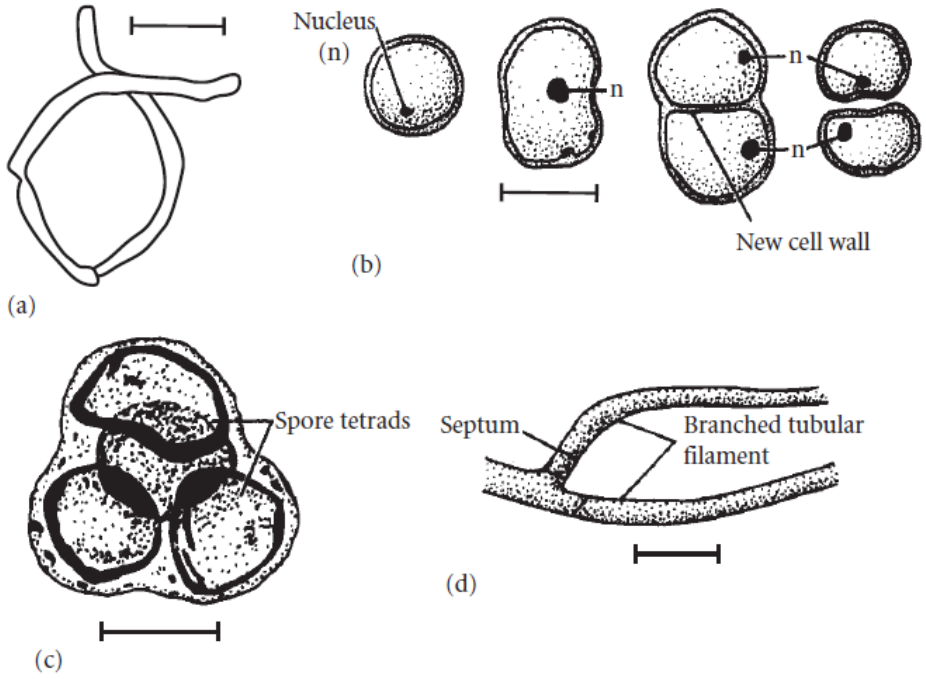
- **The oldest eukaryote is controversial**
  Lipid biomarkers indicate that eukaryotes were around at least by 2.7 Ga

The Origin of Life

Basal Eukaryotes

- **The oldest eukaryote fossil may be Grypania,**
- **A coiled, spaghetti-like organism that has been reported from rocks as old as 1.85 Ga**

The Origin of Life



Early fossil "Eukaryotes".

http://www.blackwellpublishing.com/bookcontent/figure2.asp?bid=08&fig=Fig8-9&img=c08f011

The Origin of Life

Multicellularity and sex

- **True multicellular organisms arose only among the eukaryotes.**
- **Allowed plants and animals to become large (kelp, reach**

The Origin of Life

Multicellularity and sex

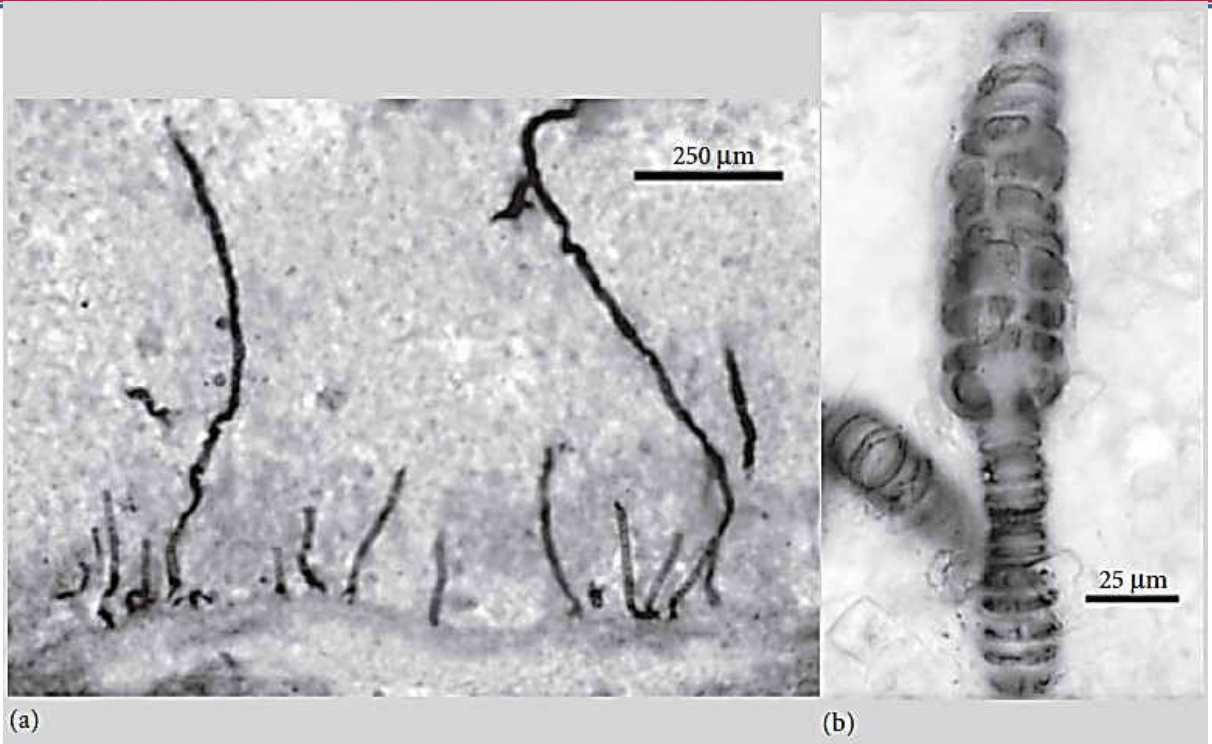
- **Sexual reproduction involves the exchange of gametes (sperms and eggs) between organisms**

The Origin of Life

Bangiomorpha

- **One of the oldest multicellular organisms is Bangiomorpha**
- **1.2 Ga**
- **Multicellular and a member of a modern group that engages**

The Origin of Life



The oldest multicellular eukaryote, Bangiomorpha,

http://www.blackwellpublishing.com/content/BPL_Images/Content_store/Sample_chapter/0632030674/08/c08f013.jpg?chapter=08&fig=Fig8-9&img=c08f013

Protists

Introduction

Protists

Micropaleontology

A multidisciplinary science, focused on the study of microorganisms or the microscopic parts of larger organisms.

Protists

Prokaryotes

- **Unicellular microbes lacking nuclei and organelles, include the carbonate producing cyanobacteria**
- **Promoted an oxygen-rich**

Protists

Protists

- **Unicellular organisms with nuclei, a variety of organisms with external protective coverings (tests and cysts)**
- **Kingdoms Protozoa and**

Protists

Fossilized Protists

- **Split into**
- **Organic (acritarchs, dinoflagellates, chitinozoans),**
- **Calcareous (coccolithophores, foraminiferans)**
- **Siliceous (diatoms**

Protists

Foraminifera

- **Single-celled animal-like protozoans**
- **Contain both benthic and planktonic form**
- **With chitinous, agglutinated tests throughout the**

Protists

Rock Formers

- **Radiolarians: animal-like protozoans with siliceous tests,**
- **Diatoms: plant-like protozoans with silicic skeletons**
- **Both important**

END

Protists

Kingdom
Protista

Protists

Kingdom
Protista

- **Single-celled organisms with nuclei and organelles**
- **Autotrophs**
- **Heterotrophs**
- **The Protista is a convenient grouping but it is not well**

Protists

Kingdom Protista

- **Subdividing the diversity of protists is equally problematic**
  - **On the basis of Trophism**
  - **Phylogenetic**
  - **Mode of locomotion**
- **Flagellates and**

Protists

The First Protists

- **Heterotrophs, but chloroplasts were acquired separately in at least six lineages, producing autotrophs,**
- **Lost secondarily even more**

Protists

The First Protists

- **Heterotrophs, but chloroplasts were acquired separately in at least six lineages, producing autotrophs,**
- **Lost secondarily even more**

Protists

The First Protists

- **Groups with microfossil records are widely scattered across the diversity of protists**
- **Modern molecular genetic and cytologic**

END

Protists

Protozoa

Protists

Protozoans

- **Neither animal nor plant, but single-celled eukaryotes that show animal characteristics such as motility and heterotrophy**
- **Able to form**

Protists

Foraminifera

- **Foraminifera are shelled & heterotrophic**
- **Phanerozoic sedimentary rocks**
- **Considerable bio stratigraphic and paleoenviron**

Protists

Radiolaria

- **The radiolarians are marine, unicellular, planktonic protists with delicate skeletons**
- **Usually composed of a framework**

Protists

Radiolaria

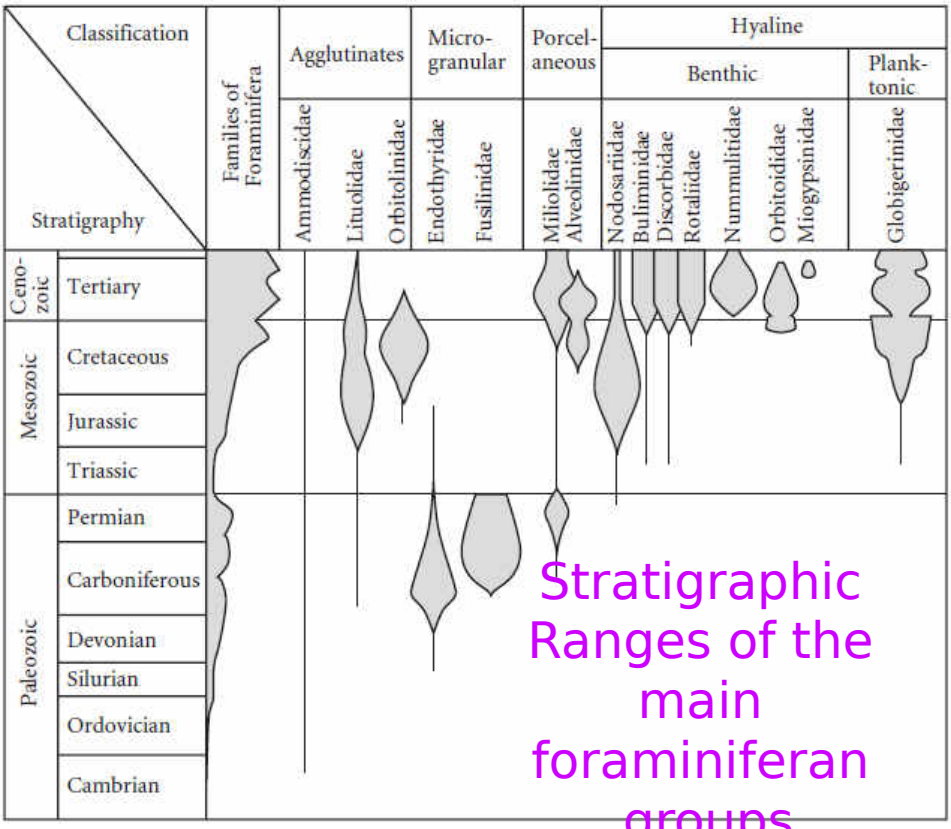
- **Origin in the Mid Cambrian or earlier**
- **Became common in the Ordovician**
- **Often found in deep-sea cherts associated with major**

Protists

Radiolaria

- **Radiolarian cherts commonly occur in oceanic facies preserved in mountain belts**
- **associated with ophiolites**
- **origins and**

Protists



Stratigraphic Ranges of the main foraminiferan groups

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=09&fig=Fig9-8&img=c09f008

Protists

Acritarchs

- **A mixed bag of entirely fossil, hollow, organic-walled microfossils that are impossible to classify**
- **The acritarchs are probably polyphyletic**

Protists

Acritarchs

- **A mixed bag of entirely fossil, hollow, organic-walled microfossils that are impossible to classify**
- **The acritarchs are probably polyphyletic**

Protists

Dinoflagellates

- **The dinoflagellates, or "whirling whips", comprise a group of microscopic algae with organic-walled cysts.**

Protists

Dinoflagellates

- **Dinoflagellate biomarkers have been identified in Upper Proterozoic and Cambrian rocks.**
- **A number of Paleozoic acritarch taxa may in fact be**

Protists

Ciliophora

- **Consist of some 8000 species of single-celled organisms that swim by beating cilia**
- **Tithonian (Upper Jurassic) to the Albian (Middle Cretaceous)**

END

Protists

Chromista

Protists

Chromistans

- **A paraphyletic group of eukaryotes that usually contains chloroplasts with chlorophyll c**
- **Chlorophyll c is absent from all known plant**

Protists

Chromistans

- **The group includes various algae, the coccolithophores and the diatoms**
- **Primary producers, functioning as part of the phytoplankto**

Protists

Nannoplankton

- **Defined as plankton less than 63 µm across, the smallest standard mesh size for sieves**
- **Includes organic-walled and siliceous**

Protists

Coccolithophores:

- **Dominant members of the fossil calcareous nannoplankton, and calcareous plates**
- **Coccoliths**
- **Dominate nannofossil assemblages**

Protists

Coccolithophores:

- **Calcareous nannoplankton**
- **Appeared: Late Triassic**
- **Increased: Jurassic and Cretaceous**
- **Reaching an acme of diversity: Late**

Protists

Coccolithophores

- **Severely affected: KT mass extinction**
- **Radiated: Early Paleogene and throughout the Cenozoic**
- **Extremely abundant;**

END

Protists

Chromista: Diatoms

Protists

Diatoms

- **Unicellular autotrophs that are included among the Chrysophyte algae characterized by large green-brown chloroplasts.**

Protists

Diatoms

- **Both individuals and loosely integrated colonies**
- **Saline to freshwater**
- **Range of temperatures**
- **Common: Antarctic**

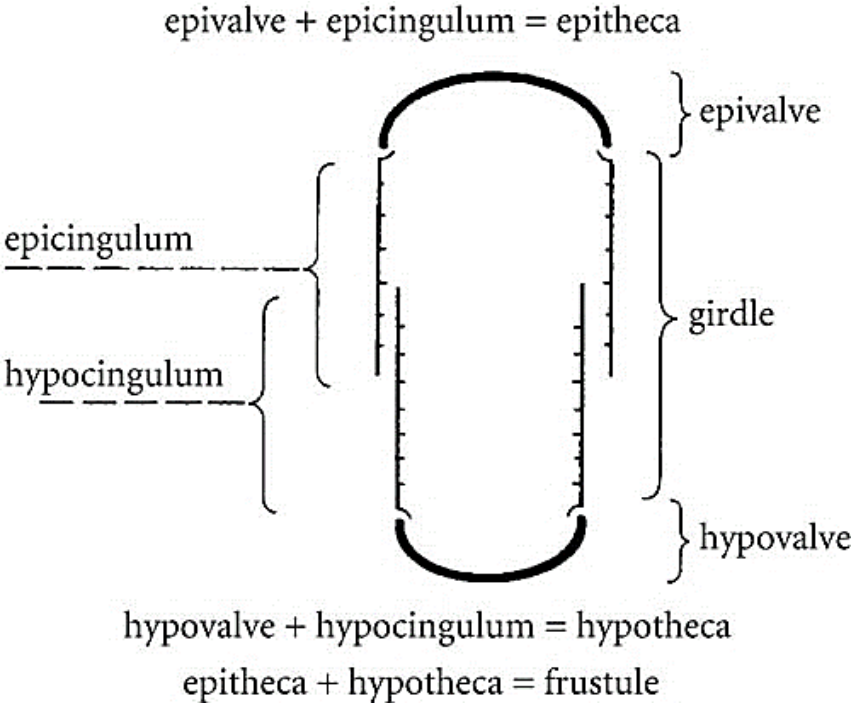
Protists

Diatoms

- **The Centrales – prefer marine environments;**
- **The Pennales –more common in freshwater lakes**
- **Diatom frustules**

Protists

Descriptive morphology of the diatoms



http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=09&fig=Fig9-19&img=c09f019

Protists

Diatoms

- **First diverse floras: mid-Cretaceous,10 families from Aptian rocks**
- **100 genera of centric diatoms: the Upper Cretaceous.**

Protists

Diatoms

- **The first pennate diatoms appeared during Paleogene colonizing freshwater for the first time**
- **The group**

END

Origin of the metazoans

Introduction

Origin of the metazoans

Fossil evidence

- **Few basic body plans have appeared in the fossil record**
- **most animals have triploblastic architecture**
- **Three fundamental**

Origin of the metazoans

Molecular Data

- **Show three main groupings of animals:**
  - **Deuterostomes**
  - **Spiralians**
  - **Ecdysozoans**
- **Spiralians and Ecdysozoans: the**

Origin of the metazoans

Three Groups

- **The deuterostomes (echinoderm–hemichordate–chordate group)**
- **The Spiralians (mollusk–annelid–brachiopod–**

Origin of the metazoans

Three Groups

- **The ecdysozoans (arthropod–nematode–priapulid plus other taxa group)**

Origin of the metazoans

Five lines of evidence

- **Body fossils**
- **Trace fossils**
- **fossil embryos**
- **The mol. Clock**
- **Biomarkers**
- **Suggest metazoans originated before Ediacaran 600 Ma**

Origin of the metazoans

Coincidence or Design

- **Snowball Earth by coincidence or design was a pivotal event in metazoan history; bilaterians evolved after the Marinoan**

Origin of the metazoans

The First Metazoans

- **Probably similar to the demosponges, occurring first before the Ediacaran**

Origin of the metazoans

The Ediacaran Biota

- **A soft-bodied assemblage of uncertain affinities**
- **Reaching its acme: the Late Proterozoic**
- **Earliest ecosystem having large, multicellular organisms**

Origin of the metazoans

Cambrian Explosion

- **The Cambrian explosion generated a range of new body plans during a relatively short time interval.**

Origin of the metazoans

Ordovician Radiation

- **Marked by accelerations in diversification at the family, genus and species levels along with complexity in marine communities.**

END

Origin of the metazoans

Origins

Origin of the metazoans

Precambrian life

- **Evidence of metazoan body and trace fossils**
- **The investigation of minute fossil embryos**
- **Carefully calibrated**

Origin of the metazoans

Metazoan Life

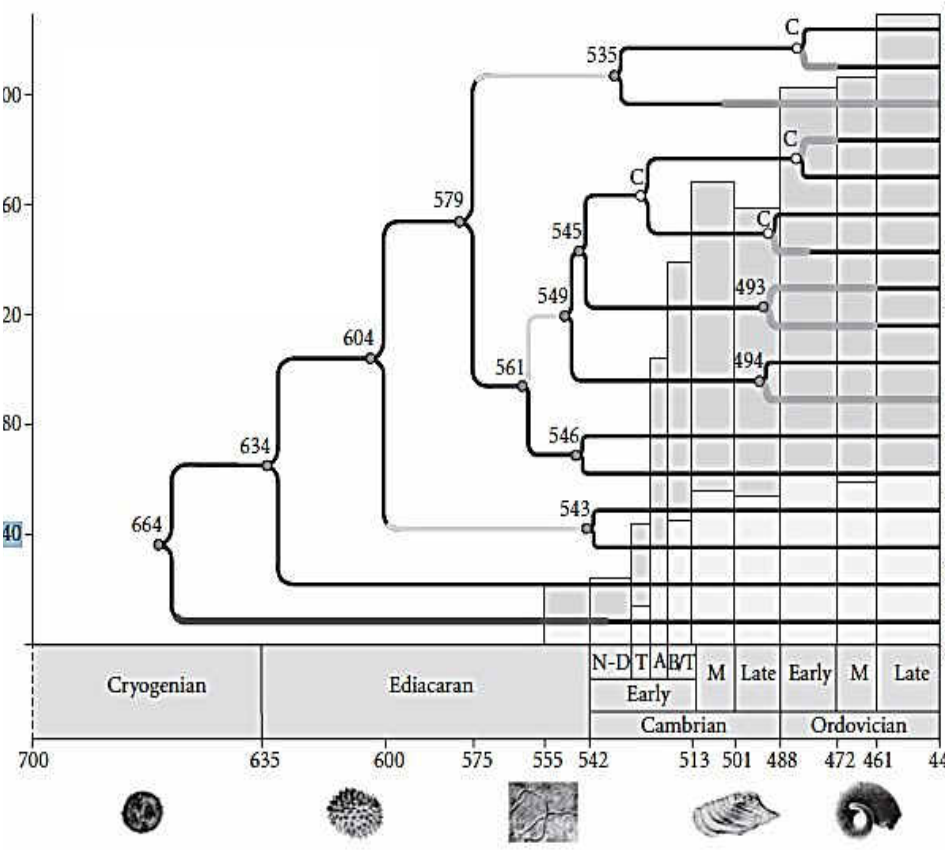
- **Molecular data suggest metazoans have been around for at least 600 myr**
- **During which time as many as 35 separate**

Origin of the metazoans

Metazoan Life

- **Recalibrated molecular clocks**
- **Animal origins be tracked back only to the Ediacaran, when there was also a sudden rise in oxygen levels**

Origin of the metazoans



Time scale and Tempo of early animal evolution

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=10&fig=Fig10-1&img=c10f001

Origin of the metazoans

Body Fossil Evidence

- **Earliest metazoans occur in Ediacara biota 600–550 Ma**
- **Significant Proterozoic record for the cnidarians and sponges**

Origin of the metazoans

Trace Fossil Evidence

- **The oldest locomotory trace fossils are from about 550 Ma northwest Russia**
- **Fecal strings from rocks some 600 Ma suggesting**

Origin of the metazoans

Embryo Fossil Evidence

- **Best studied example: Doushantuo Formation, South China**
- **580 Ma**
- **Earliest body fossil evidence for metazoan life**

Origin of the metazoans

Molecular Evidence

- **Molecular clock**
- **the metazoan clade excluding the sponges and cnidarians, has been placed at anywhere**

Origin of the metazoans

Biomarker Evidence

- **Biomarkers, essentially the biochemical fingerprints of life**
- **BMs associated with metazoan demosponges**

END

Origin of the metazoans

Invertebrate Body & Skeletal Plans

Origin of the metazoans

Invertebrate Body & Skeletal Plans

- **Body plans are usually defined by the number and type of enveloping walls of tissue together with the presence**

Origin of the metazoans

Invertebrate Body & Skeletal Plans

- **The first metazoans were multicellular with one main cell type & peripheral collar cells or choanocytes, with a whip or**

Origin of the metazoans

The Parazoan Body Plan

- **Seen in sponges**
- **characterized by cells organized in two layers separated by jelly-like material punctuated by so-called**

Origin of the metazoans

The Diploblastic Body Plan

- **Cnidarians and the ctenophorans**
- **an outer ectoderm**
- **an inner endoderm**
- **Two layers are separated by acellular mesogloea**

Origin of the metazoans

The Triploblastic Body Plan

- **Seen in most other animal**
- **Has three layers of tissues from the outside in: the ectoderm, mesoderm and**

Origin of the metazoans

Bilateral Symmetry

- **Defines the bilaterians.**
- **The development of the celom or body cavity characterizes Most of the animal groups found as fossils**

Origin of the metazoans

Skeleton

- **The skeleton is an integral part of the body plan of an animal, providing support, protection and attachment**

Origin of the metazoans

Hydraulic Skeleton

- **Many animals such as the soft-bodied mollusks (slugs) possess a hydraulic skeleton in which the movement of**

Origin of the metazoans

Rigid Skeletons

- **Mineralized material**
- **may be external (exoskeleton) in the case of most invertebrates**
- **Internal (endoskeleton) structures, in the case of**

Origin of the metazoans

Skeleton Growth

- **Growth is accommodated in a number of ways.**
- **Most invertebrate skeletons grow by the addition of new material, a process**

Origin of the metazoans

Skeleton Growth

- **Arthropods, however, grow by periodic bursts between intervals of ecdysis or molting**

END

Origin of the metazoans

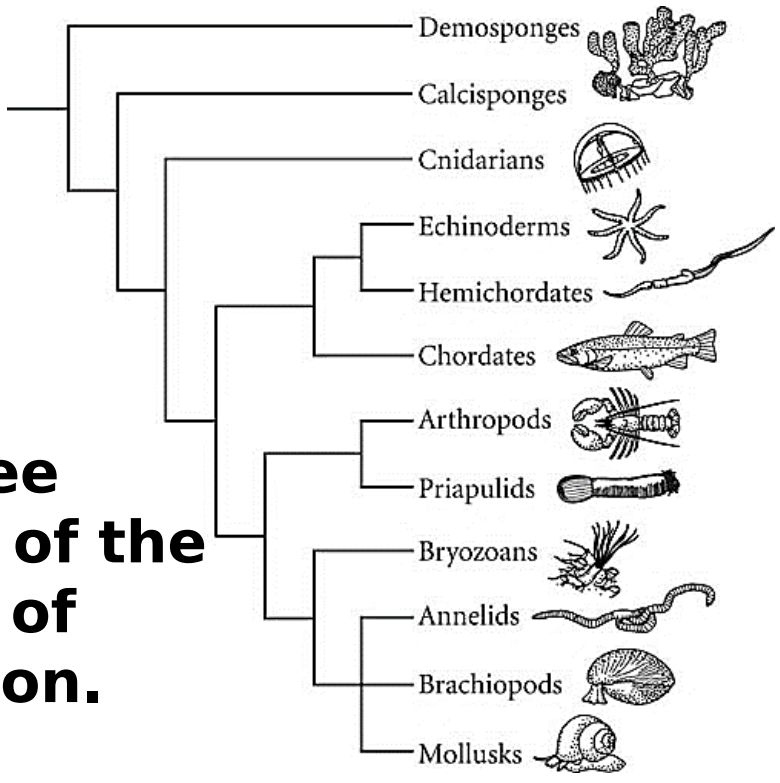
Classification & Relationships

Origin of the metazoans

Classification

- **Based on purely morphological data and embryology has problems**
- **Difficulties in establishing homologous characters and**

Origin of the metazoans



The locator tree outlines some of the main features of animal evolution.

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=10&fig=Fig10-6&img=c10f006

Origin of the metazoans

Basal Eumetazoans

- **The demosponges and calcisponges are the simplest animals**
- **The cnidarians are the most basal**

Origin of the metazoans

Three Groups

- **Three robust bilaterian groupings are recognized mainly on molecular data**
  - **Ecdysozoans,**
  - **Spiralians**
  - **Deuterostomes**

Origin of the metazoans

Protostomes

- **Ecdysozoans, spiralians comprise the protostomes.**
- **“First mouth” mouth develops directly from the blastopore**
- **By cell growth and migration**

Origin of the metazoans

Deuterostomes

- **“Second mouth” however, have a mouth arising from a secondary opening**
- **True blastopore develops as anus**
- **Echinoderm-**

Origin of the metazoans

Larval Types

- **Nauplius larva: crustaceans**
- **Planula: cnidarians**
- **Trochophore larva: mollusks and the polychaetes**
- **Shelled**

Origin of the metazoans

Larval Types

- **Invertebrate larvae are occasionally identified in the fossil record.**
- **More advanced preparatory and high-tech investigative**

END

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PPT Slides 01 TO 180

Merged File date 08/07/2021

Regards : Zarva Chaudhary

Admin:

* Zarva Chaudhary *

Chaudhary Moazzam

* Laiba Mahi *

Origin of the metazoans

Four Key Faunas

Origin of the metazoans

Evolutionary Faunas

- **The three great evolutionary faunas of**
  - **Phanerozoic**
  - **Cambrian**
  - **Paleozoic**
- **Modern**
- **Developed during last 550 myr.**

Origin of the metazoans

Evolutionary Faunas

- **The Ediacara biota**
- **Faunas during Cambrian explosion & Ordovician radiation**
- **Set the scene for life on our planet.**

Origin of the metazoans

Ediacara Biota

- **The Ediacaran biota consisted of enigmatic tubular and frond-shaped,**
- **mostly sessile organisms that lived during the Ediacaran Period (ca.**

Origin of the metazoans

Ediacara Biota

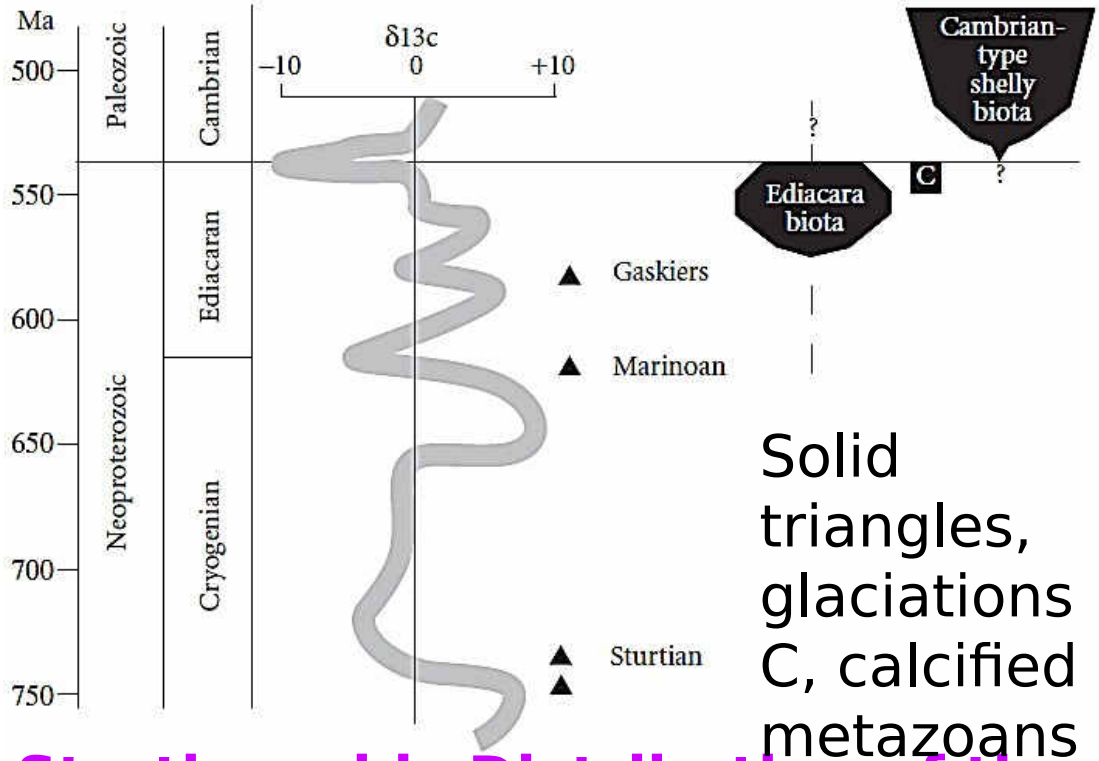
- **First impressions of soft-bodied organisms**
- **Upper Proterozoic rocks of Namibia**
- **In the Pound Quartzite**
- **In the Ediacara Hills,**

Origin of the metazoans

Ediacara Biota

- **Shallow-water siliciclastic sediments**
- **Soft-bodied, with high SA/V ratios**
- **Radial or bilateral symmetries**
- **Extinct about 550 Ma**

Origin of the metazoans



Solid triangles, glaciations
C, calcified metazoans

Stratigraphic Distribution of the Ediacara Biota

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=10&fig=Fig10-7&img=c10f007

Origin of the metazoans

Cambrian Explosion

- **Cambrian radiation**
- **Relatively short span event 20my**
- **541 million years ago**
- **Most major animal phyla appeared**

Origin of the metazoans

Cambrian Explosion

- **Generated many entirely new and spectacular body plans**
- **Sequential appearance of successively more complex metazoans**

Origin of the metazoans

Cambrian Explosion

- **Phylogenetic analysis shows metazoans evolved monophyletically from flagellated colonial protists similar to**

END

Origin of the metazoans

Ordovician Radiation

Origin of the metazoans

Ordovician Radiation

- **Great Ordovician biodiversification event (GOBE),**
- **Evolutionary radiation of animal life during the Ordovician Period, 40 my**

Origin of the metazoans

Ordovician Radiation

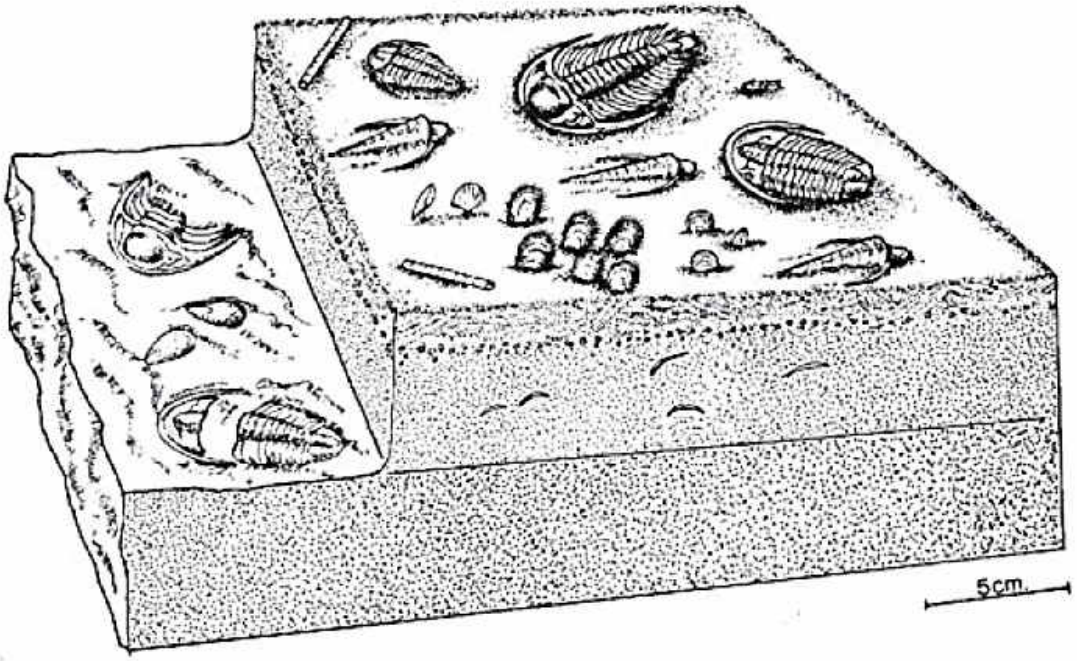
- **Followed a series of Cambrian–Ordovician Extinction events**
- **Fauna went on to dominate the Palaeozoic**
- **Marine**

Origin of the metazoans

Ordovician Radiation

- **The majority of "Paleozoic" taxa were derived from Cambrian stocks**
- **Interplay of many geological and ecological**

Origin of the metazoans

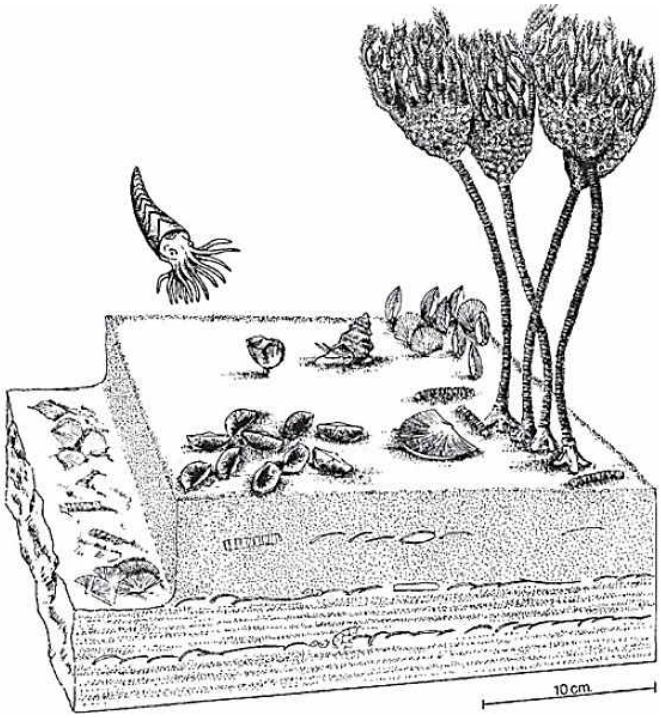


(a)

The Cambrian Seafloor

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=10&fig=Fig10-17&img=c10f017

Origin of the metazoans



The Ordovician Seafloor

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=10&fig=Fig10-17&img=c10f017

Origin of the metazoans

Ordovician Radiation

- **Ordovician diversification generated witnessed a staggering increase in biodiversity at the family, genus and species levels.**

END

Origin of the metazoans

Soft-bodied Invertebrates

Origin of the metazoans

Inadequate Fossil Record

- **Out of 25 or so commonly recognized animal phyla fewer than nine (35%) have an adequate fossil record**

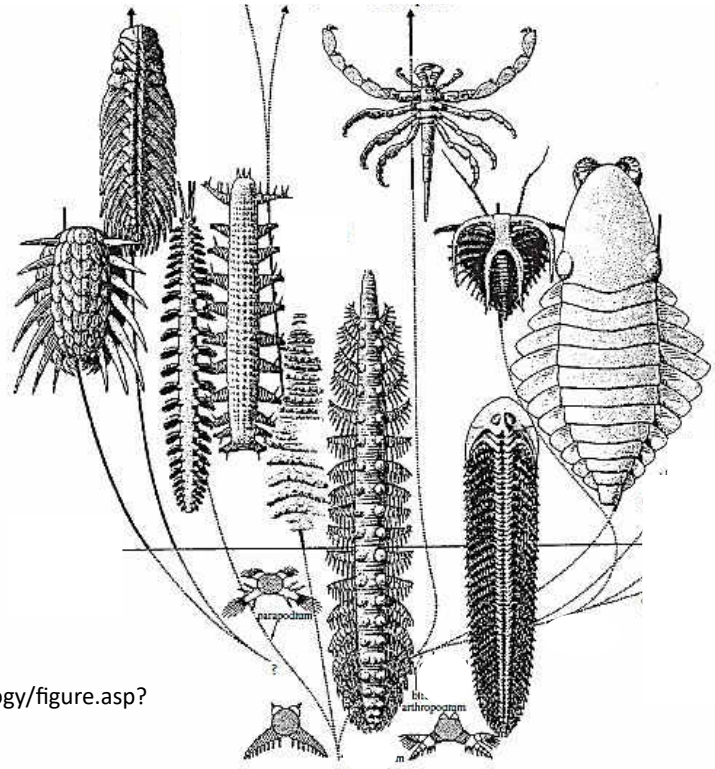
Origin of the metazoans

Inadequate Fossil Record

- **A number of larger soft-bodied phyla lack a preservable skeleton**
- **Soft-bodied forms are preserved in fossil Lagerstätten**

Origin of the metazoans

Significance of the diverse worm-like animals at the Precambrian–Cambrian boundary and the postulated origins of some major clades



http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=10&fig=Fig10-19&img=c10f019

Origin of the metazoans

Burgess Shale

- Burgess Shale and other exceptionally preserved faunas suggests that many of these soft-bodied groups dominated certain marine paleocommuni

Origin of the metazoans

Platydendron

- The platyhelminths or the flatworms are bilateral animals
- *Platydendron* from the Middle Cambrian Burgess Shale has been

Origin of the metazoans

Polychaetes

- A diverse polychaete fauna has been described from the Burgess Shale
- Even contains *Canada spinosa*
- Similar to some living

Origin of the metazoans

Polychaetes

- Paddle worms: most complete fossil record
- Record is enhanced by the relatively common preservation of elements of the phosphatic jaw: scolecodonts

END

The Basal Metazoans

Introduction

The Basal Metazoans

Parazoa

- **Parazoans are metazoans composed of multicellular complexes with few cell types and lack variation in tissue or organs**
- **I.e. The sponges**

The Basal Metazoans

Parazoa

- **Two groups, the Porifera and the Cnidaria, form the basal parts of the metazoan tree, diverging during Neoproterozoic**

The Basal Metazoans

Sponges

- **Sponges are filter-feeding members of the sessile benthos**
- **Contains a variety of grades of functional organization**

The Basal Metazoans

Sponges

- **Sponge reefs dominated: Phanerozoic**
- **Calcareous grades**
- **Siliceous sponges were important reef builders: Mesozoic**

The Basal Metazoans

Stromatoporoids

- **A grade of organization within the Porifera with a secondary calcareous skeleton**
- **Important in reefs during the mid-Paleozoic and mid-Mesozoic**

The Basal Metazoans

Archaeocyaths

- **Cambrian organisms of sponge grade**
- **Mainly solitary**
- **Developed branching, modular growth**
- **Successfully built reefs in unstable**

The Basal Metazoans

Cnidarians

- **The simplest of the higher metazoans with a radial diploblastic body plan and stinging cells or cnidoblasts**
- **Sea anemones, jellyfish and**

The Basal Metazoans

Reef-Type Structures

- **Reef-type structures were already present in the Late Precambrian hosting large, robust, colonial organisms**

The Basal Metazoans

Reef Development

- **Reef development through time has waxed and waned**
- **Dominated at different times by different groups of reef-building**

The Basal Metazoans

Coloniality

- **Evolved many times**
- **One hypothesis suggests that a Precambrian colonial organism may have been a source for the**

END

The Basal Metazoans

Porifera

The Basal Metazoans

Porifera

- **Dr Robert Grant "Porifera is a unique group in its own right"**
- **Unique porous structure and cellular body plan**

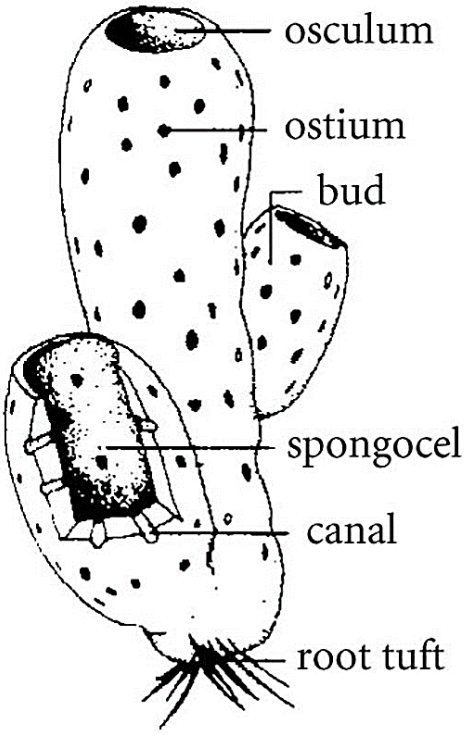
The Basal Metazoans

Porifera

- **Most lack symmetry, true differentiated tissues, and organs, although their cells, like those of the protists, can switch**

The Basal Metazoans

Basic Sponge Morphology



http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=11&fig=Fig11-1&img=c11f001

The Basal Metazoans

Skeleton

- **Sponges are skeletal organisms. Skeletons are composed of a colloidal jelly or spongin**

The Basal Metazoans

Chamber Organization

- **Three levels**

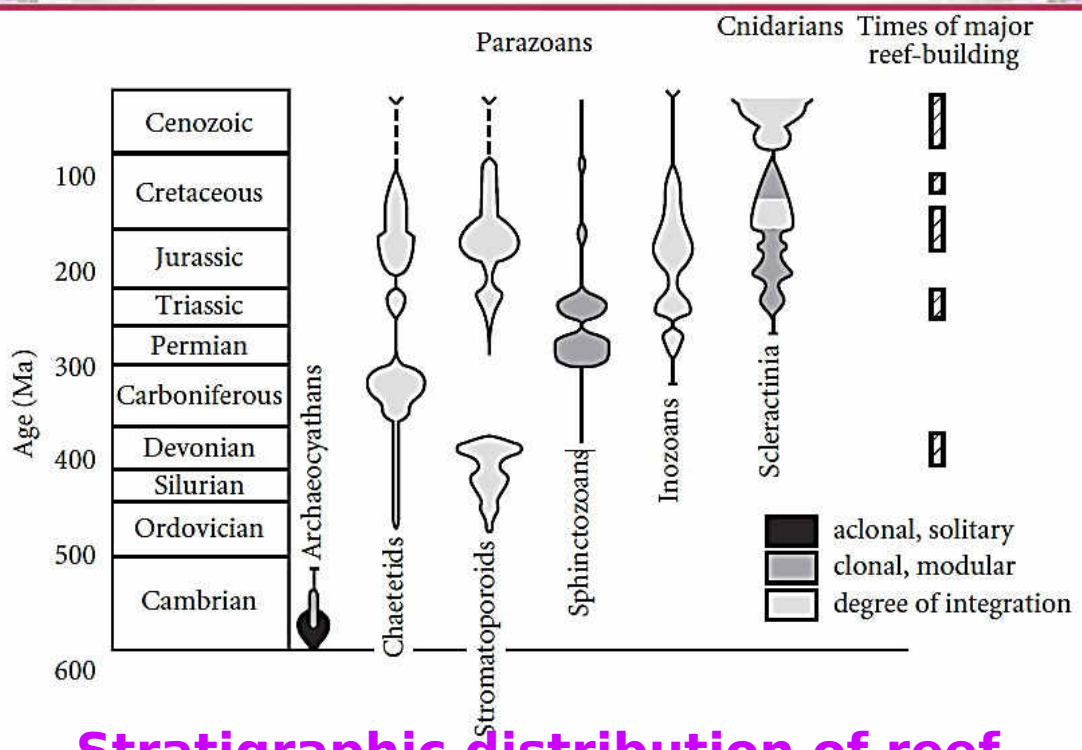
1. **Ascon: Sacs with a single chamber lined by flagellate cells**
2. **Sycon: a number of simple chambers**

The Basal Metazoans

Chamber Organization

3. **Leucon: most common where a series of sycon chambers access a large central**

The Basal Metazoans



Stratigraphic distribution of reef-building sponges and related parazoans

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The Basal Metazoans

Stromatoporoidea

- **Common in the fossil record from the Ordovician through the Devonian.**
- **Especially abundant in the Silurian and**

The Basal Metazoans

Stromatoporoidea

- **These invertebrates were important reef-formers throughout the Paleozoic and the Late Mesozoic.**

The Basal Metazoans

Archaeocyatha

- **“Ancient cups” are one of only a few major animal groups that are entirely extinct.**
- **Reef-building marine organisms of warm tropical and**

The Basal Metazoans

Archaeocyatha

- **Lived during the early (lower) Cambrian Period.**
- **It is believed that the center of the Archaeocyatha origin are now located**

END

The Basal Metazoans

Cnidaria

The Basal Metazoans

The Cnidarians

- **"Nettle-bearers"**
- **Include the**
- **Sea anemones, jelly fish, corals**
- **The least complex of the true metazoans**

The Basal Metazoans

The Cnidarians

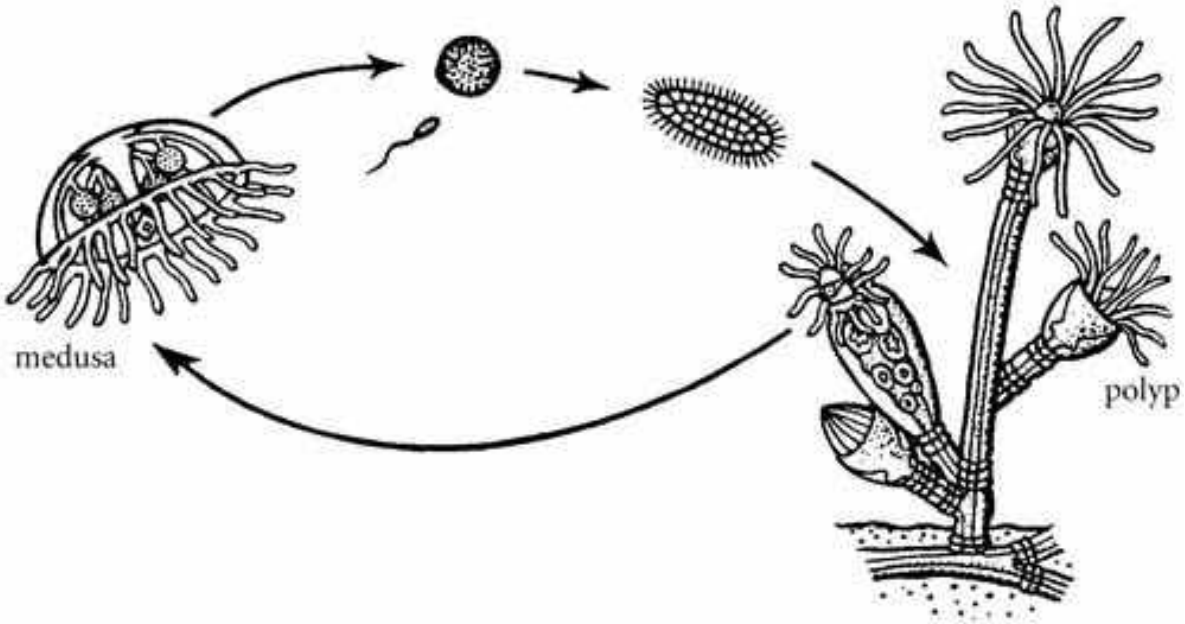
- **Although there are no specialized organs and only a few tissue types,**
- **They are more complex than the parazoans**

The Basal Metazoans

The Cnidarians

- **Two basic life strategies**
- **Polyps: sessile**
- **Medusae: swim,**
- **Medusoids and polyps appear different, they are**

The Basal Metazoans



Cnidarian life cycles
generalized view of the life of the hydrozoan Obelia, alternating between the conspicuous polyp and medusa stages

http://www.blackwellpublishing.com/matthews/biology.html?chap=11&fig=Fig11-17&img=c11f017

The Basal Metazoans

Class Hydrozoa

- **Polymorphic forms**
- **Undivided enteron, solid tentacles, colonies**
- **Chondrophora oldest cnidarians**
- **Ediacaran to Recent**

The Basal Metazoans

Class Scyphozoa

- **Jellyfish**
- **Lagerstätten.**
- **The extinct Conulata**
- **Appeared: Cambrian**
- **Extinct: Mid Triassic**
- **Ediacaran to Recent**

The Basal Metazoans

Class Anthozoa

- **Marine, sessile, colonial forms**
- **Mobile planula larvae**
- **Octocorallia class includes corals, sea anemones**
- **Produce spicules microfossils**

The Basal Metazoans

Class Cubozoa

- **The sea wasps and box jellyfish**
- **Both medusae and polyps**
- **Restricted to tropical and subtropical latitudes**
- **Carboniferous to Recent**

The Basal Metazoans

Corals

- **Most diverse and most threatened ecosystems**
- **The coral reef**
- **Shallow-water coral reefs in zone extending 30° north and south of**

END

Spiralians

Spiralians: Lophophorates

Spiralians

The Spiralians

- **Morphologically diverse clade of protostome animals**
- **Molluscs**
- **Annelids**
- **Platyhelminths and other taxa**

Spiralians

Lophophores

- **Lophophores, a filamentous feeding organ**
- **Three spiralian invertebrate groups**
- **Brachiopods**
- **Bryozoans**
- **Phoronids**

Spiralians

Brachiopods

- **Twin-valved shellfish**
- **Lophophore and a pedicle,**
- **Linguliformeans: organophosphatic shells**
- **Craniiformeans & rhynchonelliformeans: calcareous**

Spiralians

Paleozoic Communities

- **Orthides and Strophomenides**
- **Rhynchonellides and Terebratulides were in Lower-diversity post-Paleozoic brachiopod assemblages**

Spiralians

Paleozoic Communities

- **Brachiopods dominated the filter-feeding benthos of the Paleozoic**
- **Never fully recovered during the end-Permian mass extinction**

Spiralians

Living Brachiopods

- **Living brachiopods are relatively rare, occupying mostly cryptic and deep-water habitats.**

Spiralians

Bryozoans

- **Colonial invertebrates with Lophophores**
- **Displaying marked non-genetic variation across a wide range of environment**

Spiralians

Stenolaemata

- **Dominated Paleozoic bryozoan faunas**
- **Only the cyclostomes surviving the combined effects of the end-Permian and end-Triassic mass**

Spiralians

END

Cyclostomes

- **Cyclostomes continued to decline after the end-Cretaceous extinction event**
- **Cheilostomes radiated to dominate Cenozoic**

Spiralians

Lophophorates: Brachiopoda

Spiralians

Brachiopoda

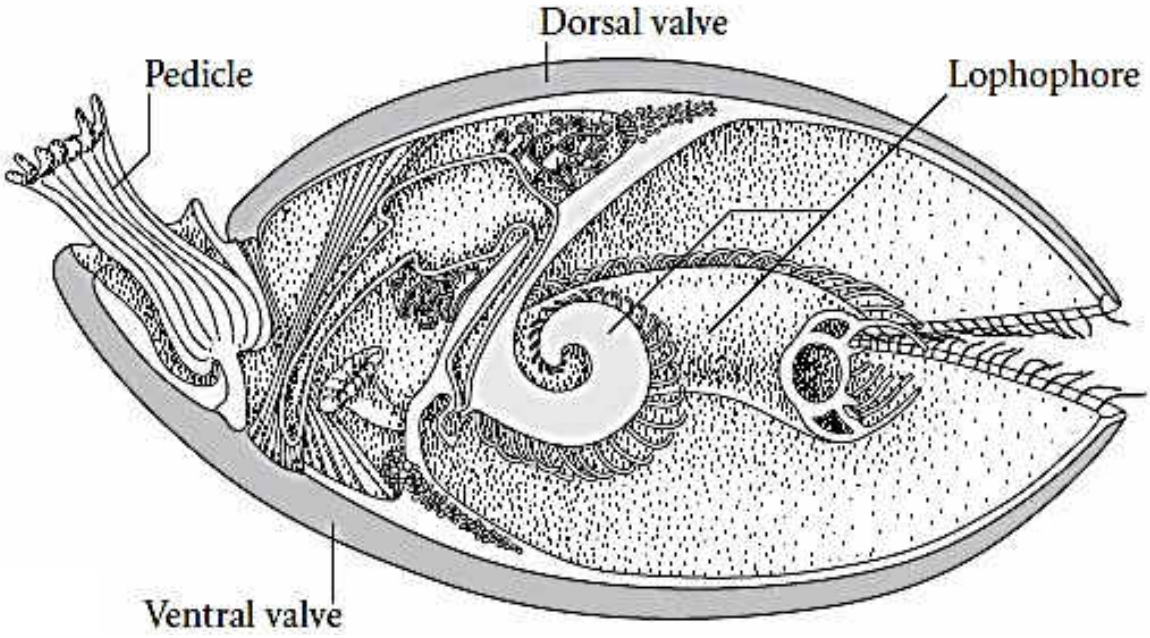
- **Most successful invertebrate phyla**
- **Appeared: Early Cambrian**
- **Diversified: Paleozoic**
- **Dominate the low-level, suspension**

Spiralians

Morphology

- **The brachiopod soft parts are enclosed by two morphological ly different shells or valves with variety of muscles**
- **The ventral or**

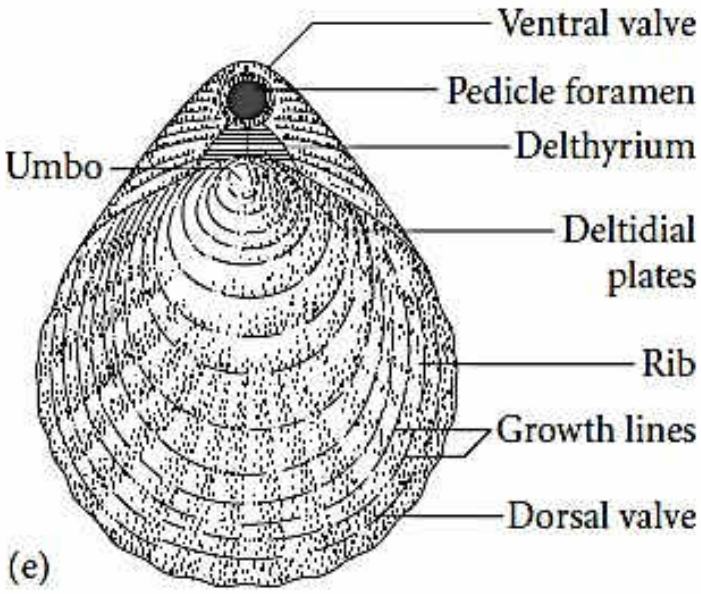
Spiralians



Internal Features of a Terebratulide

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=12&fig=Fig12-1&img=c12f001

Spiralians



External Terminology of a Typical Articulate

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=12&fig=Fig12-1&img=c12f001

Spiralians

Distribution in time

- Cambrian
- Paleozoic
- Modern brachiopod faunas
- Fundamentally different
- A dominance of different orders

Spiralians

Cambrian Faunas

- Dominated by a range of non-articulated groups
- with groups of disparate articulated taxa
- Chileides
- Naukatides

Spiralians

Ordovician Radiation

- **Deltidiodont, Orthides and Strophomenides**
- **First evolved: Early Ordovician island complexes**
- **Dominated the shelf benthos & basis of the**

END

Spiralians

Brachiopoda: Five Extinction Events

Spiralians

Five Main Extinctions

- **The brachiopods experienced five main extinction events**
- **Followed by recoveries and radiations of varying**

Spiralians

The End-Ordovician Event

- **Occurred in two phases**
- **glaciation & loss of almost 80% of brachiopod families**
- **Decline of deltidiodont groups**
- **Dominance of the spiriferides**

Spiralians

Late Devonian events

- **Climate change**
- **Removed the Atrypides & Pentamerides**
- **Severely affected Orthides & Strophomenides**
- **Spiriferides & Rhynchonellide**

Spiralians

Carboniferous Era

- **Intervals of spectacular experimentation**
- **Mimicked corals or developed extravagant clusters of spines**
- **Reduced shells, presenting soft tissues to outside**

Spiralians

End-Permian Mass Extinction

- **Demise of over 90% of brachiopod species,**
- **Disaster taxa including lingulids**
- **later diversified with in a few clades dominated by**

Spiralians

End-Triassic Event

- **Removed the majority of the remaining spiriferides and the last strophomenides**
- **Dominance of Rhynchonellide and terebratulide groups**

Spiralians

END

Modern Brachiopods

- **Exhibit a remarkable range of adaptations based on a simple body plan and a well defined role in the fixed, low-level benthos.**

Spiralians

Lophophorates
Bryozoa

Spiralians

Bryozoans

- **All species are colonial.**
- **Skeletons fragment easily after death**
- **least well-known invertebrates**
- **6000 living & 16,000 fossil species**

Spiralians

Bryozoans

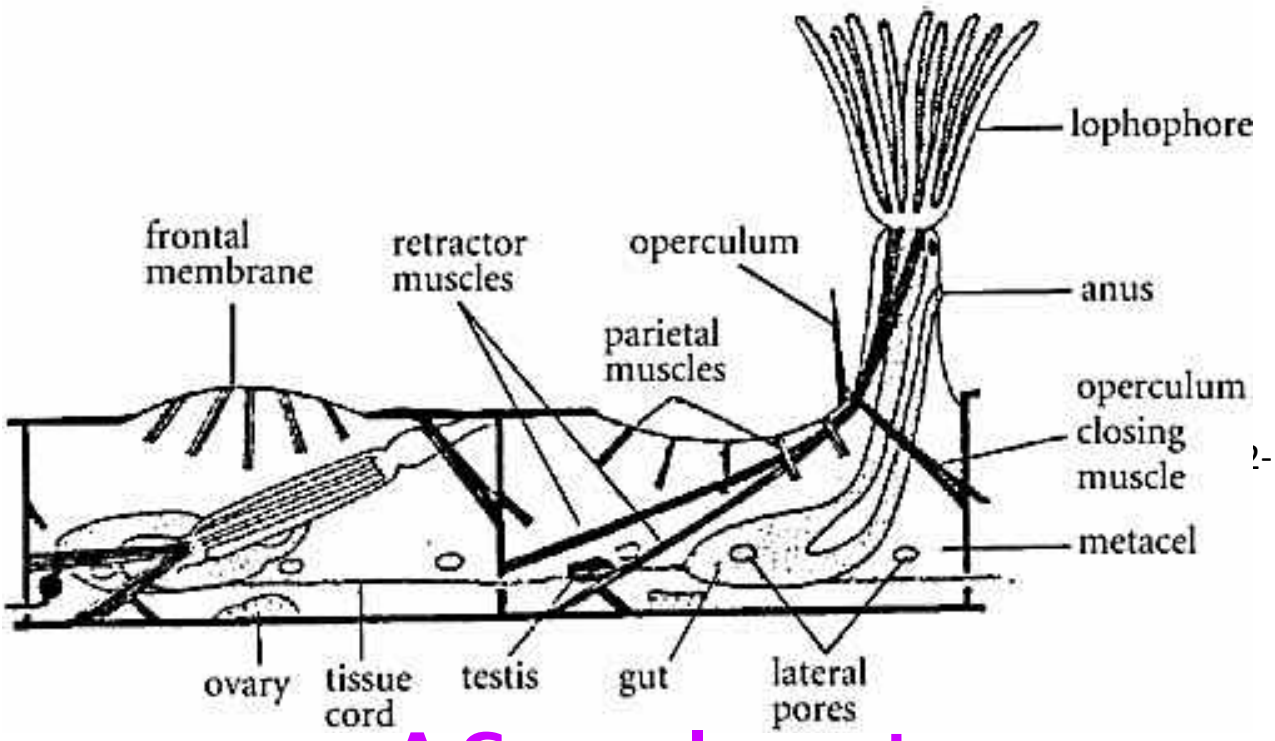
- **Superficially resembling the corals and hydroids,**
- **“Moss animals”**
- **Filter feeders**
- **Sieve food particles using a retractable lophophore**

Spiralians

Bryozoans

- **The genus *Bowerbankia* is a relatively simple Bryozoan**
- **Useful for illustrating the general anatomy of bryozoan zooids.**

Spiralians



A Gymnolaemate

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=12&fig=Fig12-15&img=c12f015

Spiralians

Morphology

- **Each living zooid is enclosed by a body wall/cystid**
- **The lophophore, with its beating cilia, A ring of 10 tentacles direct food to**

Spiralians

Oldest Bryozoans

- **Occur in the Tremadocian Stage of the Lower Ordovician**
- **Primitive, soft-bodied bryozoans existed during the Cambrian but**

Spiralians

Oldest Bryozoans

- **Stenolaemata dominated Paleozoic bryozoan faunas**
- **Genera such as Monticulipora, Prasopora and Parvohallopora are typical**

Spiralians

Old Bryozoans

- **Cheilostomes**
- **Polymorphic zooids,**
- **Appeared: during the Late Jurassic;**
- **Common in the Late Cretaceous and Paleogene of**

Spiralians

Brachiopods and Bryozoans

- **Members of the filter-feeding Paleozoic evolutionary fauna.**
- **Brachiopods a minor part of the Recent marine fauna but bryozoans**

END

Spiralians

Spiralians: Mollusks

Spiralians

Mollusks

- **The Phylum Mollusca can be traced back to at least the Late Precambrian, when *Kimberella* probably fed on algae in Ediacaran communities**

Spiralians

Early Mollusks

- **Characterized by some short-lived, unusual forms**
- **Molluskan features: mantle, mineralized shell and radula**
- **Members of**

Spiralians

Bivalves

- **Characterized by a huge variety of shell shapes, dentitions and muscle scars**
- **Adapted for a wide range of life strategies in marine and some freshwater**

Spiralians

Gastropods

- **Most gastropods undergo torsion in early life; they have a single shell, often coiled.**
- **The group adapted to a wide range of environments**

Spiralians

Cephalopods

- **The most advanced mollusks, with a head, senses and a nervous system**
- **Nautiloids, Ammonoids and the Coleoids**

Spiralians

Mollusks

- **During the Mesozoic developed a number of protective strategies**
- **Robust armor**
- **Deep infaunal life**
- **Multiformity of shape and color**

Spiralians

Annelid worms

- **Annelid worms were a sister group to the mollusks**
- **Their jaws, the scolecodonts, are relatively common in Paleozoic**

END

Spiralians

Mollusks: Introduction

Spiralians

Phylum Mollusca

- **The Phylum Mollusca includes**
  - **The slugs, snails, squids, cuttlefish and octopuses**
  - **All manner of marine shellfish such as clams, mussels and**

Spiralians

Phylum Mollusca

- **The most common marine animals today,**
  - **Occupy wide range of habitats**
  - **Abyssal depths of the oceans and intertidal**

Spiralians

Phylum Mollusca

- **Mollusks are usually**
- **Unsegmented**
- **Soft-bodied animals**
- **With a body plan based on four features**

Spiralians

Four Features

1. **The head contains the sensory organs, and a rasping feeding organ, the radula**
   Composed of chitin and designed to scrape and in

Spiralians

Four Features

2. **The foot is primitively a sole-like structure on which the animal crawls, but is considerably modified in many**

Spiralians

Four Features

3. **The visceral mass of the digestive, excretory, reproductive and circulatory organs is enclosed in the celomic cavity**

Spiralians

Four Features

4. **The mantle is a sheet of tissue lying dorsally over the visceral mass that is responsible for secreting the shell.**

Spiralians

Molluskan shells

- **Secreted as calcium carbonate, mainly aragonite, with an organic matrix and an outer organic layer.**

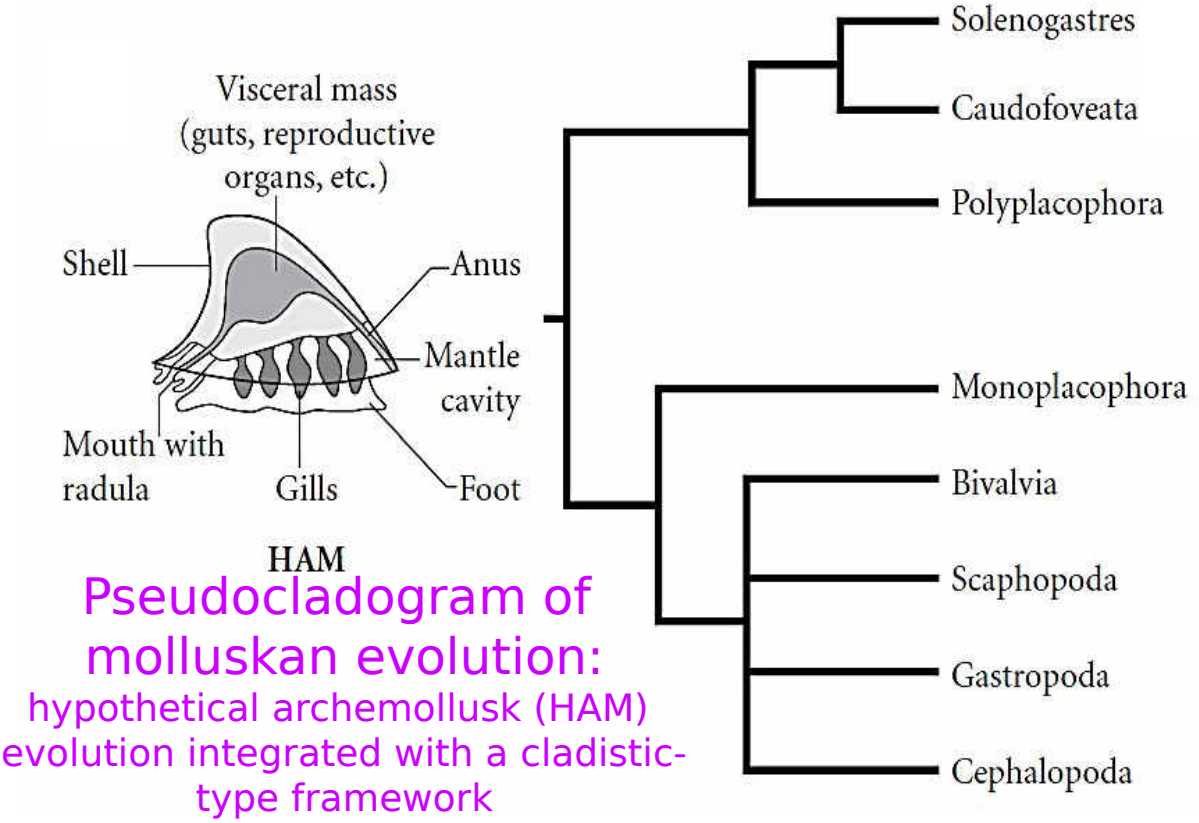
Spiralians

Molluskan shells

- **Visualizing molluskan evolution**
- **Hypothetical ancestor Archemollusk ,**
- **Merged with a recent cladogram for the phylum**

END

Spiralians



Pseudocladogram of molluskan evolution:
hypothetical archemollusk (HAM) evolution integrated with a cladistic-type framework

http://www.blackwellpublishing.com/paleobiology/jpg/300_96dpi/c13f001.jpg

Spiralians

Early Mollusks

Spiralians

Early Mollusks

- **Early Cambrian: A time of experimentation**
- **A variety of short-lived, often bizarre molluskan groups**
- **Dominating**

Spiralians

Early Mollusks

- **First mollusks descended from forms like living flatworms**
- **Spiculate animals**
- **Radula and gills on the posterior**
- **Similar to modern soft-**

Spiralians

Aplacophorans

- **A group of shell-less mollusks.**
- **Aplacophorans and shelled mollusks shared a common ancestor probably during the Late**

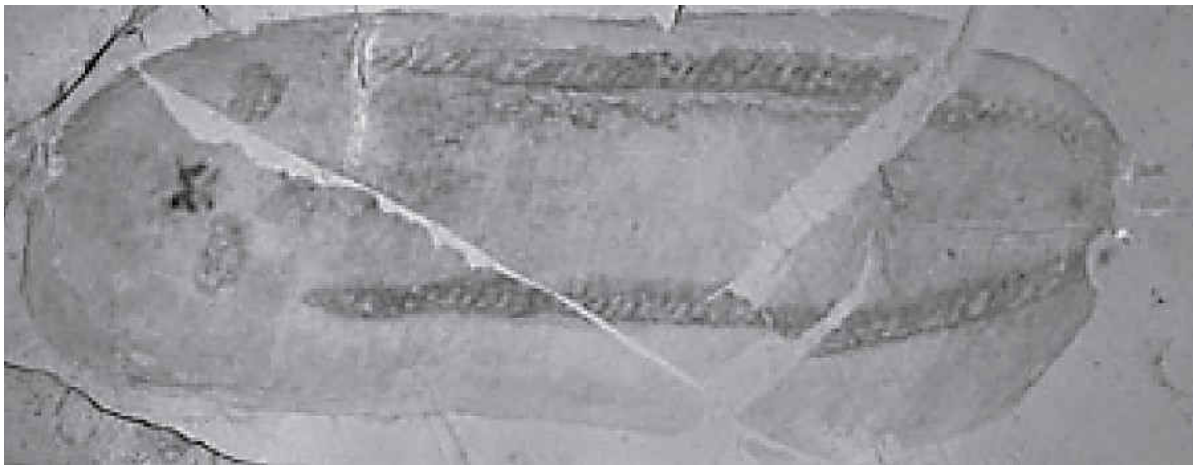
Spiralians

The body fossils and trace fossils place Kimberella near the base of the Molluskan clade and suggest a deep origin for the phylum



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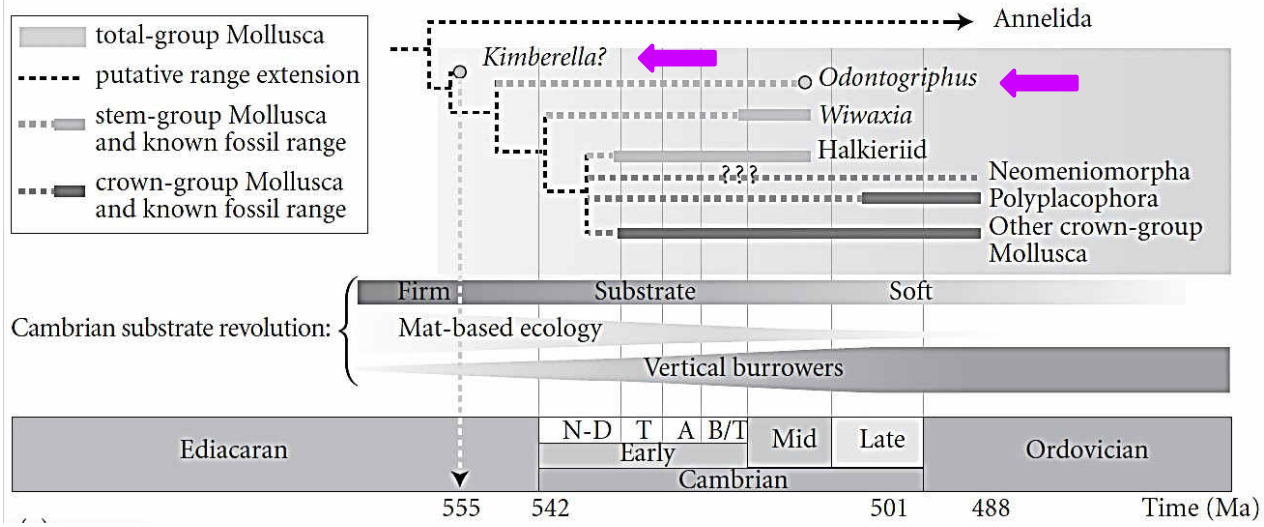
Spiralians



Odontogriphus possesses a radula, a broad foot and a stiffened dorsum, so placing it firmly within the mollusks, close to Kimberella

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Spiralians



Phylogeny and stratigraphic ranges of early mollusks mapped onto some ecological changes.

N-D, Nemakit-Daldynian; T, Tommotian; A, Atdabanian; B/T, Botomian. (a, courtesy of Ben Waggoner; b, c, courtesy of ten-Bernard Caron.)

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=13&fig=Fig13-2&img=c13f002

Spiralians

Halkieria

- **Cambrian rocks of the Danish island of Bornholm.**
- **Articulated specimens from the Early Cambrian Sirius Passet fauna from North Greenland**

Spiralians

Halkieria **is a mollusk, possessing most of the features that define the phylum, but a number of characters (such as the shells at the anterior and posterior of the animal) have formed the basis for a new class of mollusk, the**



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Spiralians

Origins

- **Halkieriid mollusks**
- **Lower Cambrian**
- **The hyoliths – long, conical, calcareous shells with an operculum-covered aperture**
- **Cambrian to**

END

Spiralians

Mollusks:
Class Bivalvia

Spiralians

Bivalves

- **Among the commonest shelly components of beach sands**
- **Many taxa are farmed and harvested for human consumption**
- **Pearls: a**

Spiralians

Bivalves

- **Spectacular variety of shell shapes and life strategies**
- **Spanning the entire Phanerozoic**
- **All based on a simple bilaterally symmetric**

Spiralians

Morphology

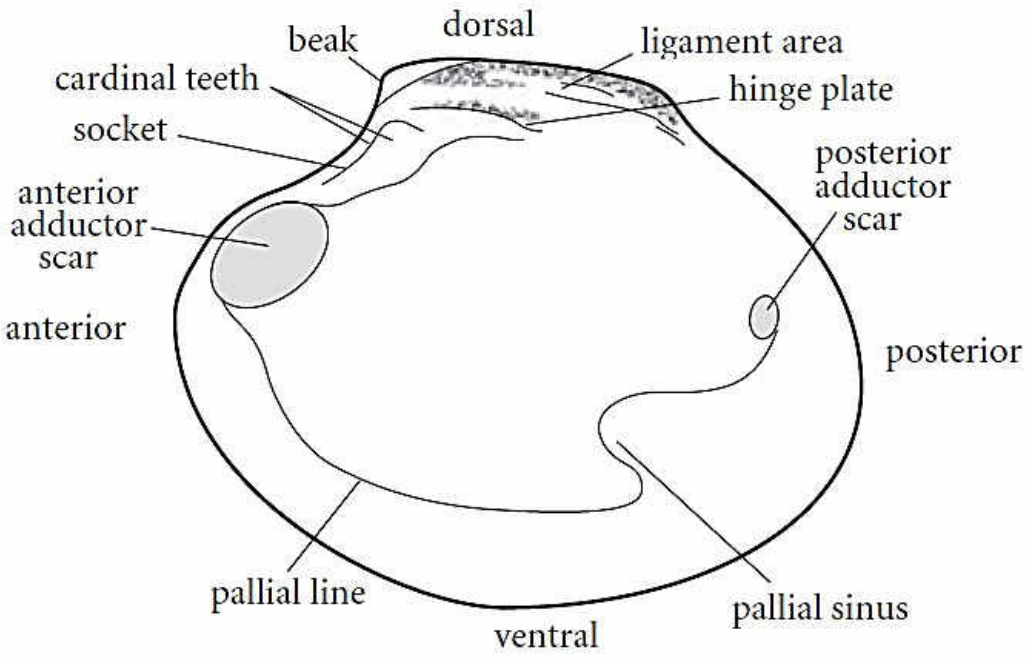
- **Bivalves are twin-valved shellfish superficially resembling the brachiopods**
- **Common in modern seas**
- **Bivalve shells: calcium**

Spiralians

Morphology

- **Two valves are virtually mirror images of each other.**
- **Termed lamellibranchs or pelecypods, but they were first named Bivalvia by Linnaeus in 1758**

Spiralians

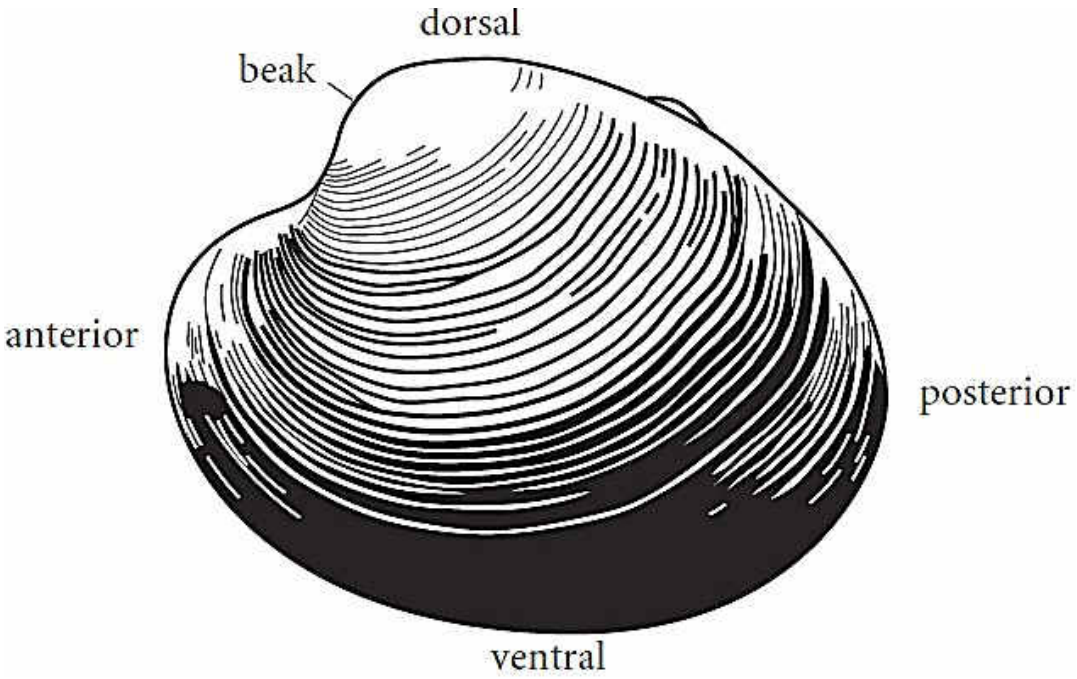


Bivalve morphology based on a living bivalve:

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=13&fig=Fig13-5&img=c13f005

internal features of the right valve

Spiralians



Bivalve morphology based on a living bivalve:

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External features of the left valve

Spiralians

Evolution

- **Basal Cambrian**
- **Two Early Cambrian genera**
  1. **Pojetaia from Australia and China**
  2. **Fordilla from Denmark, North America and**

Spiralians

Evolution

- **Evolved from Rostroconchs**
- **The class evolved rapidly in the Early Ordovician to include basal forms of all bivalve infrasubclass es**

Spiralians

Evolution

- **Major diversification: Paleozoic**
- **Evolved extensive siphons helping deep-burrowing life modes**
- **Early Mesozoic radiation: featured**

END

Spiralians

Mollusks:
Class
Gastropoda

Spiralians

The Gastropods

- **The “belly-footed” mollusks**
- **Most varied and abundant of the molluskan classes today**
- **Snails and slugs**
- **Forms both with and**

Spiralians

The Gastropods

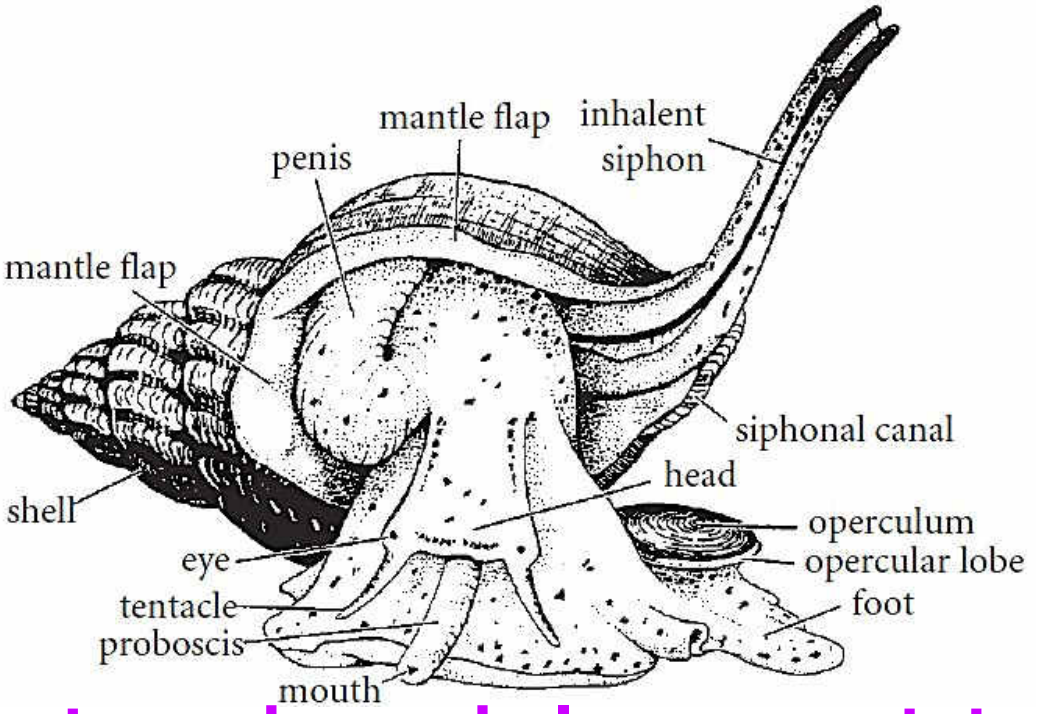
- **Entire Phanerozoic,**
- **Evolved**
- **Swimming strategies: creeping, floating and**
- **Trophic styles: razing, predatory and parasitic.**

Spiralians

Torsion

- **Mantle cavity containing gills and anus, excretory and reproductive openings comes to lie above head.**
- **Seems to be disadvantage ous loss of**

Spiralians



Gastropod morphology: annotated reconstruction of a living gastropod

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Spiralians

Evolution

- **No general agreement**
- **Derived from a monoplacophoran- type ancestor by torsion and development of an exogastric condition**
- **Shell is coiled away from the**

Spiralians

Evolution

- **An origin from among coiled forms such as *Pelagiella* may link the monoplacophoran grade through the Tommotian *Aldanella* to the**

Spiralians

Evolution

- **Most Paleozoic gastropods: herbivores or detritus feeders**
- **Classic study of Late Tertiary snails from Lake Turkana, Kenya, Williamson (1981): punctuated**

END

Spiralians

Mollusks:
Class
Cephalopoda

Spiralians

Cephalopods

- **Most highly organized of the mollusks**
- **The greatest complexity of any of the spiralians**
- **Well-defined head with the foot modified into tentacles,**

Spiralians

Cephalopods

- **High metabolic and mobility rates**
- **Developed nervous system, sharp eyesight & an advanced brain**
- **Adaptations for a carnivorous**

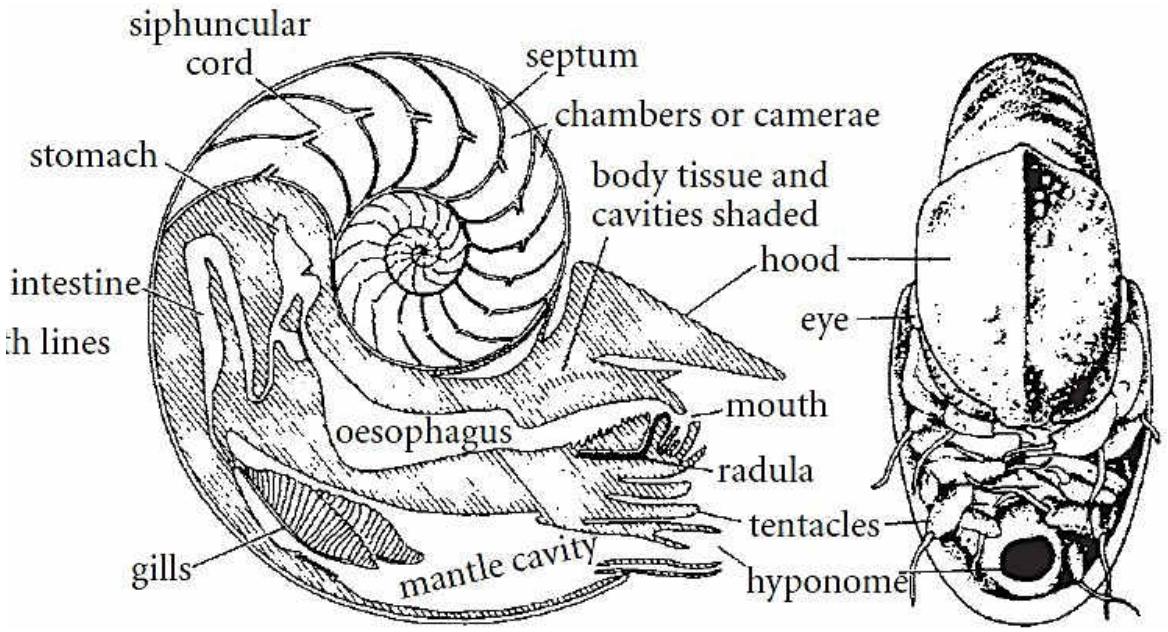
Spiralians

Cephalopods

- **A tripartite division**
- **Three subclasses include**

1. ***Nautiloidea*, with straight or coiled external shells with simple sutures (Late**

Spiralians



Features of the shell and internal morphology of a living Nautilus

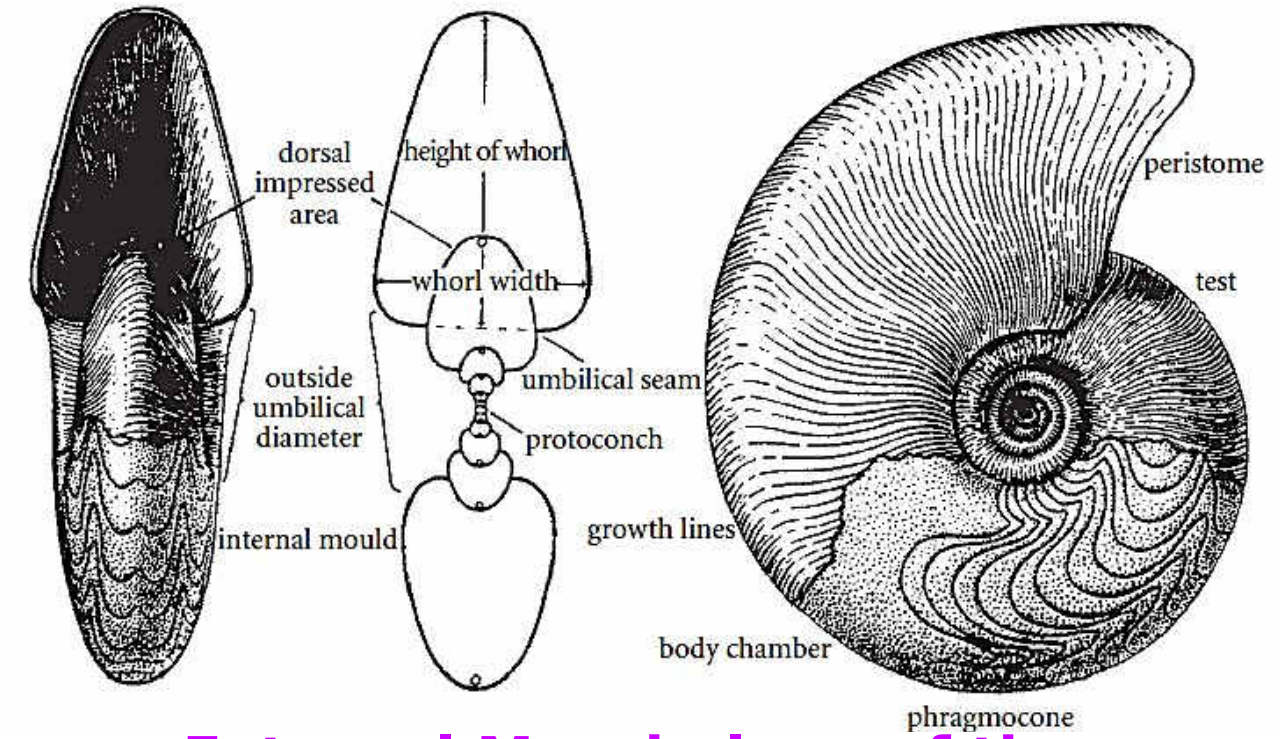
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Spiralians

Cephalopods

2. ***Ammonoidea***, **with coiled, commonly ribbed external shells with complex sutures (Early Devonian to latest Cretaceous, possibly**

Spiralians



External Morphology of the ammonoids

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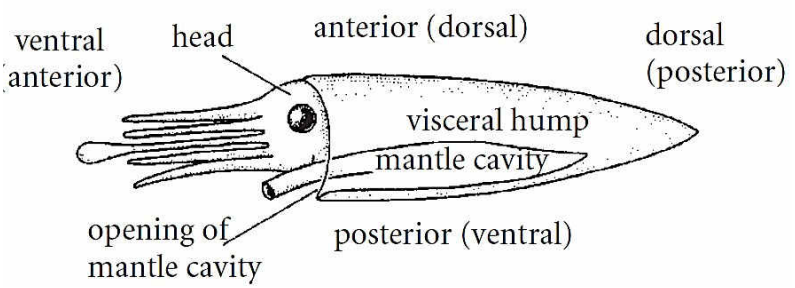
Spiralians

Cephalopods

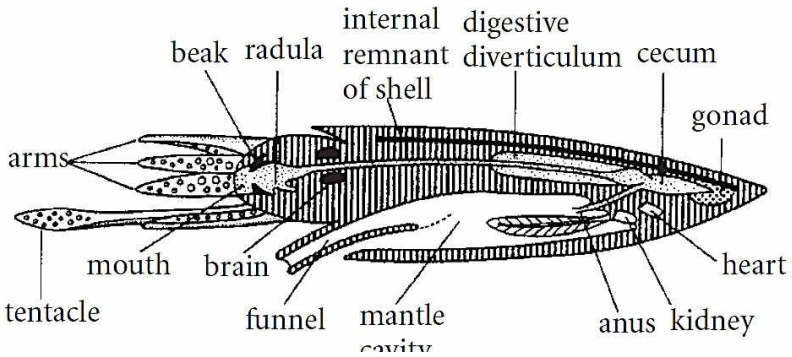
3. ***Coleoidea*, with straight or coiled internal skeletons (Carboniferous To Recent).**
   - **Belemnites (extinct), the squids and cuttlefish**
   - **The octopods:**

Spiralians

Reconstruction of a living belemnite,



Soft-part morphology of the belemnites



Coleoid morphology

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=13&fig=Fig13-14&img=c13f022

Spiralians

Mollusks:
Class
Scaphopoda

Spiralians

Scaphopods

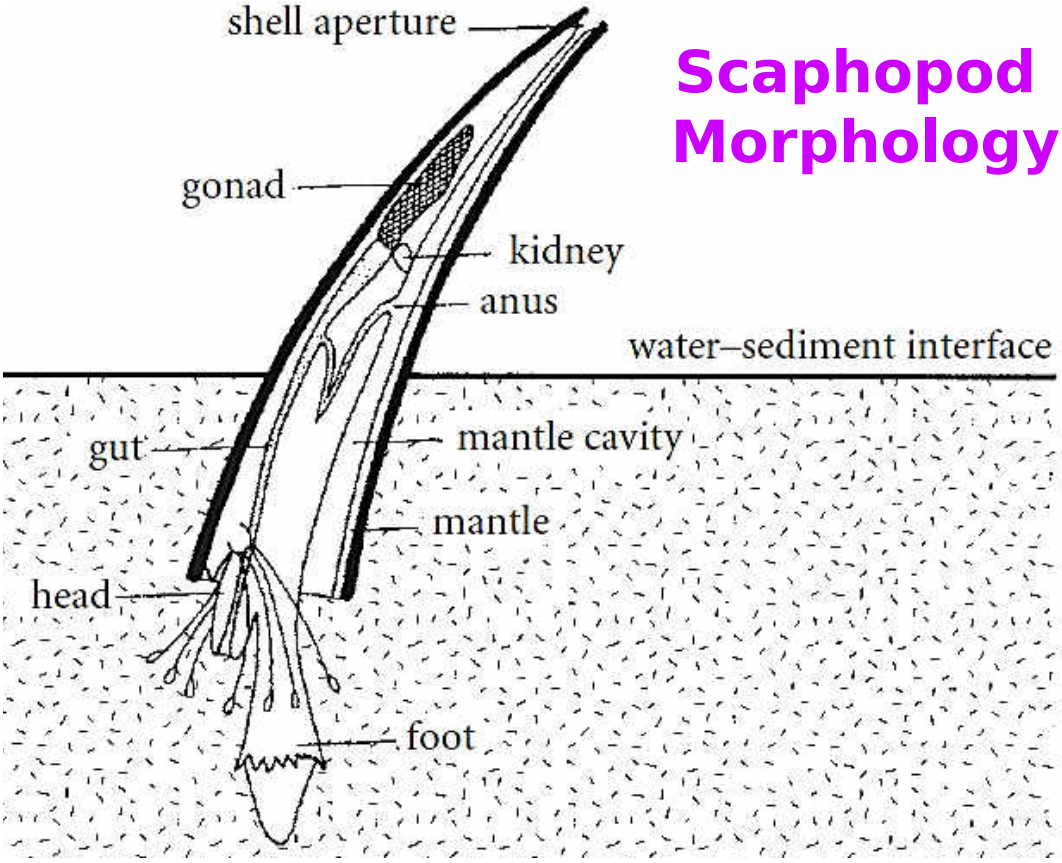
- **Are generally rare as fossils**
- **The Scaphopoda, or elephant-tusk shells, have a single, slightly curved high conical shell, open at both**

Spiralians

Scaphopods

- **They lack gills and eyes,**
- **Have a mouth equipped with a radula**
- **A foot, surrounded by tentacles similar to that of the bivalves, adapted for**

Spiralians



Scaphopod Morphology

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Spiralians

Scaphopods

- **Carnivorous, feeding on small organisms, foraminiferans**
- **Spend life in quasi-infaunal positions within soft sediment in deeper-water**

Spiralians

END

Scaphopods

- **The first scaphopods appeared during the Devonian and apparently had similar lifestyles to living forms such as *Dentalium***

Spiralians

Mollusks: Class Rostroconcha

Spiralians

Rostroconchs

- **Relatively recently a small class of mollusks**
- **Superficially resembling bivalves but lacking a functional hinge,**
- **Documented from the**

Spiralians

Rostroconchs

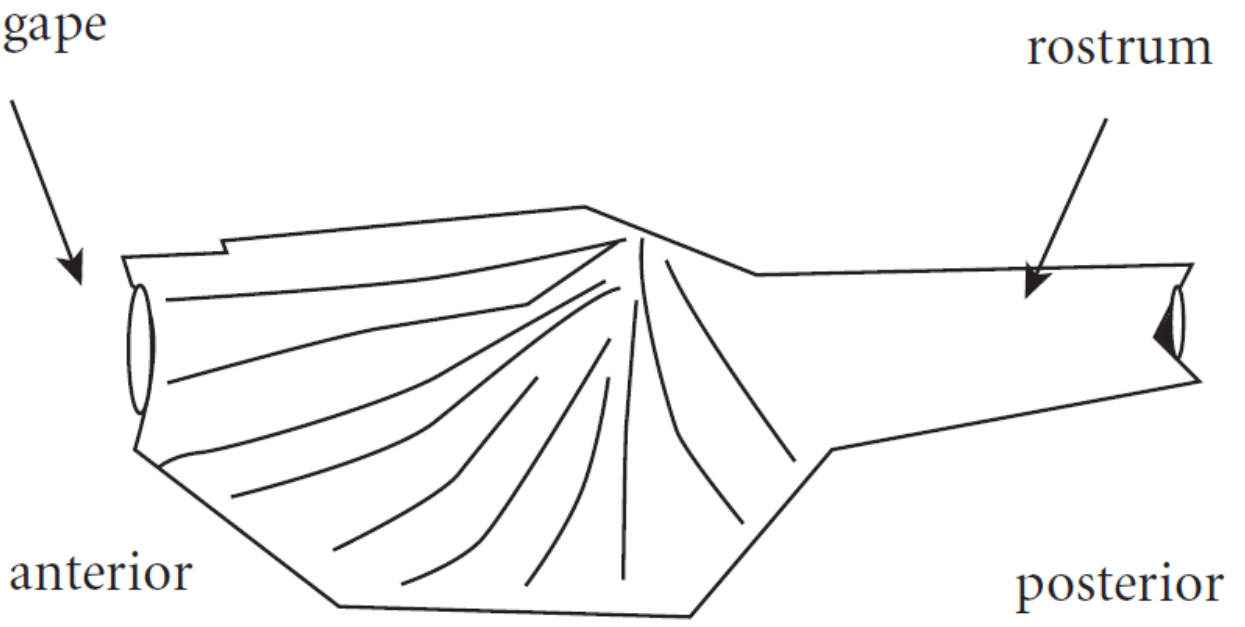
- **Over 35 genera**
- **Originally described as bivalved arthropods**
- **Had a foot that emerged through the anterior gape between the shells**

Spiralians

Rostroconchs

- **The two shells are fused along the middorsal line**
- **Posteriorly the shells are extended as a platform or rostrum**

Spiralians



Rostroconch Morphology

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=13&fig=Fig13-25&img=c13f025

Spiralians

Evolution

- **Appeared first: Early Cambrian**
- ***Heraultipegma* and *Watsonella* dominated faunas of the Tommotian**
- **Diversified: During Ordovician**

Spiralians

Evolution

- **Similar to bivalves ecological niches**
- **Decline in abundance and diversity**
- **Final extinction: end of the Permian**
- **Except**

Spiralians

Evolution

- **The Rostroconchs occupy a pivotal position in molluskan evolution**
- **Developed from within the monoplacophoran plexus**

Spiralians

Evolution

- **Generated both the bivalves and the scaphopods**
- **The gastropods and cephalopods were probably derived independently**

Spiralians

Evolution

- **Missing link between the univalved and bivalved molluskan lineages**
- **Their unlikely morphology may have contributed towards their late discovery**

END

Spiralians

Evolutionary Trends Within The Mollusca

Spiralians

Phanerozoic

- **A spectacular variety of mollusk morphotypes and life modes evolved during the Phanerozoic, from the simple body**

Spiralians

Cambrian

- **Despite the diversity of early mollusks in the Cambrian, the phylum was not notably conspicuous in the tiered suspension-**

Spiralians

Paleozoic Bivalves

- **Common in nearshore environments, associated with *lingulide brachiopods***
- **Inhabited deeper-water clastic environments**

Spiralians

Paleozoic Bivalves

- **Late Paleozoic: a variety of carbonate environments**
- **End of the Paleozoic: shallow-water belts displaced the Paleozoic associations seaward.**

Spiralians

Mesozoic and Cenozoic Bivalves

- **Late Mesozoic and Cenozoic: The significant radiation of infaunal taxa**
- **A response to increased predation**

Spiralians

Paleozoic Gastropods

- **The majority were Eogastropoda**
- **Dominated shallow-water marine environments and some carbonate reef settings**

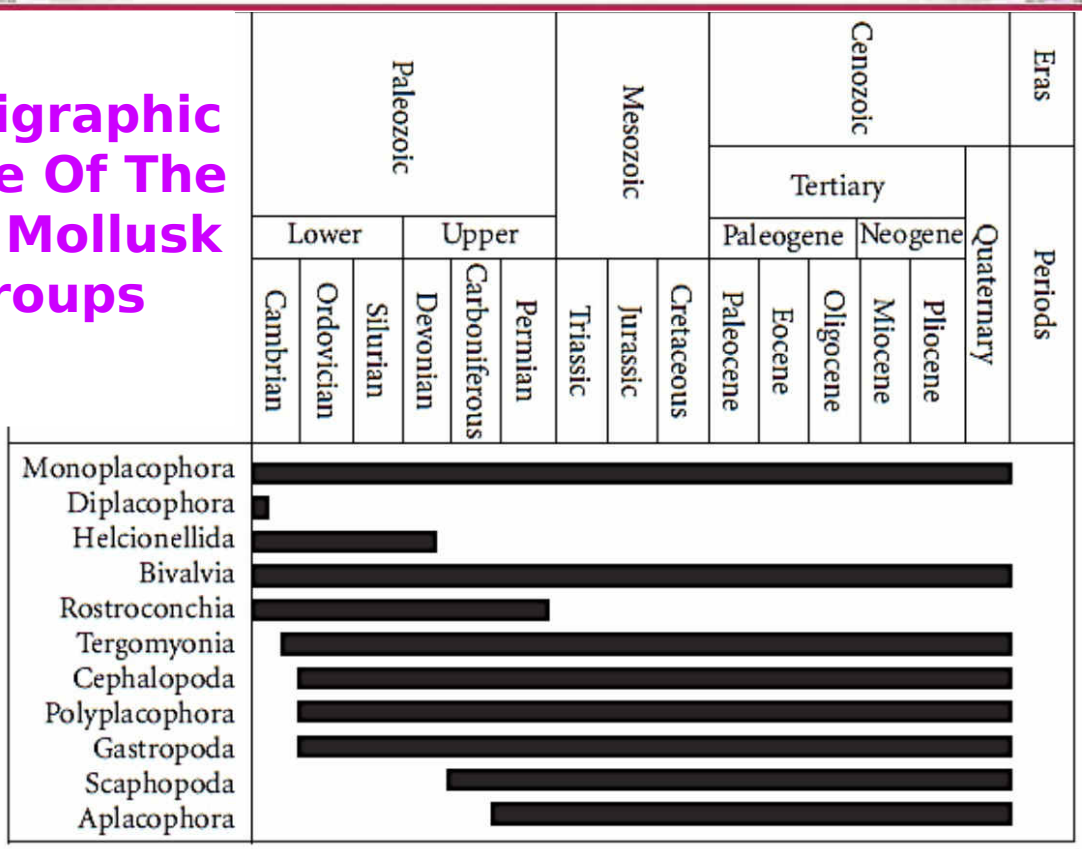
Spiralians

Mesozoic Gastropods

- **Mesogastropoda, grazed on algal-coated hard substrates**
- **The Cenozoic: the acme of the group with the radiation of the siphonal carnivorous**

Spiralians

Stratigraphic Range Of The Main Mollusk Groups



http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=13&fig=Fig13-26&img=c13f026

Spiralians

Cephalopods

- **Radiation: during the Mesozoic**
- **The development of a chambered shell with a siphuncle, which gave them considerable**

END

Ecdysozoa: Arthropods

Introduction

Ecdysozoa: Arthropods

Arthropods

- **Such as lobsters, spiders, beetles and trilobites**
- **Have legs, a segmented body plan with jointed appendages and the ability to molt**

Ecdysozoa: Arthropods

Arthropods

- **The first major faunas: Early Cambrian**
- **Appear bizarre**
- **Probably were no more morphologically different to each other than living**

Ecdysozoa: Arthropods

Arthropods

- **Arthropod-like animals in the Ediacara biota: Ancient origins**
- **Trilobites appeared: Early Cambrian and during the**

Ecdysozoa: Arthropods

Trilobites

- **Evolved advanced visual systems**
- **Enrolment structures**
- **In Order to pursue a variety of benthic and pelagic life**

Ecdysozoa: Arthropods

The Largest Arthropods

- **Chelicerates and included the giant *eurypterids***
- **Patrolled marine marginal environments during the Silurian and Devonian.**

Ecdysozoa: Arthropods

Myriapods

- **Earliest terrestrial body fossils in the Mid Ordovician**
- **Trackways of euthycarcinoids (i.e. stem-group mandibulates) show that these moved**

Ecdysozoa: Arthropods

Insects

- **Insects first appeared during the Early Devonian and diversified rapidly**
- **There are probably 10 million species of**

Ecdysozoa: Arthropods

Flight in Insects

- **Insects had probably already evolved flight before the Mid Carboniferous, when giant dragonflies patrolled the forests.**

Ecdysozoa: Arthropods

The Crustaceans

- **include many familiar groups such as crabs, lobsters and shrimps**
- **Together with the barnacles and ostracodes.**

Ecdysozoa: Arthropods

History of Phylum

- **Exceptionally preserved fossils from the faunas of**
  1. **Cambrian Burgess Shale**
  2. **Chengjiang**
  3. **Sirius Passet**

END

Ecdysozoa: Arthropods

Arthropods

Ecdysozoa: Arthropods

Arthropods

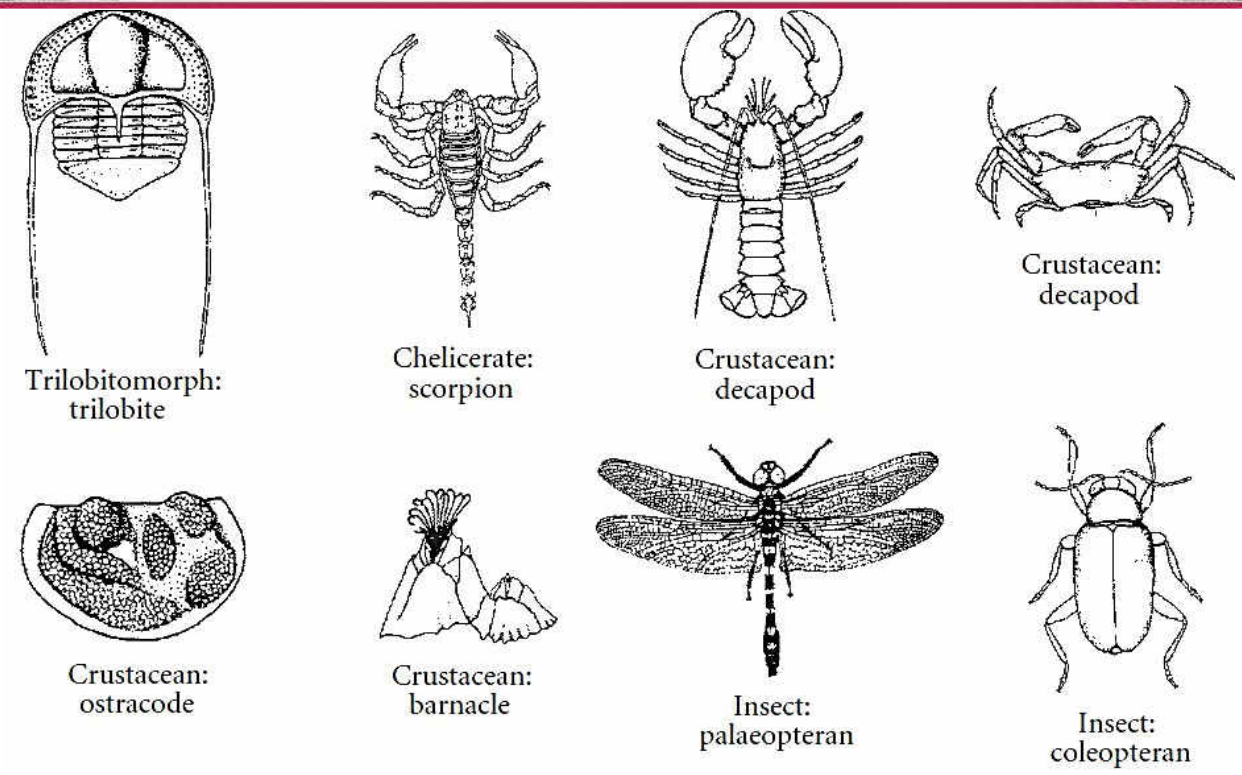
- **Arthropods are spectacularly diverse group of legged invertebrates**
- **Accounting for about three-quarters of all species living**

Ecdysozoa: Arthropods

Basic Body Plan

- **Segmented, with jointed appendages**
- **Adapted for feeding, locomotion and respiration**
- **Exoskeleton appeared during the Early**

Ecdysozoa: Arthropods



All Members of This Phylum have Both Segmented Bodies And Appendages

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=14&fig=Fig14-1&img=c14f001

Ecdysozoa: Arthropods

Basic Body Plan

- **Differentiated into a head, thorax and abdomen**
- **Often the head and thorax fused: Cephalothorax**
- **Hard mouthparts, mandibles:**

Ecdysozoa: Arthropods

Arthropod Exoskeleton

- **Organic substance, chitin**
- **Hardened or sclerotized by $CaCO_3$ or $Ca_3(PO_4)_2$**
- **Potential for preservation: Excellent**

Ecdysozoa: Arthropods

Arthropod Exoskeleton

- **Acts as a base for the attachment of locomotory muscles**
- **Permitting rapid movement**
- **Not usually mineralized**

Ecdysozoa: Arthropods

Arthropod Exoskeleton

- **Metamorphosis: Many arthropods**
- **Molting or Ecdysis: All the main groups**
- **Exuviae, or cast-off coverings: previous**

Ecdysozoa: Arthropods

Five Subphyla

- **During a geological history of at least 540 million years, the five subphyla of arthropod have adapted to life in marine, freshwater**

Ecdysozoa: Arthropods

Five Subphyla

1. **Trilobitomorpha: Cambrian to Permian**
2. **Chelicerata: Cambrian to Recent**
3. **Myriapoda: Ordovician, Silurian to Recent**

Ecdysozoa: Arthropods

Five Subphyla

4. **Hexapoda: Devonian to Recent**

5. **Crustacea: Cambrian to Recent**

END

Ecdysozoa: Arthropods

Subphylum Trilobitomorpha

Ecdysozoa: Arthropods

Trilobitomorphs

- **Highly derived arthropods**
- **lack specialized mouthparts**
- **Tagmata comprising the cephalon, thorax and pygidium**
- **Trilobitomorp**

Ecdysozoa: Arthropods

Trilobitomorphs

- **Mainly the trilobites and over 15,000 species are known**
- **Common: throughout the Paleozoic**
- **Extinction: end of the Permian**

Ecdysozoa: Arthropods

Earliest Arthropods

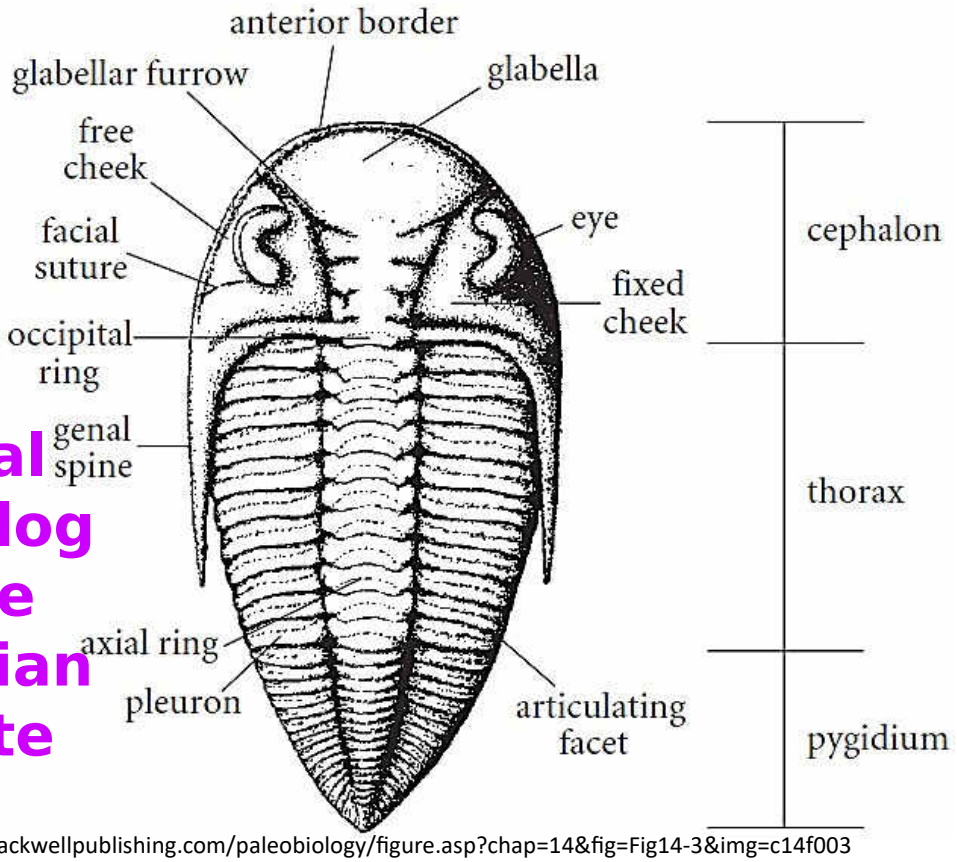
- **Earliest arthropods were trilobites**
- **Marine Cambrian strata are usually correlated on the basis of**

Ecdysozoa: Arthropods

Morphology

- **Trilobite (“three-lobed”)**
- **Exoskeleton is divided into three lobes**
- **The axial lobe protects digestive system, whereas the two pleural**

Ecdysozoa: Arthropods



External Morphology of the Ordovician Trilobite

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=14&fig=Fig14-3&img=c14f003

Ecdysozoa: Arthropods

Evolution

- **Trilobite faunas: basis for many paleogeographic reconstructions of the Cambrian and Ordovician world**
- **The Cambrian**

Ecdysozoa: Arthropods

Evolution

- **Some Early Paleozoic trilobite communities may also be interpreted as showing an onshore–offshore spectrum**

Ecdysozoa: Arthropods

Evolution

- **Trilobites (such as *Choubertella* and *Schmidtiellus*) first appeared in the Early Cambrian**
- **Survived until the end of the Permian**

Ecdysozoa: Arthropods

Extinction

- **Last genera, such as *Pseudophillipsia*, disappeared: end of the Permian**
- **History of 350 million years, the basic body plan**

Ecdysozoa: Arthropods

Macroevolution Studies

- **Trilobites have provided key evidence in studies of macroevolution**
- **Controversy over punctuated equilibrium and phyletic**

END

Ecdysozoa: Arthropods

Subphylum Chelicerata

Ecdysozoa: Arthropods

Chelicerates

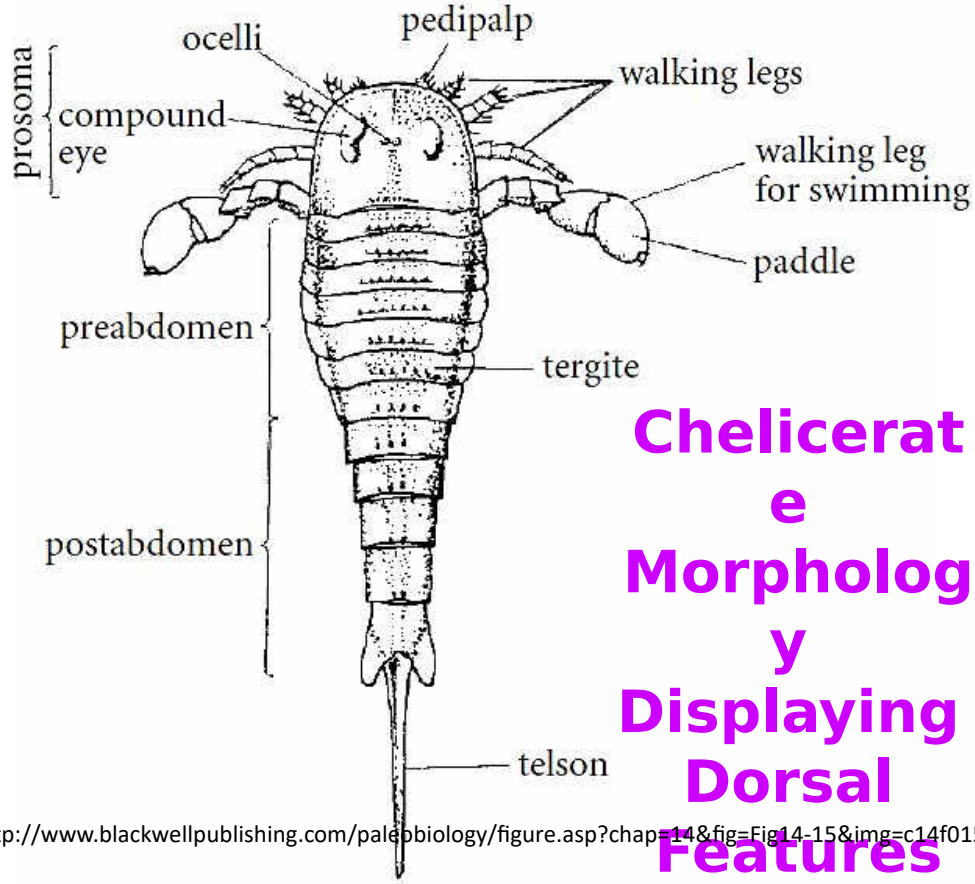
- **Diverse and heterogeneous**
- **Mites, scorpions and spiders.**
- **The familiar horseshoe crab *Limulus*, together with the extinct sea**

Ecdysozoa: Arthropods

Chelicerates

- **Prosoma (head and thorax) with 6 segments with appendages.**
- **An opisthosoma (abdomen) with 12 segments,**
- **Pair of**

Ecdysozoa: Arthropods



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Chelicerate Morphology Displaying Dorsal Features

Ecdysozoa: Arthropods

Chelicerate Groups

- **Traditionally two main groups**

1. **The merostomes, including the aquatic horseshoe crab *Limulus* and the giant sea scorpions**

Ecdysozoa: Arthropods

Chelicerate Groups

2. **The arachnids: mainly comprise the terrestrial spiders and scorpions.**

- **This split of the subphylum into marine**

Ecdysozoa: Arthropods

Evolution

- **The bizarre *Sanctacaris* from the Middle Cambrian Burgess Shale may be a basal outgroup to the clade *Cheliceriata***

Ecdysozoa: Arthropods

Evolution

- **Xiphosure (Horse Shoe crab) -like taxa, such as *Eolimulus,* have been described from the Lower Cambrian**
- **A trend towards**

Ecdysozoa: Arthropods

Evolution

- **50 genera of eurypterids have been described**
- **The group was most abundant during the Silurian and Devonian**
- **Arachnids**
- **Book lungs or**

END

Ecdysozoa: Arthropods

Subphylum Myriapoda

Ecdysozoa: Arthropods

Myriapods

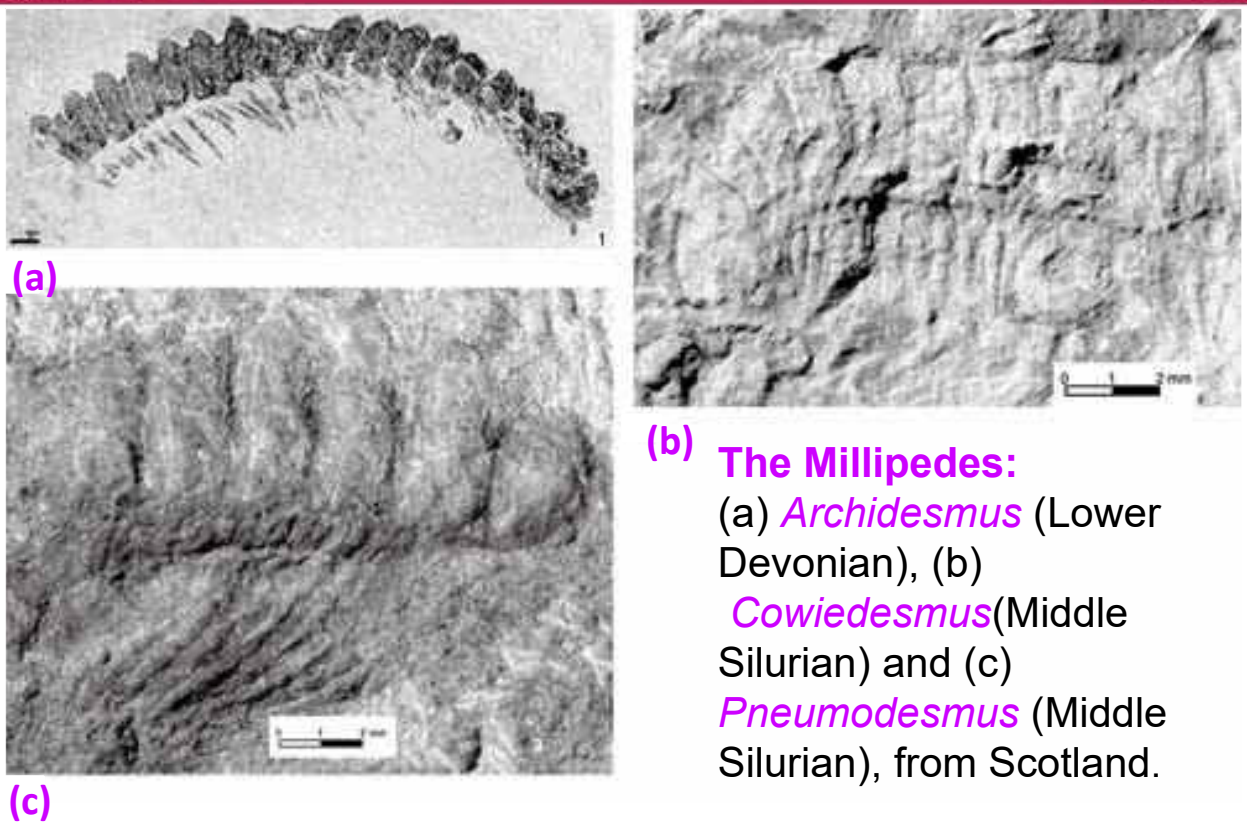
- **A varied group comprising the millipedes, centipedes, symphylans and pauropods**
- **First appeared**

Ecdysozoa: Arthropods

Invasion of land

- **The first animals to colonize the land.**
- **Heather Wilson and Lyall Anderson (2004) have described the few Silurian and Devonian**

Ecdysozoa: Arthropods



The Millipedes:
(a) *Archidesmus* (Lower Devonian), (b) *Cowiedesmus*(Middle Silurian) and (c) *Pneumodesmus* (Middle Silurian), from Scotland.

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Ecdysozoa: Arthropods

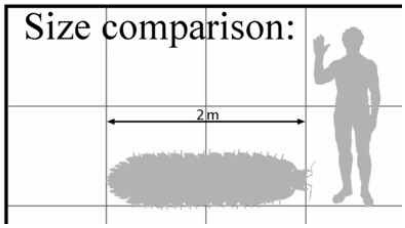
Invasion of land

- **The giant *Arthropleura*, nearly 2 m long, hoovered their way through the lush, green vegetation of the Late Carboniferous forests.**

Ecdysozoa: Arthropods



The giant *Arthropleura*



https://commons.wikimedia.org/wiki/File:Arthropleura_NT_small.jpg#/media/File:Arthropleura_NT_small.jpg

Ecdysozoa: Arthropods

Fossil footprints of Arthropleura, Laggan Harbour, Isle of Arran, Scotland.



https://commons.wikimedia.org/wiki/File:Fossil_Footprints_Arthropleura_-_geograph.org.uk_-_1994274.jpg#/media/File:Fossil_Footprints_Arthropleura_-_geograph.org.uk_-_1994274.jpg

Ecdysozoa: Arthropods

Invasion of land

- **Trackways from Middle Ordovician rocks in the English Lake District (Johnson et al. 1994) suggests that arthropods were on land about 50 myr**

Ecdysozoa: Arthropods

Invasion of land

- **Trace fossils from Cambrian rocks in Ontario push arthropod life on land back (MacNaughton et al. 2002) suggesting the presence then of large,**

Ecdysozoa: Arthropods

END

Euthycarcinoids

- **An enigmatic group of arthropods with antennae and mandibles**
- **In phylogeny somewhere near the origin of myriapods and insects**

Ecdysozoa: Arthropods

Subphylum Hexapoda

Ecdysozoa: Arthropods

Hexapoda

- **Can be divided into pterygotes (with wings) and apterygotes (without wings)**
- **Include the springtails, dragonflies, cockroaches**

Ecdysozoa: Arthropods

Hexapoda

- **The group may prove to have as many as 10 million living species when the rich faunas of the tropics have been completely described.**

Ecdysozoa: Arthropods

Hexapoda

- **Unbranched appendages, a simple gut, a single pair of antennae and a pair of mandibles, together with a toughened head capsule.**
- **Insects: six limbs**

Ecdysozoa: Arthropods

The Oldest Insect

- **Probably the springtail *Rhyniella praecursor* from the Lower Devonian Rhynie Chert of the Orcadian Basin of northeast**

Ecdysozoa: Arthropods

Insects Diversified

- **Had been earlier than had been thought (Labandeira 2006)**
- **The group probably originated in freshwater during the Late Silurian**

Ecdysozoa: Arthropods

Insects Diversified

- **Fresh water origin may account for the poor fossil record of the group before the Devonian (Glenner et al. 2006).**

Ecdysozoa: Arthropods

Insects Diversified

- **Early and Mid Devonian faunas are known from Rhynie, Gaspé, Québec and Gilboa, New York State**
- **Coincided with the diversification**

Ecdysozoa: Arthropods

Insects Flight

- **By the Late Carboniferous a very diverse insect fauna had evolved, with forms such as the dragonflies and mayflies capable of powered**

Ecdysozoa: Arthropods

Insects & Plants

- **End of the Permian: familiar insect orders had appeared.**
- **Late Mesozoic and Cenozoic: significant coevolutionary relationships between**

Ecdysozoa: Arthropods

Insects & Mammals

- **Miocene: Fossil hair trapped in amber together with the sand fly *Lutzomyia***
- **These blood suckers were already feeding on mammals**

END

Ecdysozoa: Arthropods

Subphylum Crustacea

Ecdysozoa: Arthropods

Crustaceans

- **A hard, crusty carapace.**
- **First appeared in the Cambrian**
- **Aquatic, mainly marine, with gills, mandibles, two pairs of**

Ecdysozoa: Arthropods

Crustaceans

- **The heavily armored crabs and lobsters typify this diverse subphylum**
- **The barnacles and ostracodes are crustaceans**

Ecdysozoa: Arthropods

Crustaceans

- **Eight main classes**
- **Ostracodes are considered part of the microfauna**
- **Only two groups, the Cirripedia and the Malacostraca**

Ecdysozoa: Arthropods

Cirripedes

- **Or barnacles have shells, or capitula (singular, capitulum), consisting of several plates and these animals are adapted to an encrusting lifestyle**

Ecdysozoa: Arthropods

Cirripedes

- **Acorn barnacles and goose barnacles**
- **Contrasting life strategies.**
- **Acorn barnacles During the Late**

Ecdysozoa: Arthropods

Malacostracans

- **Include two subclasses,**
- **Phyllocarids and Eumalacostracans**
- **The phyllocarids have large bivalved carapaces, seven**

Ecdysozoa: Arthropods



The First Crustaceans:*Canadaspis* from the Burgess Shale

https://en.wikipedia.org/wiki/Canadaspis#/media/File:Canadaspis_perfecta_Burgess_Shale.jpg

Ecdysozoa: Arthropods

END

Ostracodes

- **Ostracodes are crustacean arthropods, abundant and widespread in aquatic environments.**
- **Appeared first during the Early Cambrian**

Deuterostomes

Echinoderms and Hemichordates

Deuterostomes

Deuterostomes;

- **The first opening to develop in the embryo is the anus and a second forms the mouth.**
- **A dipleurula larva & body cavity that developed from an**

Deuterostomes

Echinoderms

- **Sea urchins starfish & sea cucumbers**
- **Water vascular system**
- **A mesodermal skeleton of calcitic plates**
- **Pentameral symmetry and tube feet.**

Deuterostomes

Echinoderms

- **During the Cambrian radiation many bizarre forms evolved.**
- **The spindle-shaped *Helicoplacus* may be part of the stem group for the**

Deuterostomes

Echinoderms

- **Pelmatozoans: fixed echinoderms**
- **The blastoids, crinoids and cystoids;**
- **The crinoids; four classes, the Inadunata, Flexibilia, Camerata and Articulata**

Deuterostomes

Echinoderms

- **The echinoids were part of the mobile benthos.**
- **During the Mesozoic irregular groups, adapted for burrowing, evolved from the more**

Deuterostomes

Asteroids

- **Asteroids (starfish) were more important in post-Paleozoic rocks; their Triassic radiation may have inhibited the re-radiation of some key**

Deuterostomes

Carpoids

- **Traditionally classed with the echinoderms**
- **Some have argued they were ancestral to chordates**
- **They were probably stem-group**

Deuterostomes

Hemichordates

- **Graptolites are hemichordates closely related to the living rhabdopleurids with similarly constructed rhabdosomes**

Deuterostomes

Hemichordates

- **Graptolites probably pursued benthic (dendroids), planktic (dendroids and graptoloids) and automobile (graptoloids)**

Deuterostomes

Hemichordates

- **Graptoloids evolved rapidly and were widespread**
- **The ideal zone fossils in rocks of Ordovician-Silurian and Early**

END

Deuterostomes

Echinoderms

Deuterostomes

Echinoderms

- **One of the most abundant marine animal groups**
- **As fossils they can sometimes be rather robust**
- **an unusual five-fold symmetry &**

Deuterostomes

Water Vascular System

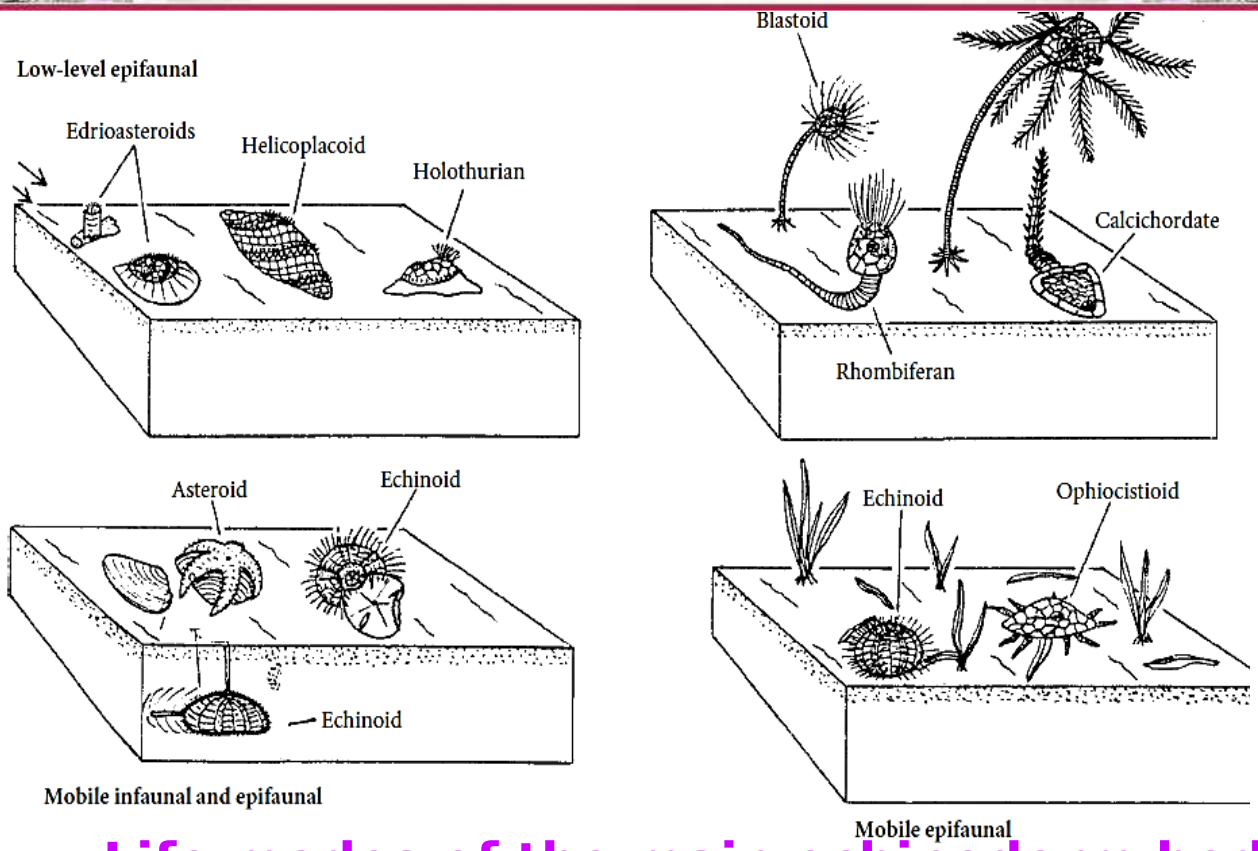
- **Water is forced around the plumbing by muscular action**
- **Tube feet: are often modified for food processing,**

Deuterostomes

Echinoderms

- **The 6000 or so living echinoderm species include familiar forms such as sea lilies, sea urchins, sand dollars, starfish and**

Deuterostomes



Life modes of the main echinoderm body pla

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=15&fig=Fig15-1&img=c15f001

Deuterostomes

Echinoderms

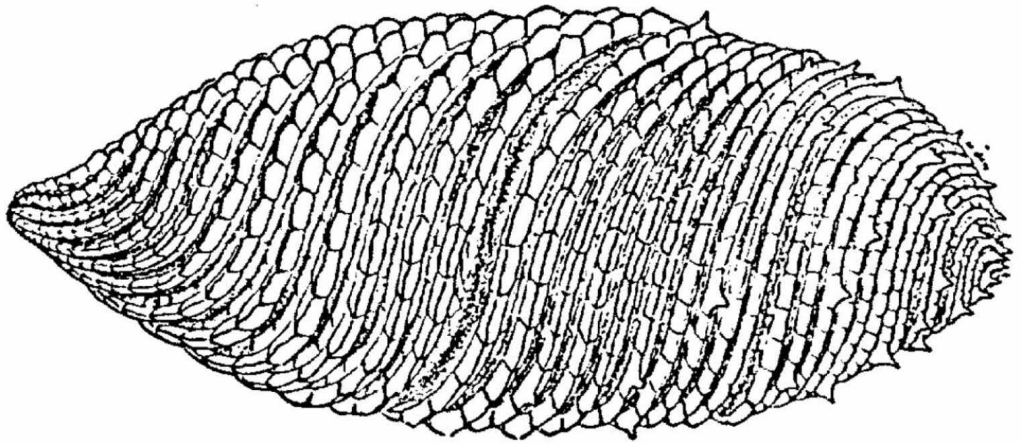
- **One of the most remarkable Lagerstätte occurs in the Upper Ordovician succession of the Craighead inlier, north of the Girvan valley,**

Deuterostomes

Echinoderms

- **During the Early Cambrian radiation: bizarre forms appeared suddenly with very different morphologies**
- **One non-pentameral group The**

Deuterostomes



Helicoplacus from the Lower Cambrian (×10).

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=15&fig=Fig15-1&img=c15f002

Deuterostomes

Classification

- **Class Eocrinoide**
  Cambrian to Silurian
- **Class Paracrinoidea**
  Ordovician
- **Class Blastoidea**
  Ordovician to Permian
- **Class Diploporita**
  Cambrian to

Deuterostomes

Classification

- **Class Rhombifera**
  Cambrian to Devonian
- **Class crinoidea**
  Ordovician to recent
- **Class Asteroidea**
  Ordovician to Recent
- **Class Echinoidea**

END

Deuterostomes

Hemichordates

Deuterostomes

Hemichordates

- **Form a small phylum of only a few hundred species**
- **Common fossil representatives, the graptolites in ancient seas**

Deuterostomes

Graptolites

- **Extinct**
- **life styles are difficult to interpret**
- **small, soft-bodied animals with bilateral symmetry and a lack of segmentation**

Deuterostomes

Hemichordata

- **Two classes**
- **First, the tiny, mainly colonial, pterobranchs in sessile benthos**
- **Second, the larger infaunal acorn or**

Deuterostomes

Hemichordata

- **Closely related to cephalochordates and urochordates or tunicates,**
- **Molecular data suggest that the latter two groups are more**

Deuterostomes

Hemichordates

- **Graptolites probably pursued benthic (dendroids), planktic (dendroids and graptoloids) and automobile**

Deuterostomes

Hemichordates

- **Graptoloids evolved rapidly and were widespread**
- **The ideal zone fossils in rocks of Ordovician-Silurian and Early**

Deuterostomes

Classification

- **Class Graptolithina**
- **Order Dendroidea Cambrian to Carboniferous**
- **Order Tuboidea Ordovician to Silurian**
- **Order Camaroidea**

Deuterostomes

Classification

- **Order Crustoidea**
  Ordovician
- **Order Dithecoidea**
  Cambrian to Silurian
- **Order Graptoloidea**
  Ordovicianto Devonian

END

Fishes & Basal Tetrapods

Introduction

Fishes & Basal Tetrapods

Vertebrates

- **Subgroup of the Phylum Chordata, a major deuterostome clade.**
- **The evolution of fishes from the Cambrian to the present day, and the Paleozoic**

Fishes & Basal Tetrapods

Vertebrates

- **Characterized by a skeleton made from bone (apatite)**
- **The oldest vertebrates are small fish-like creatures from the Early Cambrian of China.**

Fishes & Basal Tetrapods

Ancient Fishes

- **Armored fishes were abundant in Devonian seas and lakes.**
- **After the Devonian, the cartilaginous and bony fishes radiated in**

Fishes & Basal Tetrapods

Conodonts

- **Conodonts commonly occur as tooth-like elements that are useful in biostratigraphy, as are some other fish teeth and scales (ichthyoliths)**

Fishes & Basal Tetrapods

Tetrapods

- **Arose during the Devonian from lobe-finned fish ancestors, and fish-eating amphibians**
- **Diversified in the**

Fishes & Basal Tetrapods

Reptiles

- **The first reptiles were small insect eaters.**
- **Synapsids dominated ecosystems on land during the Permian and Triassic.**

Fishes & Basal Tetrapods

Reptiles

- **These groups were heavily hit by the end-Permian mass extinction event, and diapsid reptiles, most notably the dinosaurs, were key**

Fishes & Basal Tetrapods

Importance of Vertebrates

- **Humans are such a successful species**
- **The huge diversity and abundance of species of bony fishes, birds and**

Fishes & Basal Tetrapods

END

Importance of Vertebrates

- **Insects and microbes, are also abundant and diverse**
- **Vertebrates include the largest animals on land, in the sea and in the air.**

Fishes & Basal Tetrapods

Origin of the Vertebrates

Fishes & Basal Tetrapods

The Skeleton

- **Bone and cartilage.**
- **Bone: A network of collagen fibers on which needle-like crystals of hydroxyapatite (a form of apatite**

Fishes & Basal Tetrapods

The Skeleton

- **Cartilage: Flexible tissue, usually unmineralized, contains collagen and elastic tissues.**
- **In humans; early skeleton, cartilage, progressively mineralizes by**

Fishes & Basal Tetrapods

The Skeleton

- **The first vertebrates had a cartilaginous skeleton.**
- **Some of the oldest fish grow very large because the skeleton can grow with the animal**

Fishes & Basal Tetrapods

Jawless Fishes

- **Two key defining characters : the head and neural crest tissues**
- **The neural crest appears in the early embryo as a strip of cells where the**

Fishes & Basal Tetrapods

Jawless Fishes

- **The first vertebrates had no jaws**
- **Fossil sites at Chengjiang in China: Early Cambrian.**
- **Late Cambrian and Ordovician: commonest vertebrates were the conodont**

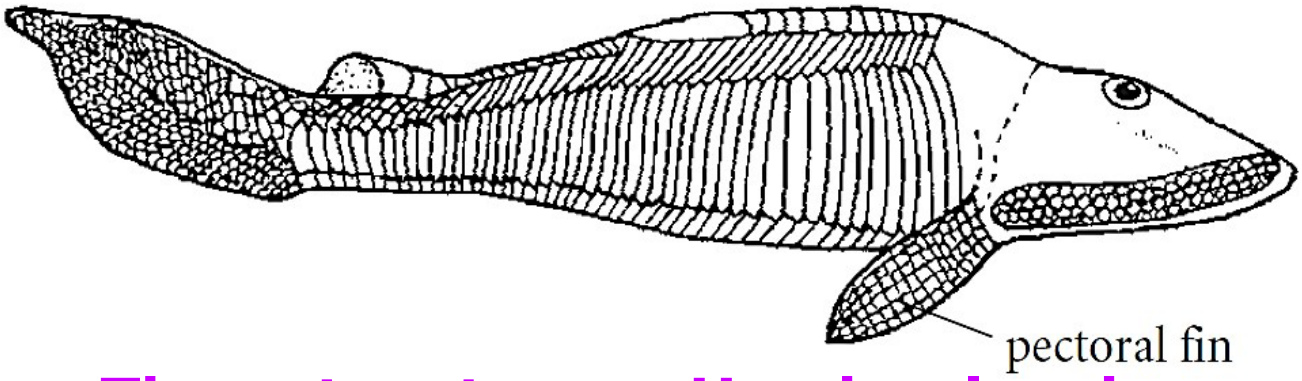
Fishes & Basal Tetrapods

Jawless Fishes

- **Ostracoderms**
- **Were jawless, generally armored**
- **Had their heyday in the Devonian.**
- ***Hemicyclaspis***
- **Today, the 50 or so species of lampreys and hagfishes,**

Fishes & Basal Tetrapods

Jawless Fishes



The osteostracan Hemicyclaspis from the Devonian

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Fishes & Basal Tetrapods

END

Conodonts:

- **Animals of mystery**
- **The commonest early vertebrates (Sweet & Donoghue 2001).**
- **For over 150 years a mystery, known only from their jaw**

Fishes & Basal Tetrapods

Conodonts

Fishes & Basal Tetrapods

Conodonts

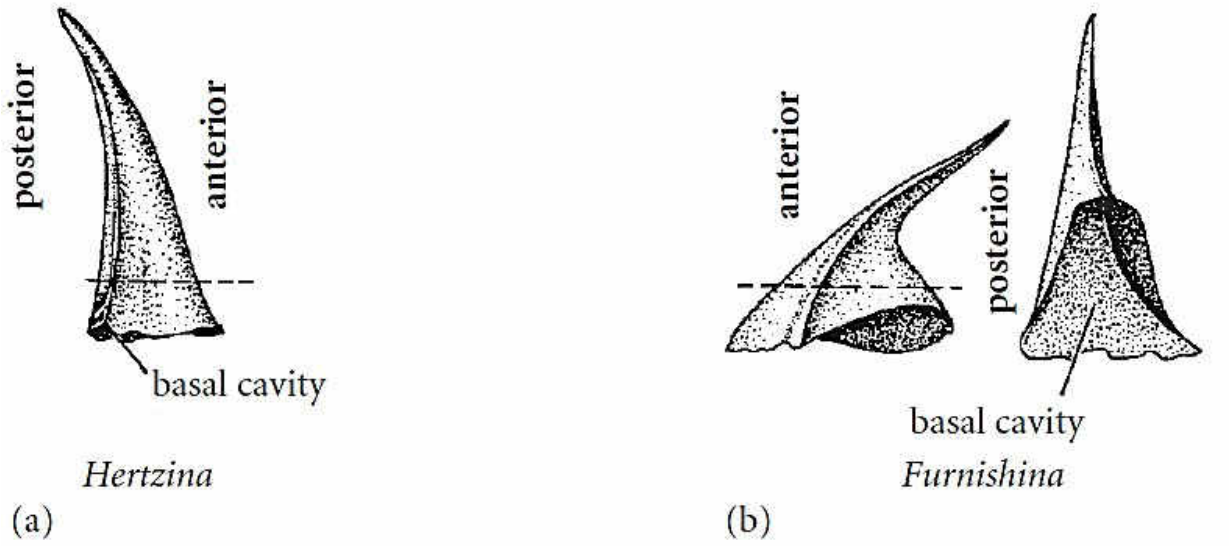
- **First identified by the Latvian embryologist and paleontologist Christian Pander in 1856.**
- **They occur as phosphatic tooth-like**

Fishes & Basal Tetrapods

Conodonts

- **Three main groups have been established**
- **Protoconodonts such as Hertzina**
- **Paraconodonts like Furnishina**
- **Euconodonts more**

Fishes & Basal Tetrapods



Descriptive morphology of the main types of conodont elements:
***(a)protoconodont Herzina* (×40);**
***(b)paraconodont Furnishina* (×40)**

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Fishes & Basal Tetrapods

Conodonts

- **Conodonts are common in certain marine facies from the Cambrian to the Triassic.**
- **Paraconodonts: Mid Cambrian**

Fishes & Basal Tetrapods

Conodont Element

- **The three main morphotypes**
- **The basis of a crude single element or form taxonomy**
- **Coniform: simplest, with the base surmounted by a cone-like**

Fishes & Basal Tetrapods

Bars or Ramiform

- **These elements consist of an elongate blade-like ridge with up to four processes developed posteriorly, anteriorly or**

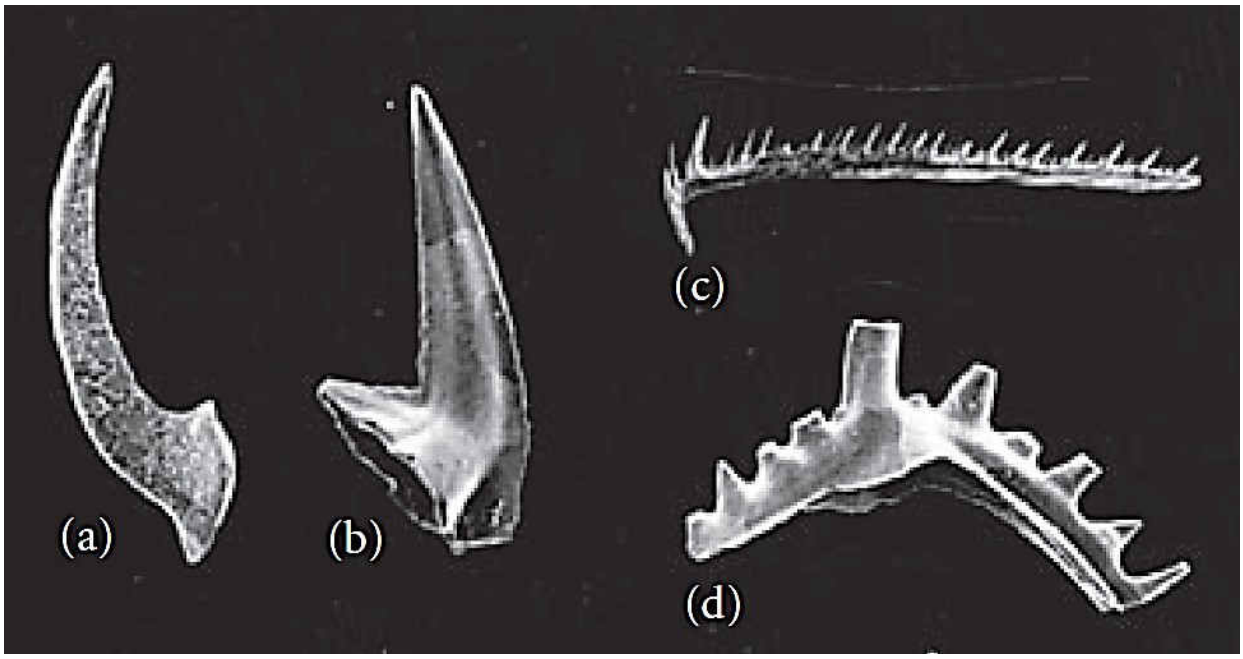
Fishes & Basal Tetrapods

Pectiniform elements

- **Platforms have a wide range of shapes, with denticulate processes extending both anteriorly, posteriorly and/ or laterally from the area of the basal cavity**

END-1

Fishes & Basal Tetrapods



Conodont elements:

(a, b) coniform, lateral view;

(c, d) ramiform, lateral view;

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Fishes & Basal Tetrapods

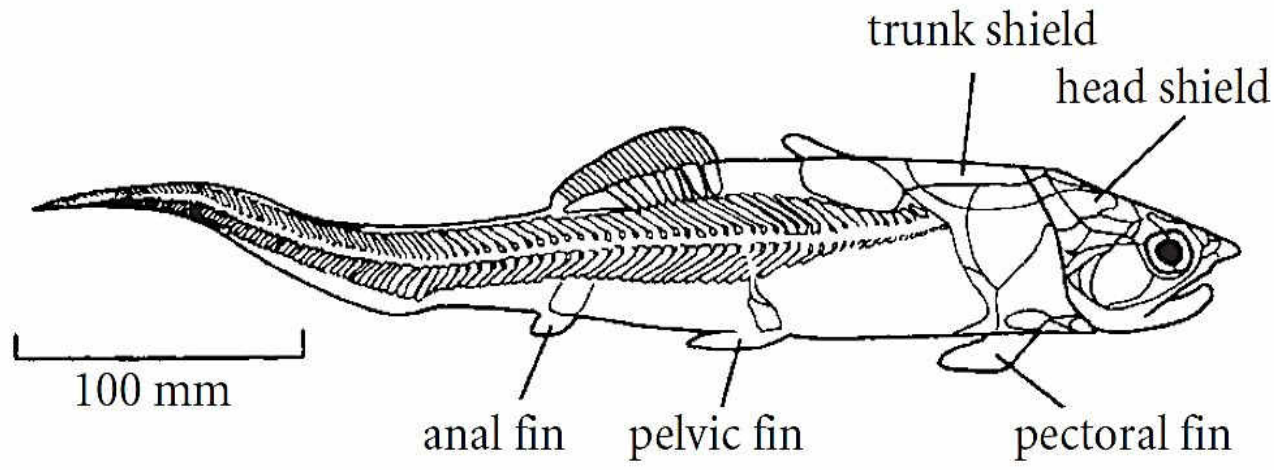
Jaws and Fish Evolution

Fishes & Basal Tetrapods

The First Jaws

- **The basal vertebrates, lacked jaws, jaws probably evolved during the Ordovician**
- **Oldest jaw-bearing fishes were the placoderms, such as**

Fishes & Basal Tetrapods



Jawed Fish of the Devonian
the placoderm *Coccosteus*

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Fishes & Basal Tetrapods

Chondrichthyans

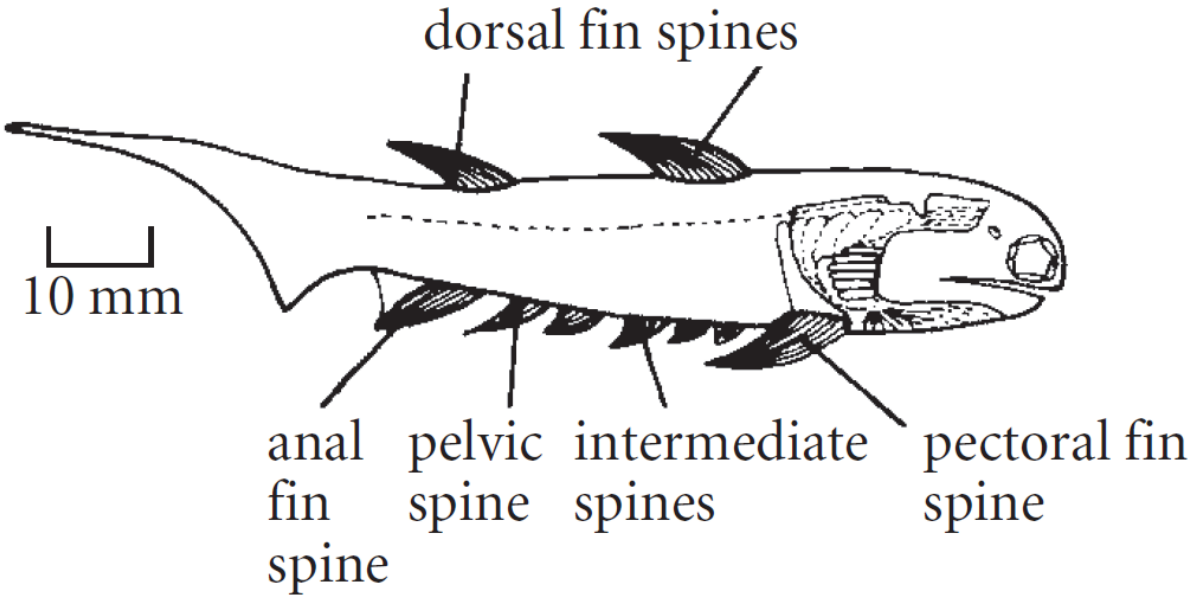
- **The first shark like chondrichthyans or cartilaginous fishes, came on the scene during the Early Devonian**

Fishes & Basal Tetrapods

Acanthodians

- **Small fishes, mostly in the range 50–200 mm in length, and they bore numerous spines at the front of each fin and spaced rows on their**

Fishes & Basal Tetrapods



Jawed Fish of the Devonian
the acanthodian *Climatius*

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Fishes & Basal Tetrapods

Bony fishes

- **The osteichthyans, or bony fishes, also appeared in the Devonian**
- **Two groups**
- **Ray fins and lobefins**

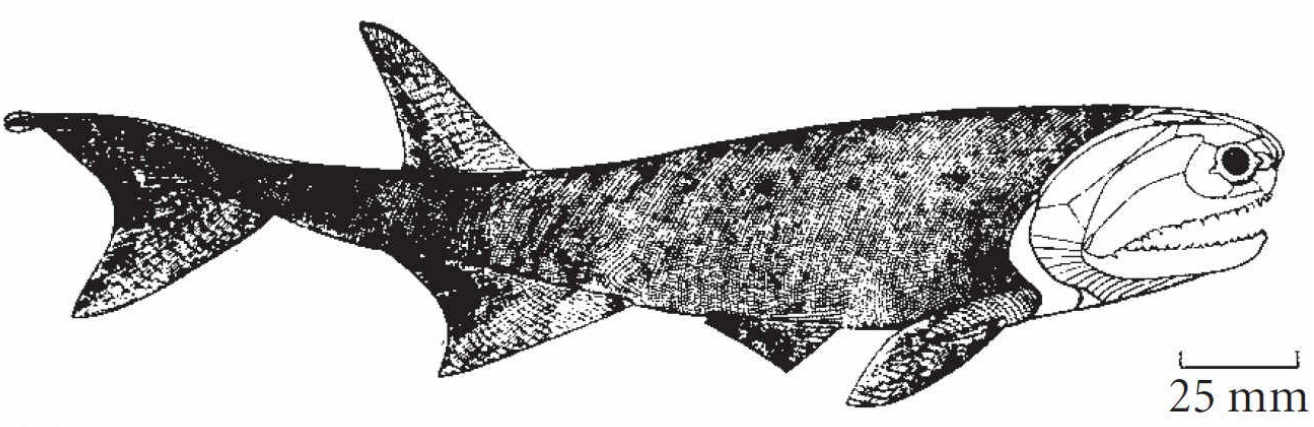
Fishes & Basal Tetrapods

Ray fins

- **Those with ray-like fins, the actinopterygians**
- **Ancestors of most fishes today**
- **From carp to salmon**
- **Seahorse to tuna**

END-2

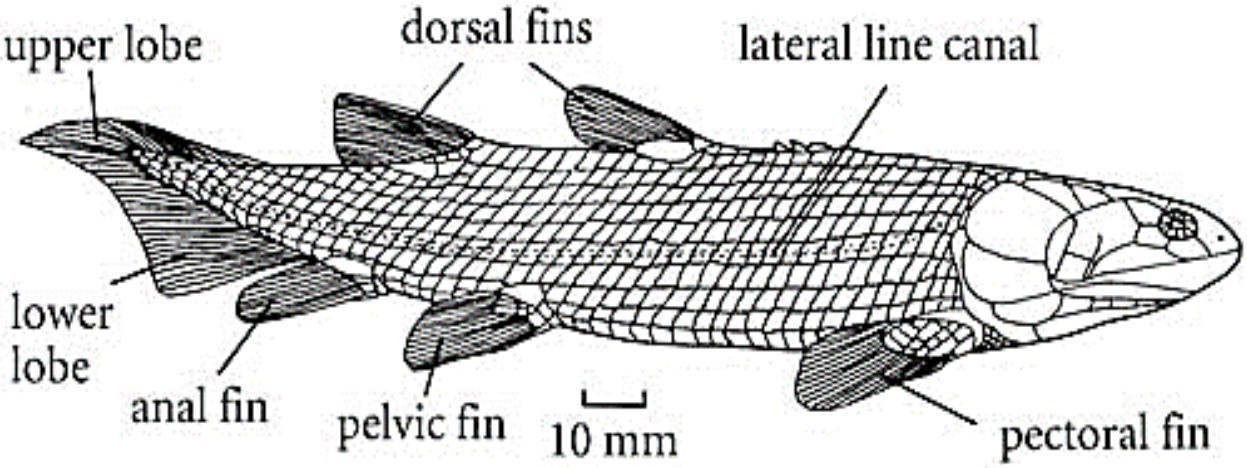
Fishes & Basal Tetrapods



Jawed Fish of the Devonian the actinopterygian bony fish Cheirolepis;

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Fishes & Basal Tetrapods



Jawed Fish of the Devonian
The lobefin Osteolepis

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Fishes & Basal Tetrapods

Tetrapods

Fishes & Basal Tetrapods

Fins to Limbs

- **When a fish became a land animal, surely the key problem was breathing air?**
- **Not so.**
- **Early bony fishes almost certainly had both lungs and gills**

Fishes & Basal Tetrapods

Main problem

- **Support**
- **In water, an animal "weighs" virtually nothing,**
- **On land the body has to be held up from the ground**
- **The internal**

Fishes & Basal Tetrapods

Other problems

- **Reproductive, osmotic (water balance) and sensory systems had to adapt**
- **These changes did not happen**

Fishes & Basal Tetrapods

Origins

- **Tetrapods arose from fishes during the Devonian**
- **Closest fishy relatives?**
- **The lobefins**
- **Complex bony and muscular pectoral (front) and pelvic (back) paired fins**

Fishes & Basal Tetrapods

Origins

- **The first good evidence of tetrapods comes from the Late Devonian**
- **Best-known forms are *Acanthostega* and *Ichthyostega*, which were**

Fishes & Basal Tetrapods



Skull of the Late Devonian amphibian

Acanthostega, showing the streamlined shape, deeply-sculpted bones and small teeth, all inherited from its fish ancestor

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Fishes & Basal Tetrapods

The Amphibians:

- **Half-way land animals**
- **4000 species of mainly small animals that live in or close to water**
- **Still rely on the water for breeding and water balance.**

Fishes & Basal Tetrapods

The Amphibians:

- **The oldest fossil form, with reduced limbs, is Jurassic in age.**
- **All living amphibians appear to be closely related**
- **Forming a**

Fishes & Basal Tetrapods

The Amphibians:

- **Subclass Lissamphibia**
- **Frogs, salamanders (newts) and caecilians (gymnophionans)**
- **Early Triassic to Recent**

Fishes & Basal Tetrapods

The Amphibians:

- **Subclass Reptiliomorpha**
- **Narrow-skulled, fish-eating amphibians**
- **High-skulled terrestrial amphibians**
- **Late Carboniferous**

END

Fishes & Basal Tetrapods

Reign of the Reptiles

Fishes & Basal Tetrapods

Origin of the Reptiles

- **Amphibians only made it halfway on to land**
- **They still produce swimming tadpoles**
- **Reptiles and their descendants:**

Fishes & Basal Tetrapods

Origin of the Reptiles

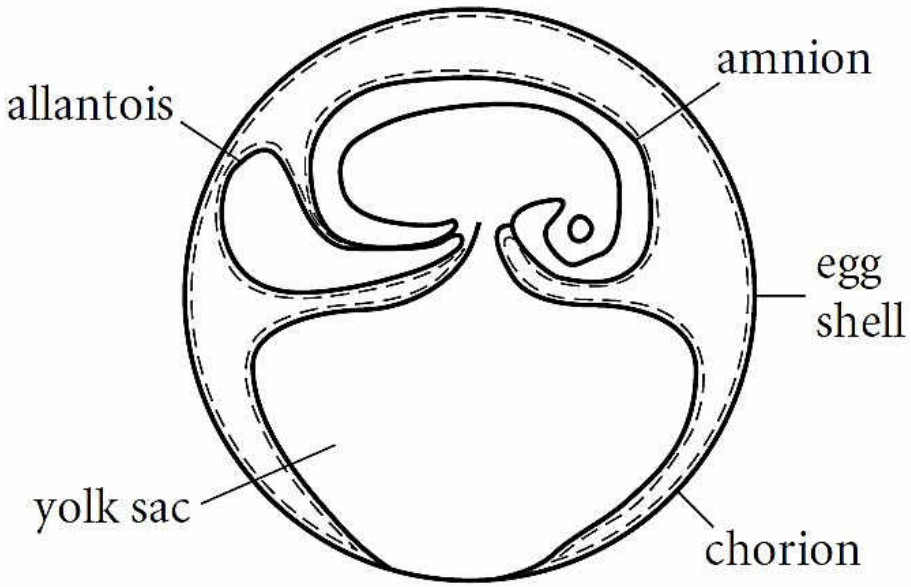
- **The cleidoic (“closed”) egg,**
- **Amniotic egg**
- **Tough semipermeable shell**
- **Clade Amniota (reptiles,**

Fishes & Basal Tetrapods

Membranes

- **Enclose the embryo (the amnion)**
- **Collect waste (the allantois)**
- **line the eggshell**
- **(the chorion)**
- **Yolk, a yellow material rich in protein.**

Fishes & Basal Tetrapods



The Cleidoic egg of amniotes in cross-section, showing the eggshell and extraembryonic membranes.

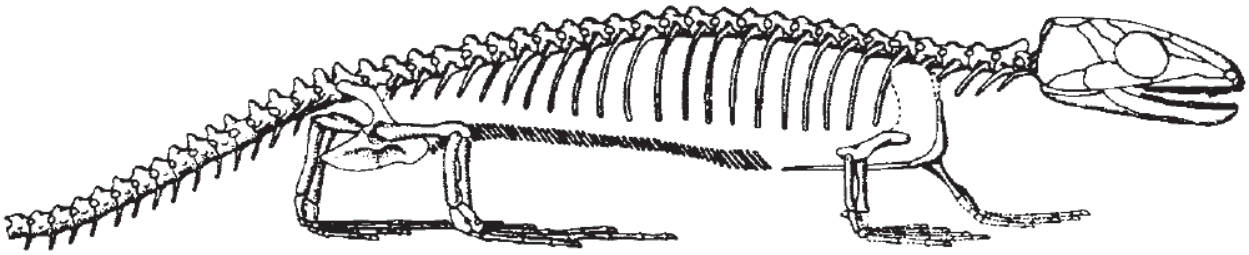
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Fishes & Basal Tetrapods

Oldest Amniote

- **Oldest-known amniote, *Hylonomus* from the mid-Carboniferous of Canada.**
- **Only skeleton; no amniotic eggs are known from the Carboniferous**

Fishes & Basal Tetrapods



(a)

The earliest reptile, The mid-Carboniferous Reptile *Hylonomus*, skeleton and skull

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Fishes & Basal Tetrapods

Radiation

- **Amniotes: Late Carboniferous**
- **Three main clades.**
- **Distinguished by the pattern of openings in the side of the skull**
- **Temporal**

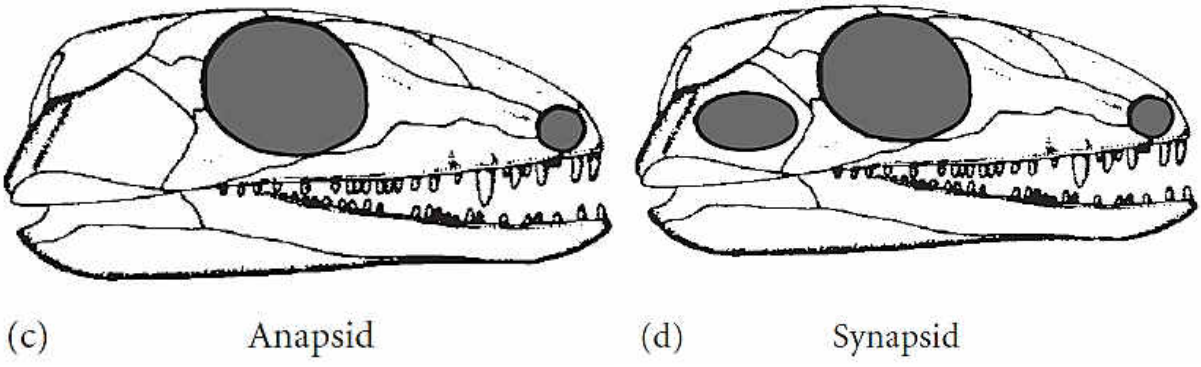
Fishes & Basal Tetrapods

Radiation

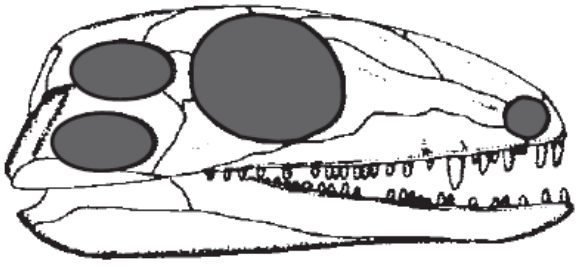
- **The anapsid (“no arch”) skull pattern, no temporal openings.**
- **The synapsid (“same arch”), lower temporal opening,**
- **The diapsid (“two arch”) pattern, two**

END-2

Fishes & Basal Tetrapods



(c) Anapsid (d) Synapsid



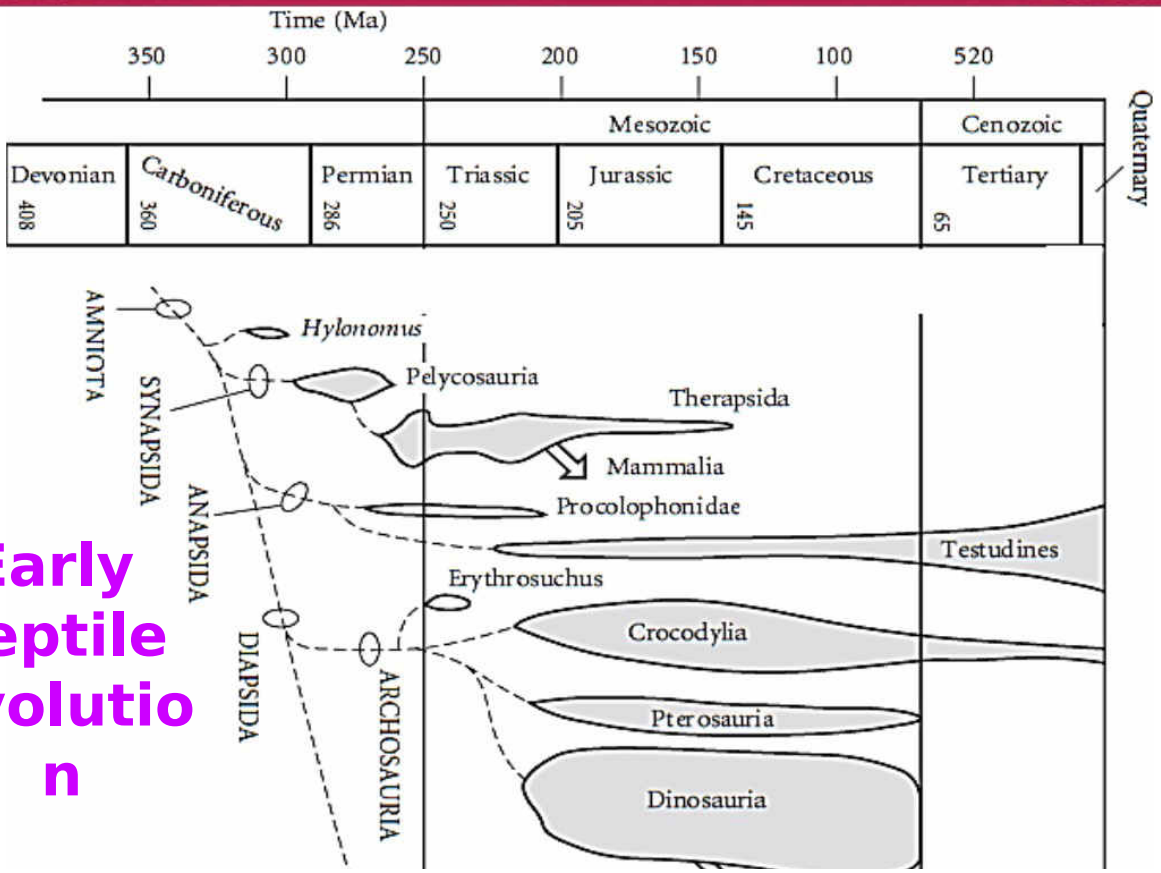
(e) Diapsid

Early Reptile Evolution

(c-e) The three major skull patterns seen in amniotes: anapsid, diapsid and synapsid. (Based on Carroll 1987.)

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Fishes & Basal Tetrapods



Early Reptile Evolution

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Fishes & Basal Tetrapods

Reign of the Reptiles (Part 2)

Fishes & Basal Tetrapods

Three Clades

- **The Anapsida: early forms such as *Hylonomus*, as well as some Permian and Triassic reptiles, and the turtles.**
- **The Synapsida: "mammal-like**

Fishes & Basal Tetrapods

Three Clades

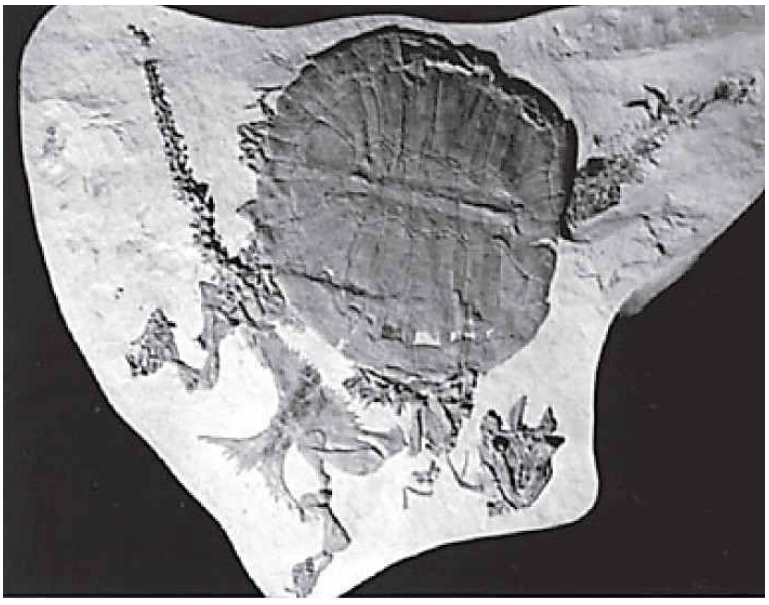
- **The Diapsida : Early groups, as well as the lizards and snakes and the crocodiles, pterosaurs, dinosaurs and birds.**
- **All modern amniotes**

Fishes & Basal Tetrapods

The Anapsida

- **Turtles and relatives**
- **The oldest were small insect eaters.**
- **During the Permian and Triassic**
- **The turtles appeared first in the Late Triassic**

Fishes & Basal Tetrapods



A Fossilized Snapping Turtle, with the head (bottom right) and skeleton at Steinheim, Germany.

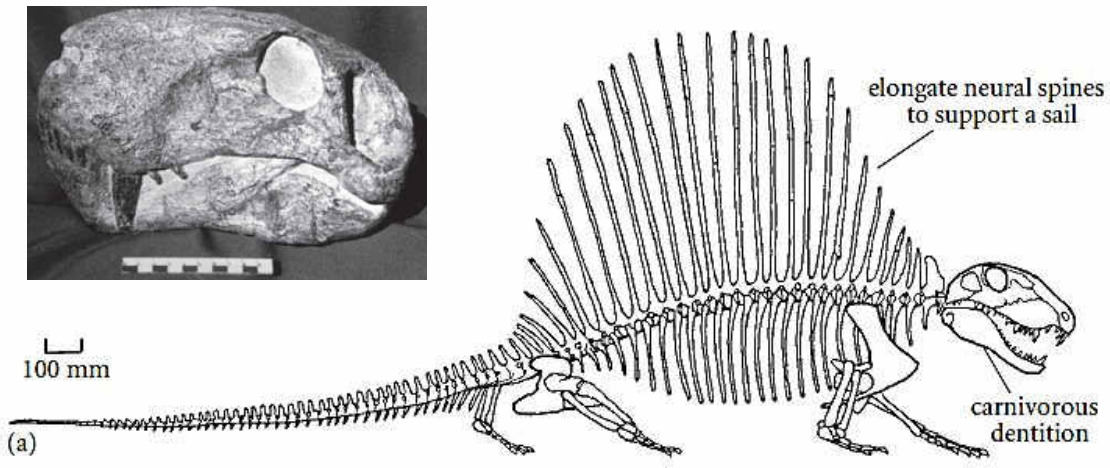
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Fishes & Basal Tetrapods

The Synapsids

- **First synapsids, known from the Late Carboniferous and Early Permian**
- **Grouped loosely as "pelycosaurs"**
- **insectivores and carnivores**

Fishes & Basal Tetrapods



Synapsids of the Permian:
(a) the carnivorous pelycosaur Dimetrodon; (Upper left) the carnivorous gorgonopsian *Lycaenops*

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Fishes & Basal Tetrapods

The Synapsids

- **Synapsids radiated dramatically in the Late Permian as a new clade, the Therapsida.**
- **The carnivores were the *gorgonopsians***
- **The cynodonts: The Early**

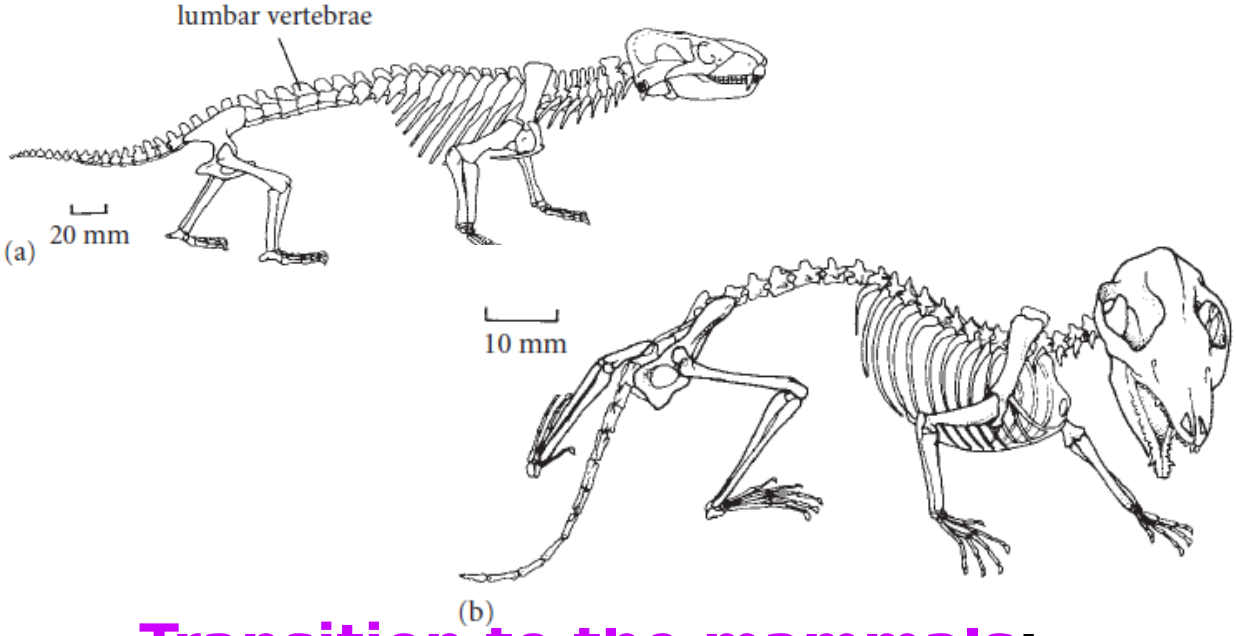
Fishes & Basal Tetrapods

Thrinaxodon

- **Looked dog-like**
- **In the snout area: the roots of sensory whiskers**
- **Thrinaxodon had whiskers,**
- **Hair on other parts of its body**
- **Insulation and**

END-1

Fishes & Basal Tetrapods



Transition to the mammals:

(a) The Early Triassic cynodont *Thrinaxodon*; (b) the Early Jurassic mammal *Megazostrodon*;

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Fishes & Basal Tetrapods

Dinosaurs and Mammals

Fishes & Basal Tetrapods

The Transition

- **The transition from basal synapsid to mammal is marked by an extraordinary shift of the jaw joint into the middle ear.**

Fishes & Basal Tetrapods

The Transition

- **Reptiles typically have six bones in the lower jaw and the articular bone articulates with the quadrate in**

Fishes & Basal Tetrapods

The Transition

- **In mammals, on the other hand, there is a single bone in the lower jaw, the dentary, which articulates with the**

Fishes & Basal Tetrapods

The Transition

- **The reptilian articular–quadrate jaw joint became reduced in Triassic cynodonts, and moved into the middle ear passage.**

Fishes & Basal Tetrapods

The Transition

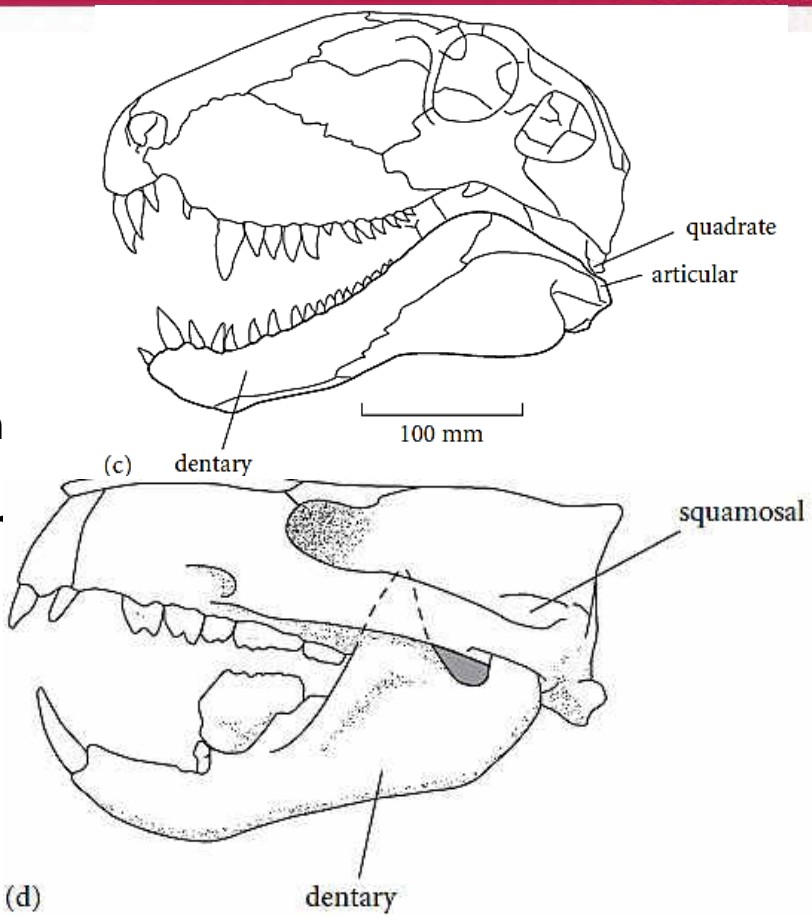
- **That is why we have three tiny ear bones, the hammer, anvil and stirrup, which transmit sound from the ear drum to the brain**
- **Reptiles have**

Fishes & Basal Tetrapods

Transition to the mammals:

skulls of an early synapsid (c) and a mammal (d) to show the reductior in elements in the lower jaw and switch of the jaw joint

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Fishes & Basal Tetrapods

A Misconception

- **People think of the dinosaurs as precursors of the mammals.**
- **Dinosaurs famously ruled the Earth for 160 Myr of the Mesozoic**
- **Replaced by**

Fishes & Basal Tetrapods

Evolution of Mammals

- **However, the mammals arose in the Late Triassic, about the same time as the first dinosaurs.**

Fishes & Basal Tetrapods

Evolution of Mammals

- **Both groups of mammals and Dinosaurs evolved side by side through the Late Triassic, Jurassic and Cretaceous**

END

Dinosaurs and Mammals

Introduction

Dinosaurs and Mammals

Dinosaurs

- **After the end-Permian mass extinction event 251 Ma, diapsid reptiles diversified in the Triassic.**
- **Dinosaurs were a hugely successful group for 160**

Dinosaurs and Mammals

Dinosaurs

- **Pterosaurs: key Mesozoic flyers**
- **Most important marine reptiles: plesiosaurs and ichthyosaurs**
- **Birds evolved from**

Dinosaurs and Mammals

The First Mammals

- **Small insect eaters of the latest Triassic**
- **The mammals achieved great diversity and abundance only after the extinction of the**

Dinosaurs and Mammals

Radiation of the Mammals

- **Molecular and paleontological evidence show that modern mammals radiated in the Late Jurassic and Early**

Dinosaurs and Mammals

Radiation of the Mammals

- **Basic splits were geographic – with major clades separated in South America, Africa, Australasia**

Dinosaurs and Mammals

Emergence of Humans

- **Humans arose 6–8 Ma, and fossil evidence points to repeated human migrations**

Dinosaurs and Mammals

- **Evolution of vertebrates forward into the Mesozoic and Cenozoic.**
- **The rise of the diapsids, and especially the dinosaurs and their descendants, the birds.**

Dinosaurs and Mammals

END

- **Modest evolution of mammals through the Mesozoic set the scene for their explosive radiation at the beginning of the Cenozoic, after the**

Dinosaurs and Mammals

Dinosaurs and Their Kin

Dinosaurs and Mammals

The Diapsids Take Over

- **Abundance of the synapsids in the Carboniferous or Permian.**
- **Change during the Triassic, (end-Permian extinction event)**
- **Devastating effect on therapsid**

Dinosaurs and Mammals

The Diapsids Take Over

- **Small and large meat eaters such as *Erythrosuchus***
- **One of the first of the archosaurs**
- **A group include the**

Dinosaurs and Mammals



Archosaurs: Skull of the Early Triassic archosaurs *Erythrosuchus*

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Dinosaurs and Mammals

The Diapsids Take Over

- **Triassic: diapsids diversified**
- **Archosaurs: large carnivores**
- **Proficient flyers: (pterosaurs)**
- **another extinction Late Triassic (about**

Dinosaurs and Mammals

The Diapsids

- **New kinds of land tetrapods radiate**
- **The dinosaurs, pterosaurs, crocodilians and lizard ancestors, as well as the turtles**

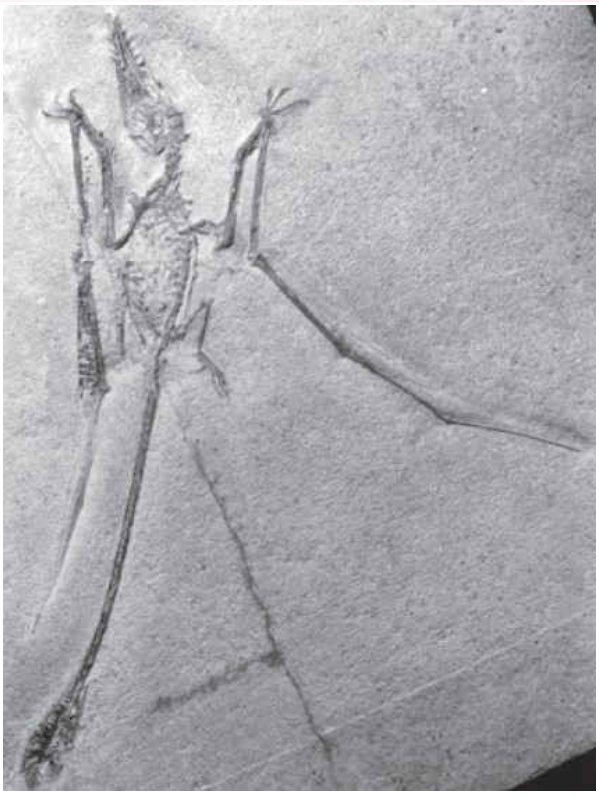
Dinosaurs and Mammals

The Pterosaurs

- **Proficient flapping flyers with a lightweight body**
- **Narrow hatchet-shaped skull**
- **a long narrow wing**
- **Almost certainly**

Dinosaurs and Mammals

Archosaurs: the Late Jurassic pterosaur *Rhamphorhynchus*, showing the elongated wing finger on each side, and the long tail with its terminal "sail" made from skin (×0.3)



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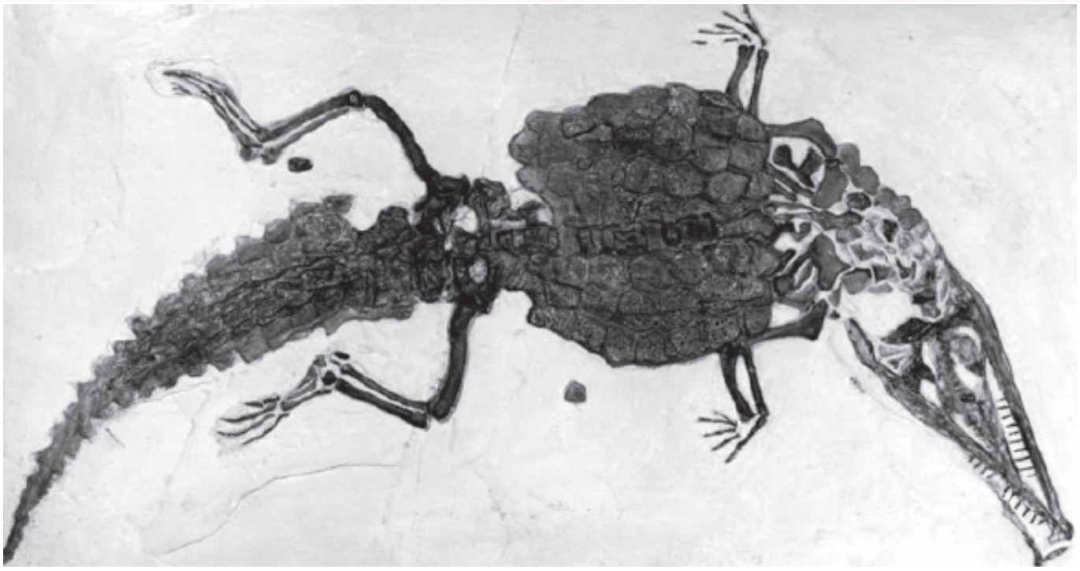
Dinosaurs and Mammals

Early Crocodilians

- **Largely terrestrial in habits, walked on all fours and had an extensive armor of bony plates**
- **More diverse and abundant during the Jurassic and**

END-1

Dinosaurs and Mammals



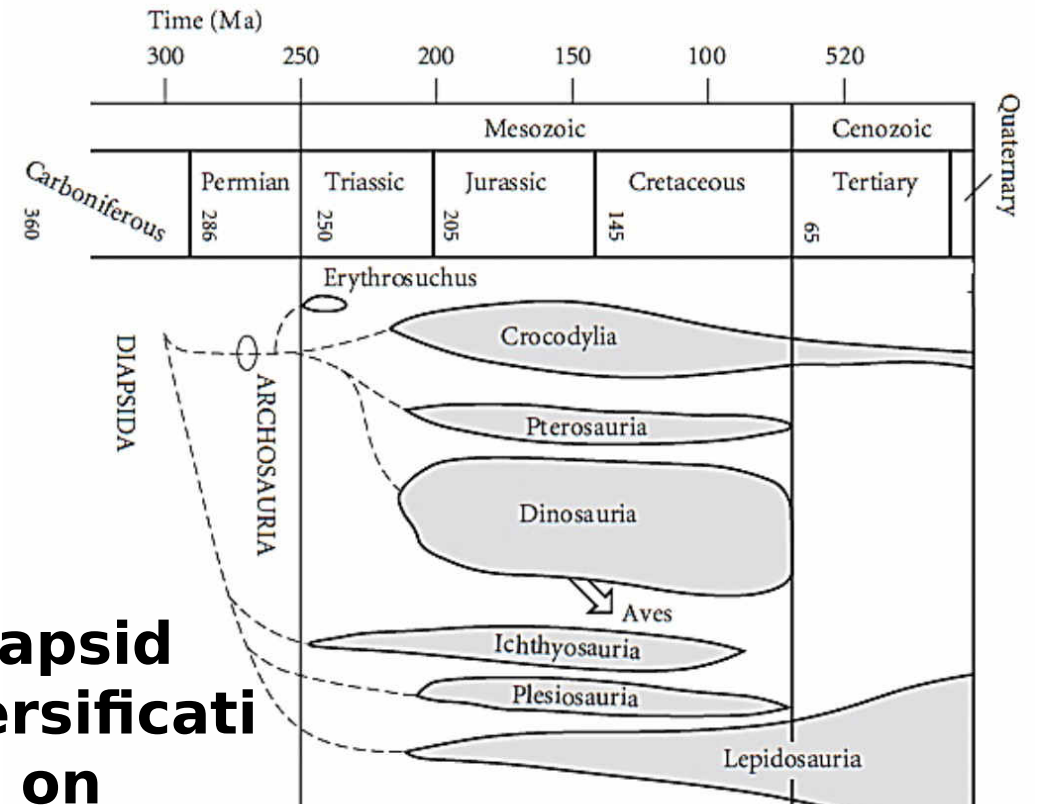
Archosaurs:

The Late Jurassic crocodilian Crocodilemus, showing the skeleton and armor covering (×0.2).

Dinosaurs and Mammals

Dinosaurs and Their Kin (Part 2)

Dinosaurs and Mammals



Diapsid Diversification

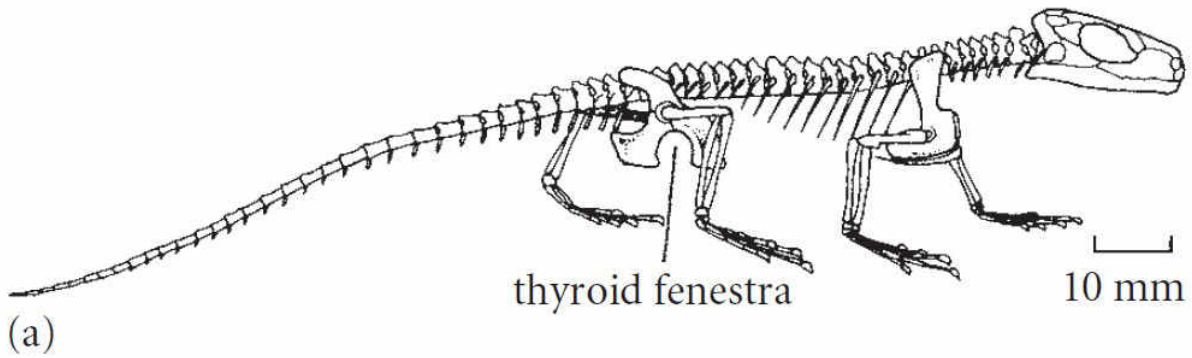
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Dinosaurs and Mammals

Lepidosaurs

- **The second major diapsid clade**
- **Lizards and snakes**
- **Diversified in the Late Triassic**
- **Key forms: sphenodontids – snubnosed,**

Dinosaurs and Mammals



Lepidosaurs:
The Late Triassic sphenodontid *Planocephalosaurus*

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Dinosaurs and Mammals

Lepidosaurs

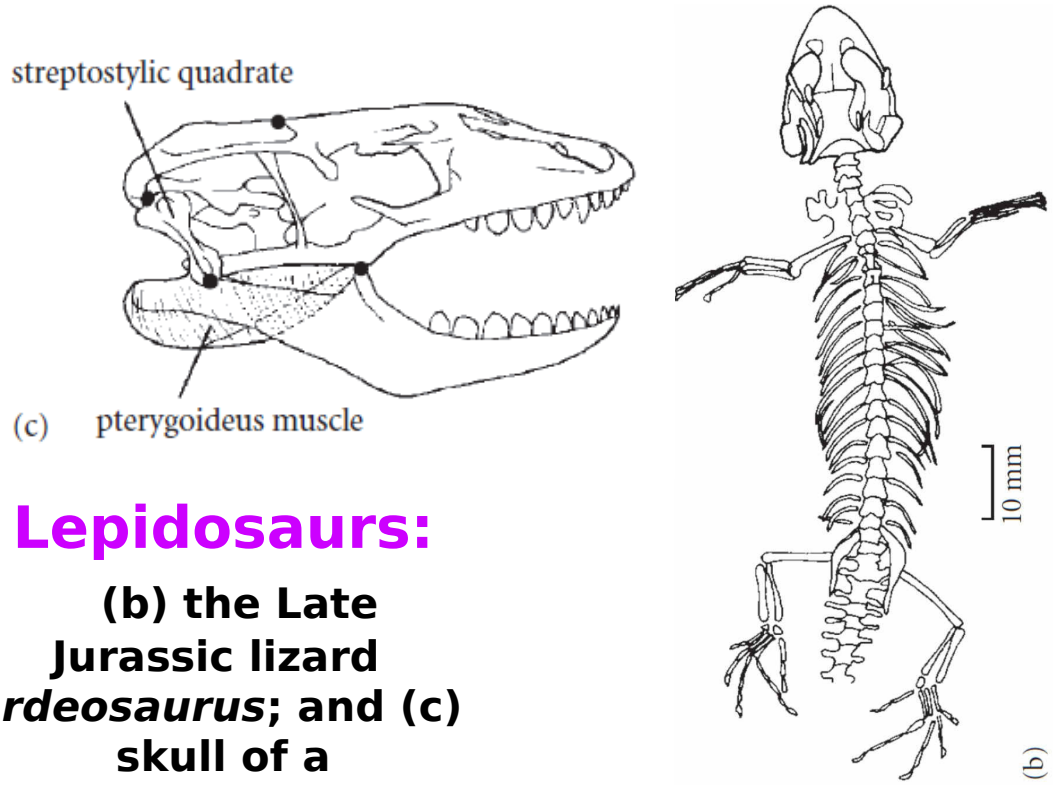
- **The group dwindled after the Jurassic, except for a single living representative**
- **Sphenodon, the tuatara of New Zealand**
- **A famous**

Dinosaurs and Mammals

Lepidosaurs

- **First true lizards: Mid and Late Jurassic**
- **Characteristic mobility of the skull**
- **The quadrate is mobile, and the snout portion of the skull can tilt**

Dinosaurs and Mammals



Lepidosaurs:

(b) the Late Jurassic lizard *Ardeosaurus*; and (c) skull of a modern lizard

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Dinosaurs and Mammals

Loosening Skull

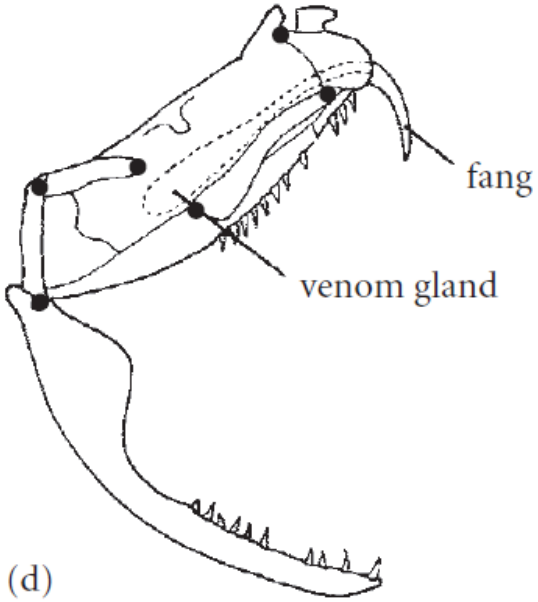
- **Taken further in the snakes**
- **Known first in the Early Cretaceous**
- **Snakes have mobile skulls**
- **swallow prey animals several times the diameter of the head**

END-1

Dinosaurs and Mammals

Lepidosaurs:

Skull of a Snake (d), showing the points of mobility that permit wide jaw opening.



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Chaudhary Moazzam

* Laiba Mahi *

Dinosaurs and Mammals

The Age of Dinosaurs

Dinosaurs and Mammals

Dinosaurs

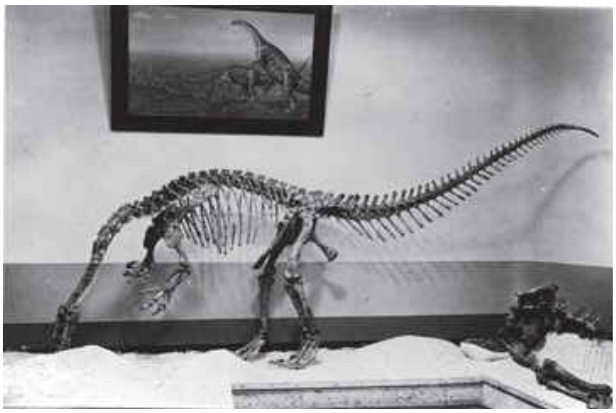
- **Most important of the new diapsid groups of the Triassic**
- **In terms of their abundance and diversity**
- **In terms of the vast size reached by**

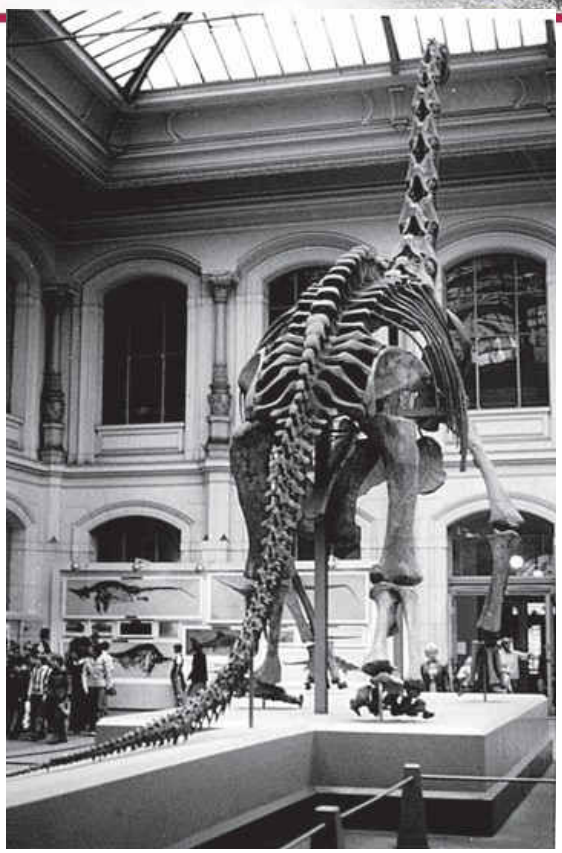
Dinosaurs and Mammals

First Dinosaurs

- **Modest-sized bipedal carnivores.**
- **After the Late Triassic extinction, a new group of herbivorous dinosaurs, the sauropodomorphs, radiated dramatically, some like**

Dinosaurs and Mammals





Sauropodomorph Dinosaurs: (a) the Late Triassic prosauropod Plateosaurus; and (b) the Late Jurassic sauropod Brachiosaurus.

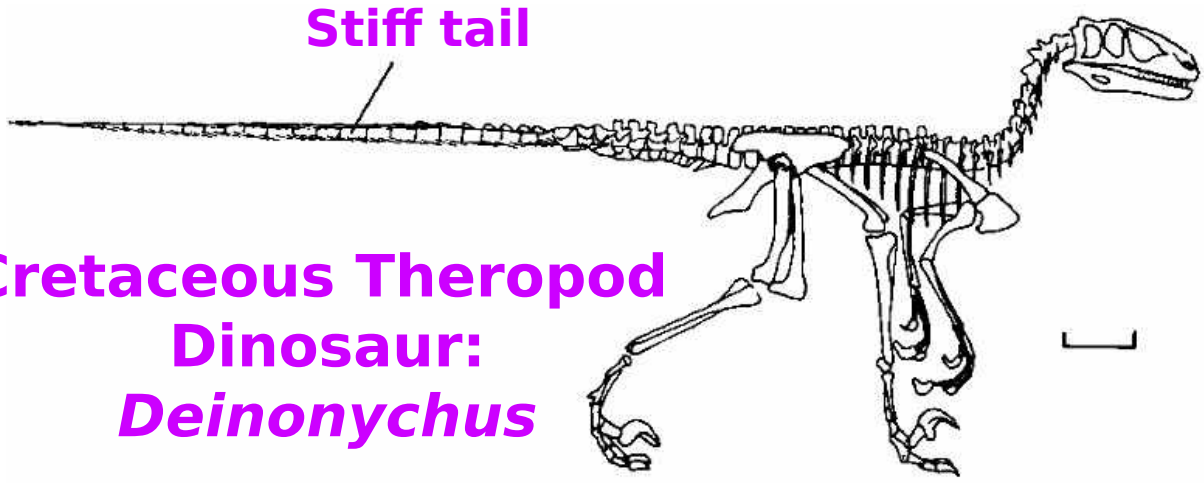
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Dinosaurs and Mammals

The Theropods

- **Include all the carnivorous dinosaurs**
- **In the Jurassic and Cretaceous, the group diversified to include many specialized small and large forms.**

Dinosaurs and Mammals



Cretaceous Theropod Dinosaur: *Deinonychus*

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Dinosaurs and Mammals

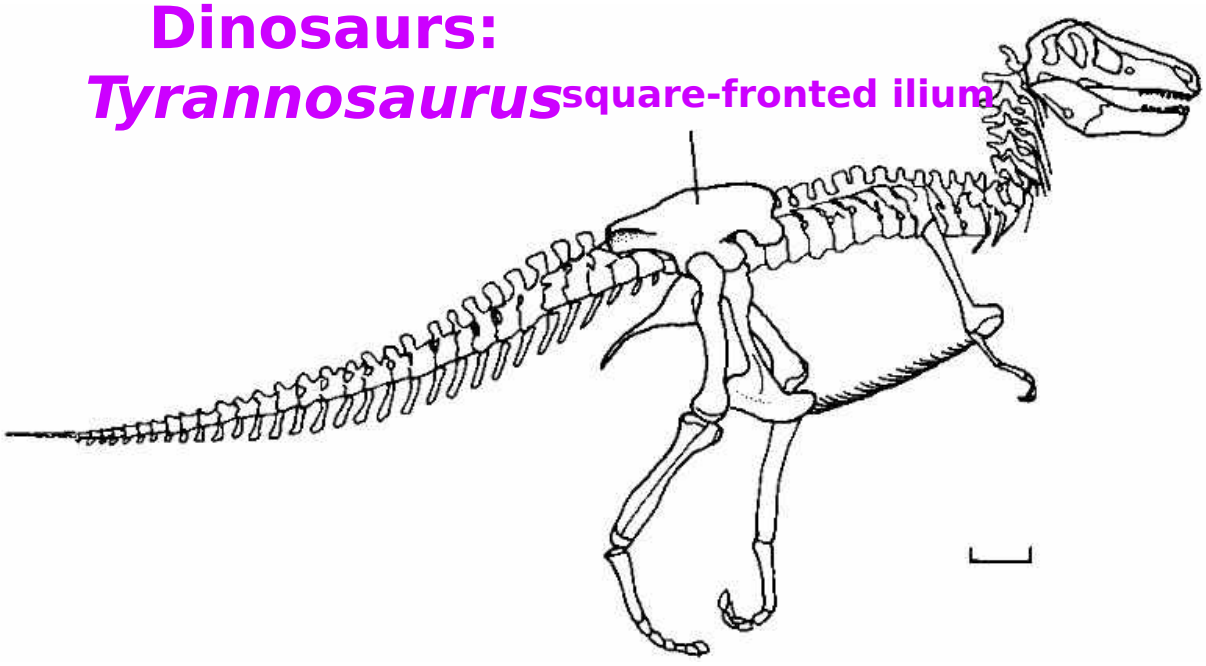
Shared Ancestors

- **The theropods and sauropodomorphs share the primitive reptilian hip pattern**
- **The two lower elements point in opposite directions, the pubis forwards and the ischium**

Dinosaurs and Mammals

Cretaceous Theropod Dinosaurs: *Tyrannosaurus*

square-fronted ilium



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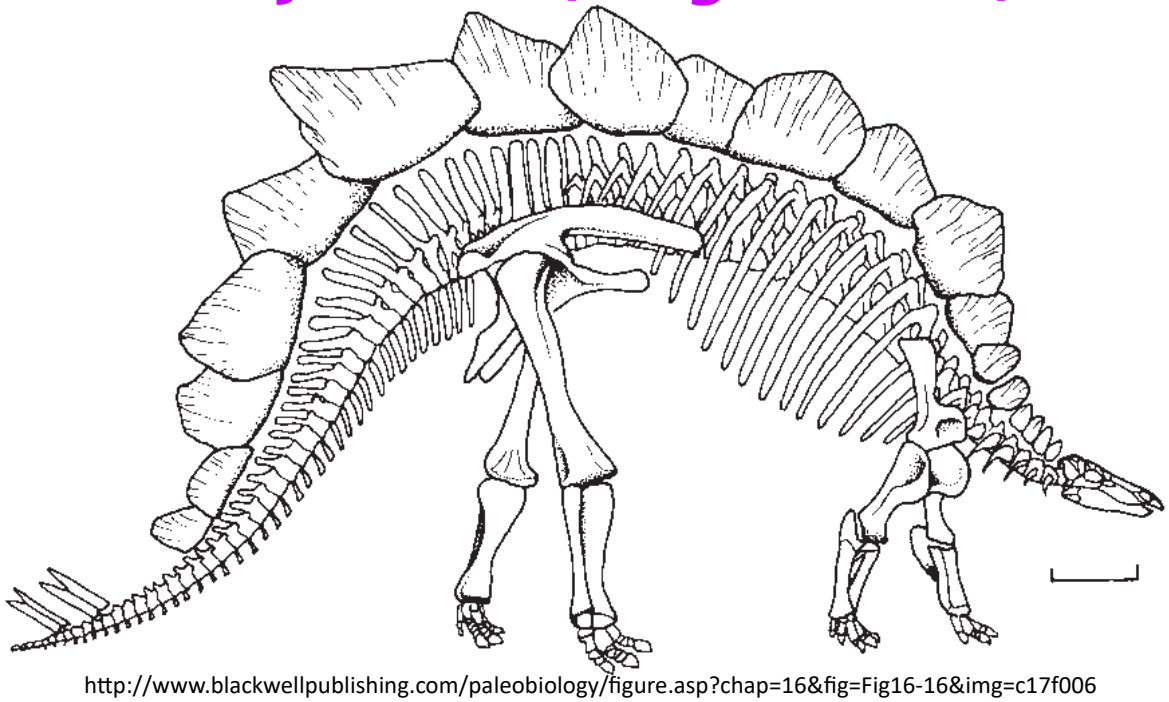
Dinosaurs and Mammals

Herbivores

- **All other dinosaurs share a unique hip pattern in which the pubis has swung back and runs parallel to the ischium.**
- **These are termed the Ornithischia.**

Dinosaurs and Mammals

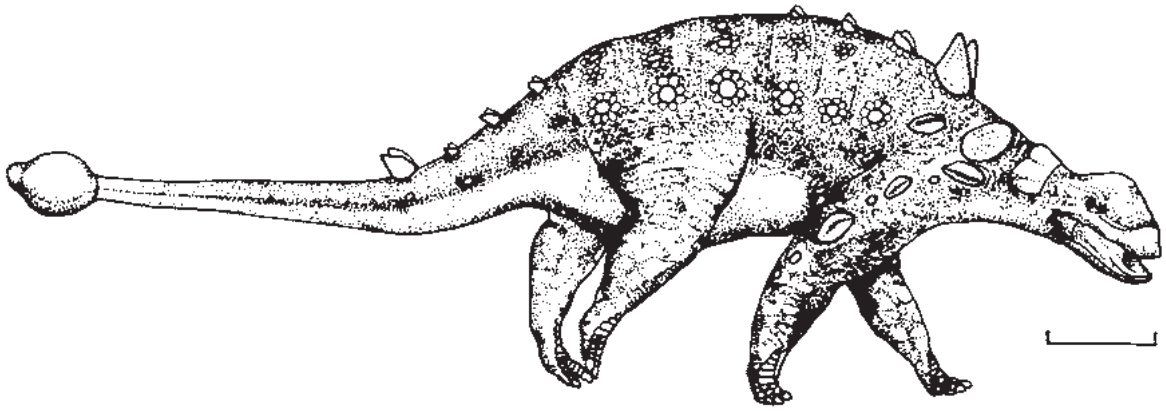
Armored Ornithischian Dinosaurs from the Jurassic (*Stegosaurus*)



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Dinosaurs and Mammals

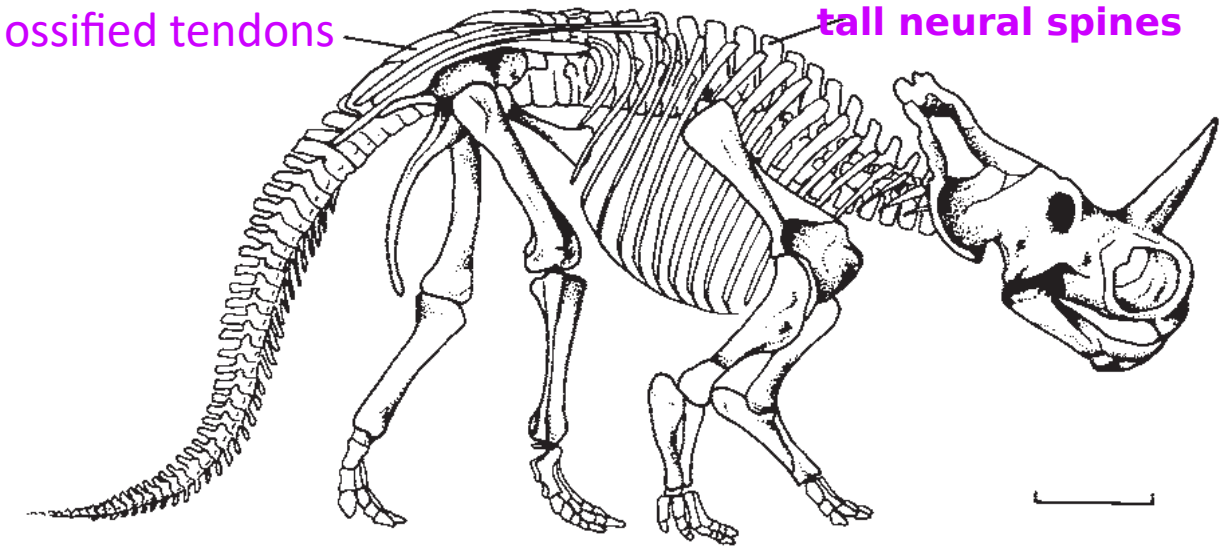
Armored Ornithischian Dinosaurs from the Cretaceous (*Euoplocephalus*)



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Dinosaurs and Mammals

Armored Ornithischian Dinosaurs from the Cretaceous (*Centrosaurus*)



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Dinosaurs and Mammals

Dinosaurs

- **Endothermic or not?**
- **Dinosaur reproductive habits**
- **Eggs and nests in North America and Mongolia: Parental care**

END-1

Dinosaurs and Mammals

Photograph of one of the *Massospondylus* eggs with a complete embryo skeleton Inside:

Measuring some 15 cm in total length. It died just before hatching. As an adult, it would have grown to a length of 5 m.



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Dinosaurs and Mammals

Dragons of the Deeps

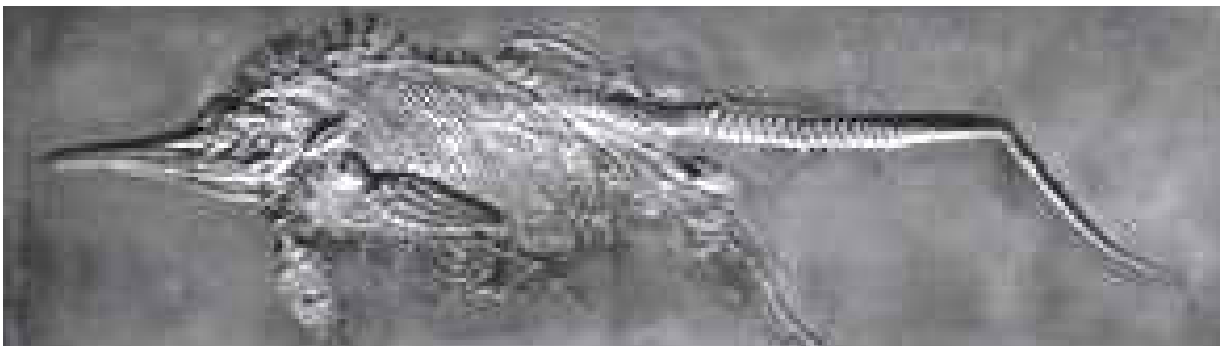
Dinosaurs and Mammals

Marine Predators

- **Mesozoic: several reptile groups became key marine predators.**
- **The *ichthyosaurs:* fish-shaped animals, adapted to life in the sea,**

Dinosaurs and Mammals

Jurassic Marine Reptiles



The ichthyosaur
Stenopterygius

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Dinosaurs and Mammals

Ichthyosaurs

- **Long, thin, snouts lined with sharp teeth**
- **Fed on ammonites, belemnites and fishes.**
- **Exquisite preservation: tail fin, dorsal fin and the**

Dinosaurs and Mammals

Ichthyosaurs

- **Swam by beating the body and tail from side to side**
- **Front paddles for steering.**
- **Specimens: mothers with developing embryos inside their bellies: like whales and**

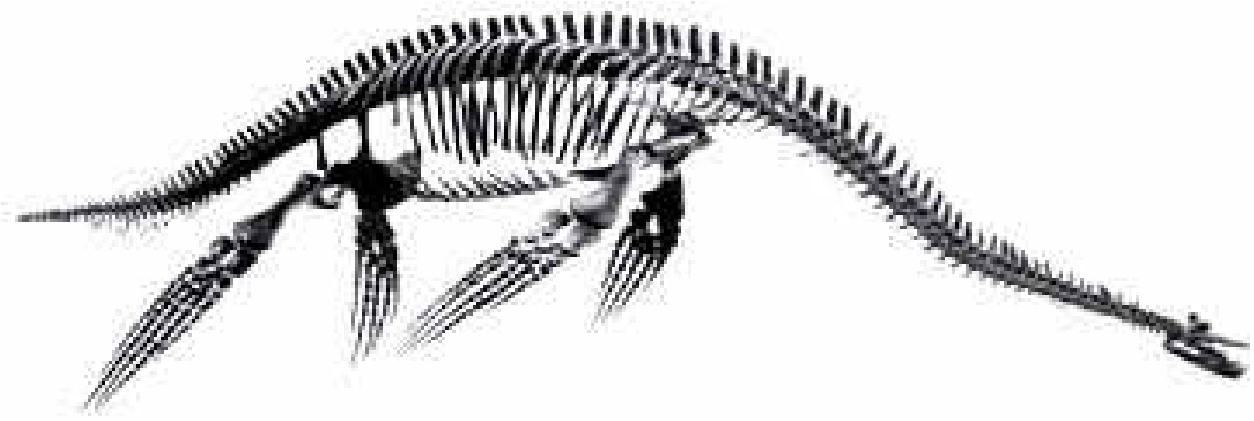
Dinosaurs and Mammals

Plesiosaurs

- **Second major marine reptile group**
- **Long necks and small heads**
- **The *pliosaurs* were larger: short necks and large heads.**
- **Fed mainly on fishes**

Dinosaurs and Mammals

Jurassic Marine Reptiles



The plesiosaur,
Cryptoclidus

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Dinosaurs and Mammals

Plesiosaurs

- **Swam by beating their paddles in a kind of "flying" motion.**
- **The extraordinary diversity of tetrapod predators in the sea came**

Dinosaurs and Mammals

END

Mass Extinction

- **During the great Cretaceous-Tertiary mass extinction**
- **The end of the dinosaurs and pterosaurs.**
- **Followed by the rise of**

Dinosaurs and Mammals

Bird Evolution

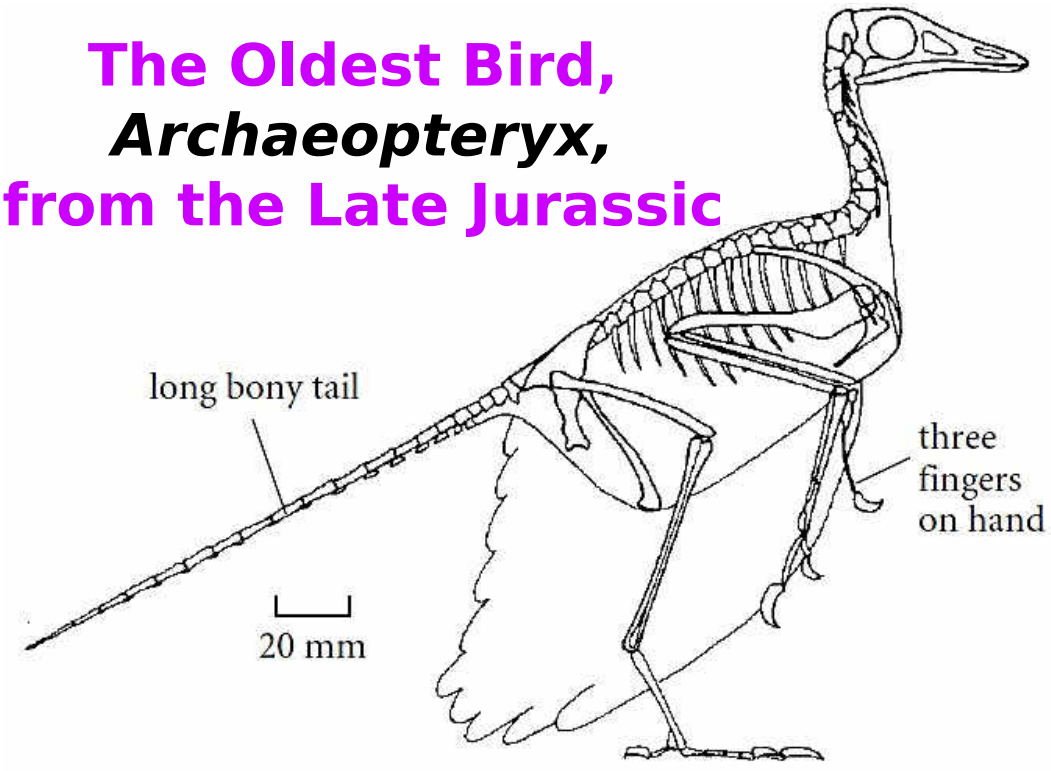
Dinosaurs and Mammals

Archaeopteryx

- **The most famous fossils**
- **Oldest known bird**
- **Found in Upper Jurassic sediments in southern Germany in 1861**
- **Hailed as the**

Dinosaurs and Mammals

The Oldest Bird, *Archaeopteryx*, from the Late Jurassic



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Dinosaurs and Mammals

Archaeopteryx

- **Proof of evolution**
- **A beak, wings and feathers, so it was clearly a bird**
- **A reptilian bony tail, claws on the hand, and teeth.**
- **Since 1861,**

Dinosaurs and Mammals

Archaeopteryx

- **The skeleton of Archaeopteryx is very like that of *Deinonychus***
- **Especially in the details of the arm and hindlimb, showing that birds are**

Dinosaurs and Mammals

Modern Birds

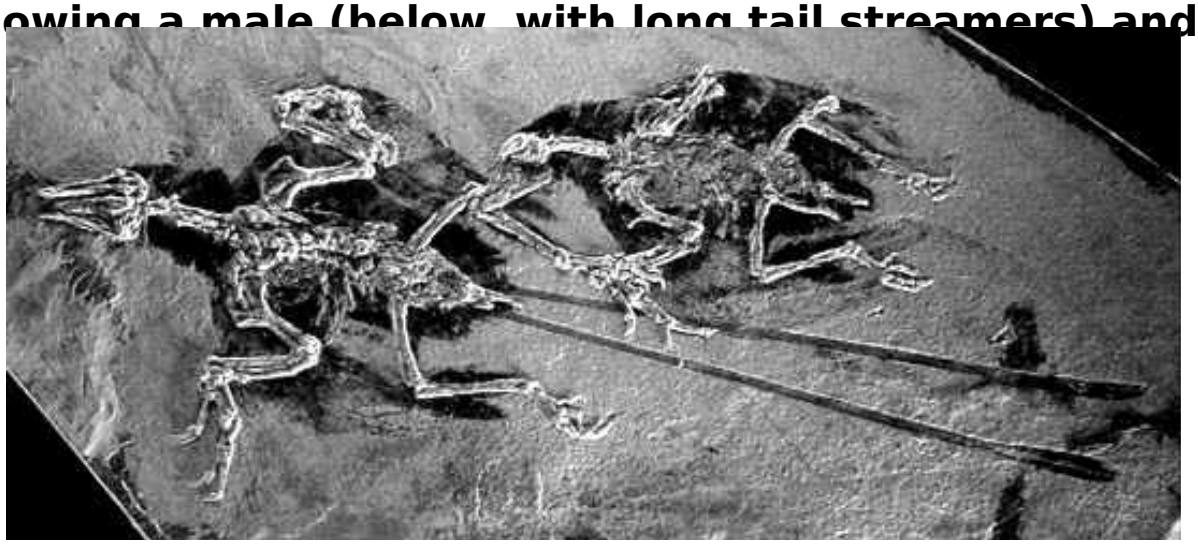
- **Appeared in the latest Cretaceous and Early Tertiary,**
- **Flightless ratites and ancestors of water birds, penguins and birds of prey.**
- **The perching birds radiated**

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Dinosaurs and Mammals

Two examples of the Early Cretaceous bird Confuciusornis from Liaoning, China,

showing a male (below, with long tail streamers) and



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Dinosaurs and Mammals

Rise of the Mammals

Dinosaurs and Mammals

Primitive forms

- **Small insect eaters in the Late Triassic and Early Jurassic**
- **Nocturnal**
- **Remained small through most of the Mesozoic**
- **Did not achieve high**

Dinosaurs and Mammals

Primitive forms

- **most basal mammal groups did not outlive the Cretaceous-Tertiary mass extinction**
- **Three Surviving clades**
- **Monotremes, marsupials**

Dinosaurs and Mammals

Monotremes

- **Restricted to Australasia,**
- **Platypus echidnas.**
- **Still laying eggs, as the cynodont ancestors**
- **The young hatch out and feed on mother's milk until large**

Dinosaurs and Mammals

Marsupials & Placentals

- **Marsupials, and Placentals, radiated dramatically in the Tertiary**
- **A classic example of an adaptive radiation due to**

Dinosaurs and Mammals

Diversification

- **Diversified within 10 myr to forms as disparate as bats and rats, monkeys and whales**
- **Mammals uniquely have differentiated teeth, with incisors,**

Dinosaurs and Mammals

Diversification

- **Differentiated teeth: huge array of diets**
- **Biting, and especially chewing**
- **High metabolic rates need lots of nutritious food**
- **Differentiated teeth allows mammals to improve the**

Dinosaurs and Mammals

Classification

- **Class MAMMALIA**
- **Subclass MONOTREMATA**
- **Females lay eggs, and newborn young grow in pouch**
- **Early Cretaceous to**

Dinosaurs and Mammals

Class MAMMALIA

- **Subclass METATHERIA (marsupials and extinct relatives)**
  - **Young are born live, but continue development in pouch**
  - **Late Cretaceous to**

Dinosaurs and Mammals

Class MAMMALIA

- **Subclass EUTHERIA (placentals and extinct relatives)**
  - **Young are born live at an advanced stage, nourished by a placenta**
  - **Mid-Cretaceous to**

END

Dinosaurs and Mammals

The Line to Humans

Dinosaurs and Mammals

Early Primates

- **One of the oldest of the modern placental mammal groups.**
- **The name “primate” (from primus, “first”)**
- **Humans are primates, and so “first”**

Dinosaurs and Mammals

Early Primates

- **Homo sapiens ("wise person"), has the privilege of choosing the name!**
- **For most of their history, the primates were a rare and rather obscure**

Dinosaurs and Mammals

Early Primates

- **All primates share a number of features**
- **Agility in the trees (mobile shoulder joint, grasping hands and feet, sensitive finger pads),**

Dinosaurs and Mammals

Early Primates

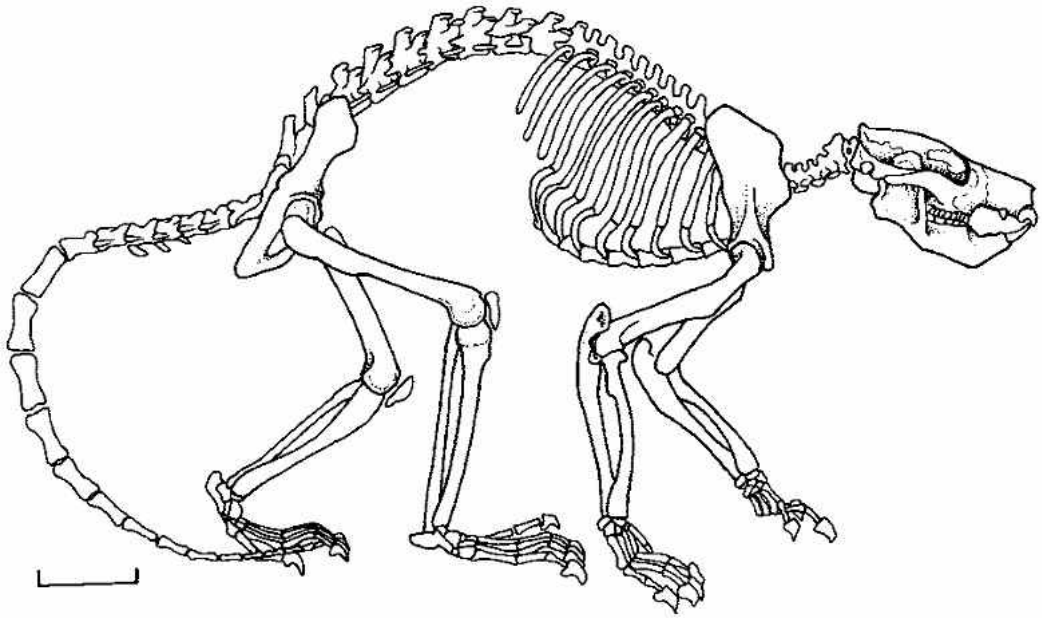
- **Good binocular vision**
- **Enhanced parental care (one baby at a time, long time in the womb, long period of parental care, delayed**

Dinosaurs and Mammals

Early Primates

- **Early primates *(Plesiadapis)* were squirrel-like animals that may have climbed trees and fed on fruit, seeds and leaves.**
- **Basal primates radiated in the Paleocene, Eocene and**

Dinosaurs and Mammals



The Paleocene primate Plesiadapis

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Dinosaurs and Mammals

True monkeys

- **True monkeys arose in the Eocene and they diverged into two groups,**
- **The New World monkeys of South America,**
- **The Old World monkeys of Africa, Asia and**

Dinosaurs and Mammals

New World Monkeys

- **Marmosets and spider monkeys, have flat noses and prehensile tails**
- **used as extra limbs in swinging through the trees**

Dinosaurs and Mammals

Old World Monkeys

- **Macaques and baboons: narrower projecting noses and non-prehensile tails, or no tails at all.**
- **Apes arose from the Old World**

Dinosaurs and Mammals

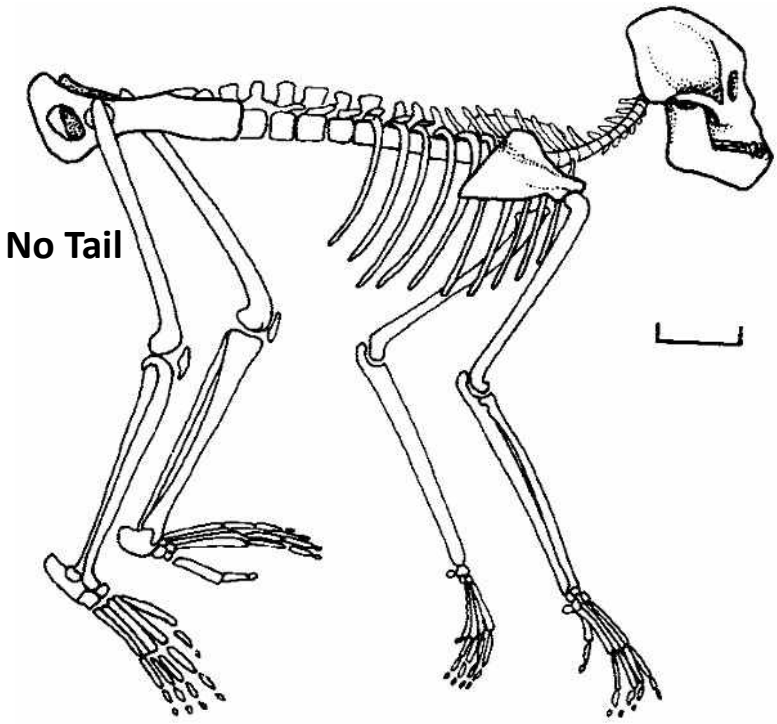
The Apes

- **Radiated in Africa in the Miocene.**
- ***Proconsul***
- **Have no tail, large braincase, high intelligence.**
- **Ran about on the ground and along low branches on all fours, and fed**

END-1

Dinosaurs and Mammals

The Miocene ape *Proconsul*.



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Dinosaurs and Mammals

The Apes and Humans

Dinosaurs and Mammals

The Apes

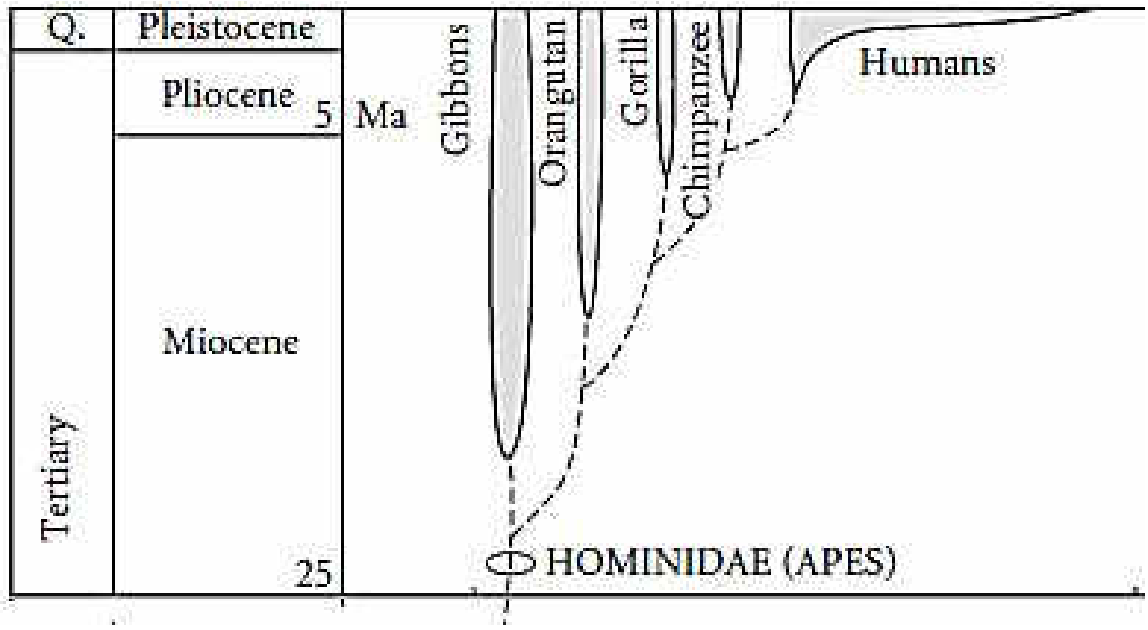
- **The apes spread out from Africa into the Middle East, Asia and southern Europe by the mid-Miocene**
- **Gave rise to some of the modern ape groups at that time**

Dinosaurs and Mammals

Early Apes

- **The gibbons of Southeast Asia are the most primitive living apes, having branched off 25– 20 Ma, followed by the orangutan 20–15 Ma.**
- **The focus of ape (and human)**

Dinosaurs and Mammals



Phylogeny of the Apes

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Dinosaurs and Mammals

Relatives of Humans

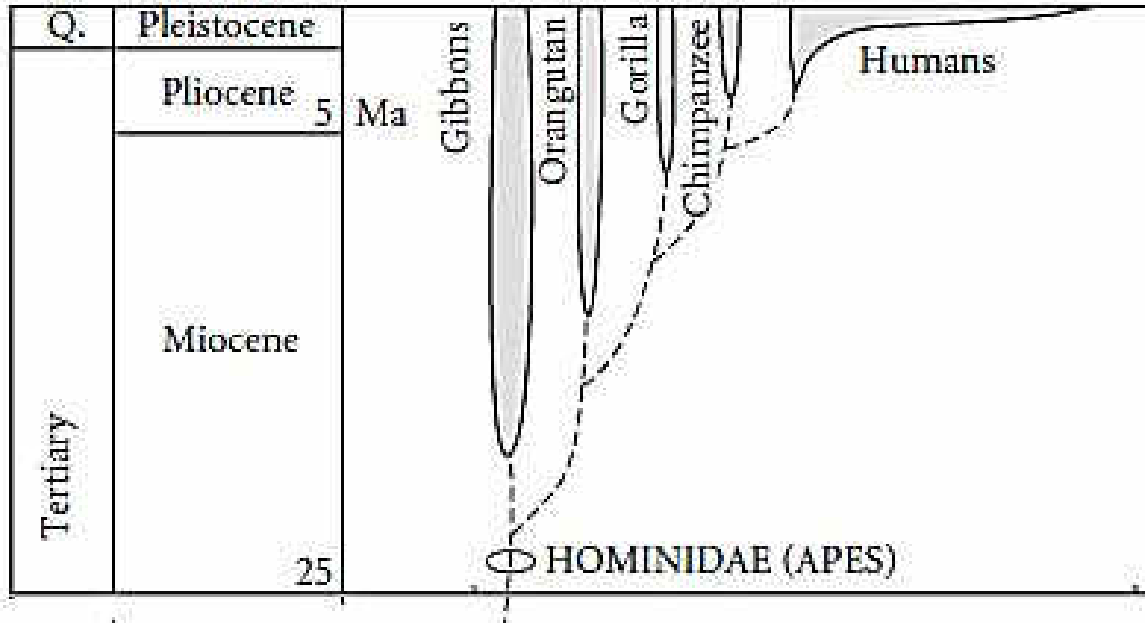
- **Gorillas, chimpanzees and humans appear to be very closely related:**
- **Share many anatomic characters and >94% of their DNA is identical.**

Dinosaurs and Mammals

Relatives of Humans

- **Gorillas seem to have diverged first, about 10 Ma, and the ancestors of humans and chimps separated**

Dinosaurs and Mammals



Phylogeny of the Apes

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Dinosaurs and Mammals

Human evolution

- **Humans are set apart from other primates by their large brain and their bipedalism, walking upright**
- **Bipedalism came first**

Dinosaurs and Mammals

Climatic Accident in Africa

- **In the late Miocene**
- **Climates became arid and the East African rift valley began to open up**
- **Separating the forests in the west from the arid grasslands**

Dinosaurs and Mammals

Climatic Accident in Africa

- **Tree-living apes (chimps and gorillas) retreated west**
- **The remaining apes (our ancestors) remained in the eastern grasslands.**

END

Dinosaurs and Mammals

The Apes and Humans (Part 2)

Dinosaurs and Mammals

Oldest Human

- **4 Ma**
- **Molecular estimate of 5 Ma for the split between humans and chimps.**
- **In 2001 and 2002, two French teams announced human fossils that were 6**

Dinosaurs and Mammals

Oldest Human

- **A number of incomplete human fossils reported during the 1990s from Africa, dated between 6 and 4 Ma.**
- **It may be that *Sahelanthropus* and *Orrorin* were already bipedal by 6**

Dinosaurs and Mammals

Our oldest ancestor?

The spectacular skull of *Sahelanthropus* from the upper Miocene of Chad, over 6 Ma.



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Dinosaurs and Mammals

Oldest Human

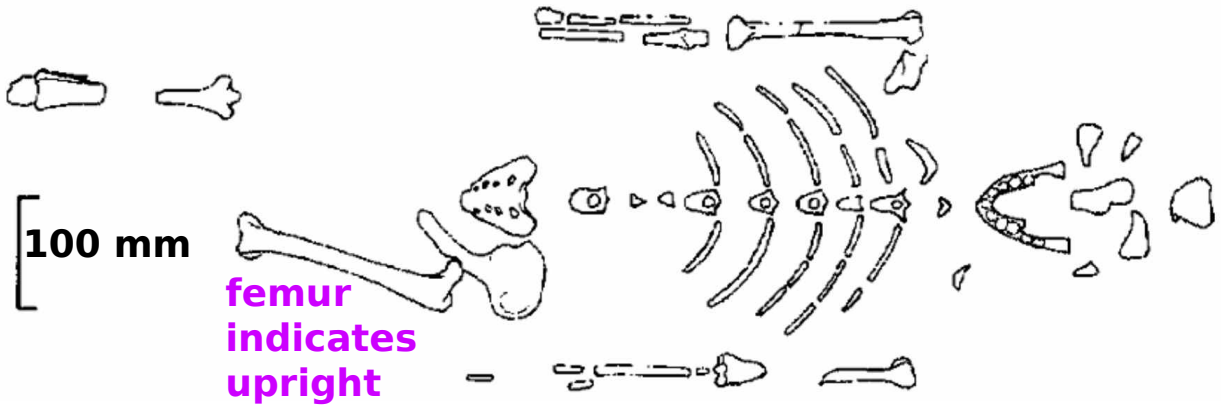
- **The oldest clear evidence for bipedalism: human tracks in volcanic ash from Tanzania, 3.75 Ma.**
- **The oldest substantial skeletons, of *Praeanthropus afarensis*, 3.2 Ma**

Dinosaurs and Mammals

Lucy

- **The famous skeleton of a female *P. afarensis* from Ethiopia, called Lucy by its discoverer Don Johanson in the 1970s has a rather modern humanoid**

Dinosaurs and Mammals



femur indicates upright posture

The pelvis is short and horizontal, rather than long and vertical as in apes, the thighbone slopes in towards the knee, and the toes can no longer be used for grasping. Lucy's brain, however, is small, only 415 cm3 for a height of 1–1.2 m – not much different from a chimpanzee.

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Dinosaurs and Mammals

Australopithecus

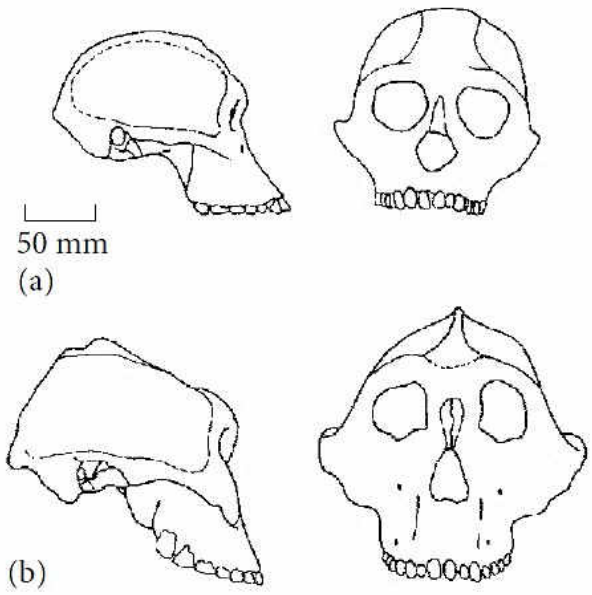
- **Continued to evolve in Africa from about 3 to 1.4 Ma, giving rise to small & large robust species**
- **reached heights of 1.75 m, brain capacities did not exceed 550 cm3, a rather**

Dinosaurs and Mammals

Skulls of fossil humans in front and side views:

(a)Australopithecus africanus

(b)A. boisei



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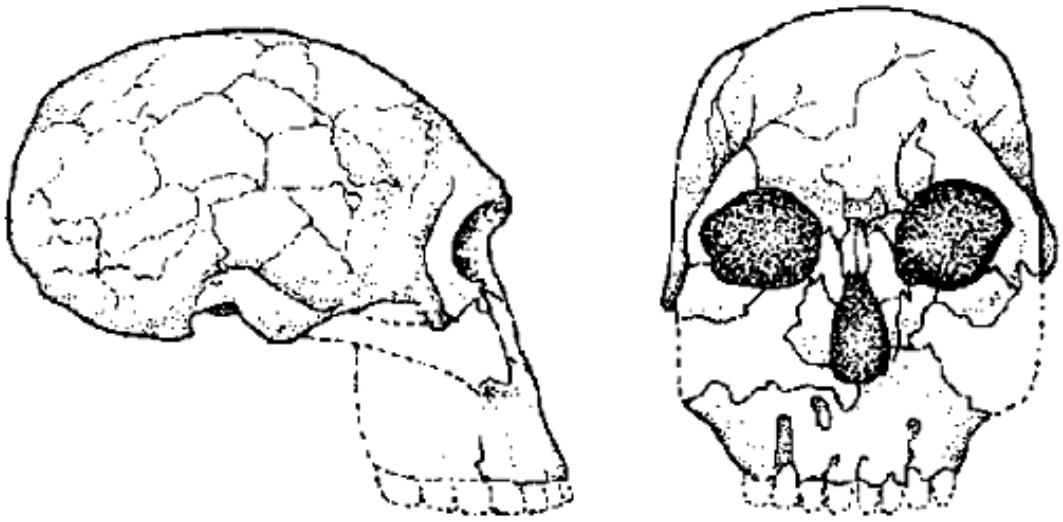
Dinosaurs and Mammals

Homo habilis

- **Lived in Africa from 2.4 to 1.5 Ma**
- **Brain capacity of 630– 700 cm3 in a body only 1.3 m tall.**
- **Used tools.**
- **For over 1 myr, three or four different human species lived side by**

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Dinosaurs and Mammals



Skull of fossil humans in front and side views:

(a)Homo habilis

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Dinosaurs and Mammals

Modern Peoples

Dinosaurs and Mammals

Homo erectus

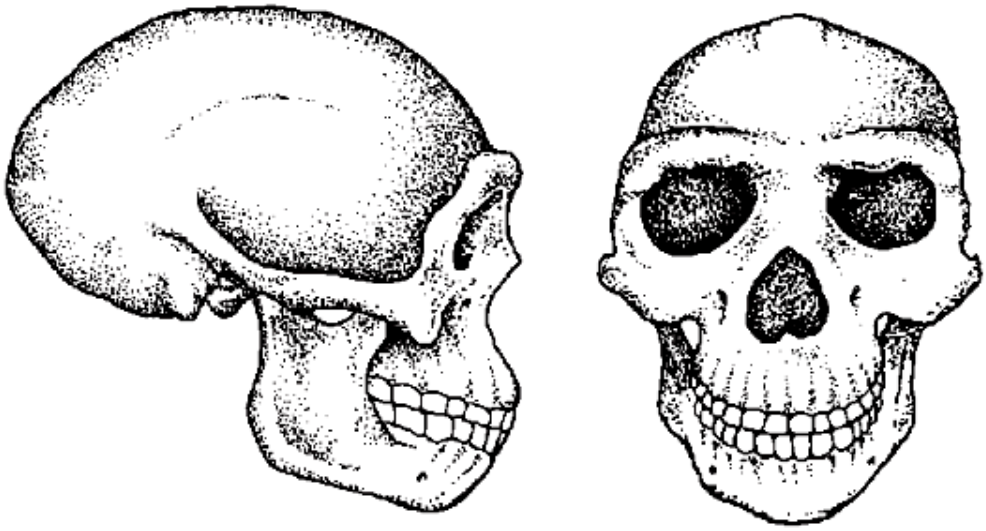
- **The focus of human evolution: Africa,**
- **A new species, *H. erectus*, which arose 1.9 Ma in Africa, spread to China, Java and central Europe.**
- **Brain size of 830-1100 cm3**

Dinosaurs and Mammals

Homo erectus

- **Clear evidence that this early human species had semipermanent settlements, a basic tribal structure**
- **Knew about use of fire for cooking, made tools weapons from stone and bone**

Dinosaurs and Mammals



Skull of fossil humans in front and side views: *H. erectus*

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Dinosaurs and Mammals

Homo Sapiens

- **Truly modern humans, *H. sapiens,* may have arisen as much as 400,000 years ago, and certainly by 150,000 years ago, in Africa,**
- **Evolved from *H. erectus.***
- **All modern humans arose**

Dinosaurs and Mammals

Homo Sapiens

- **Spread to the Middle East and Europe by 90,000 years ago.**
- **H. erectus stocks in Asia and Europe died out.**

Dinosaurs and Mammals

The European story

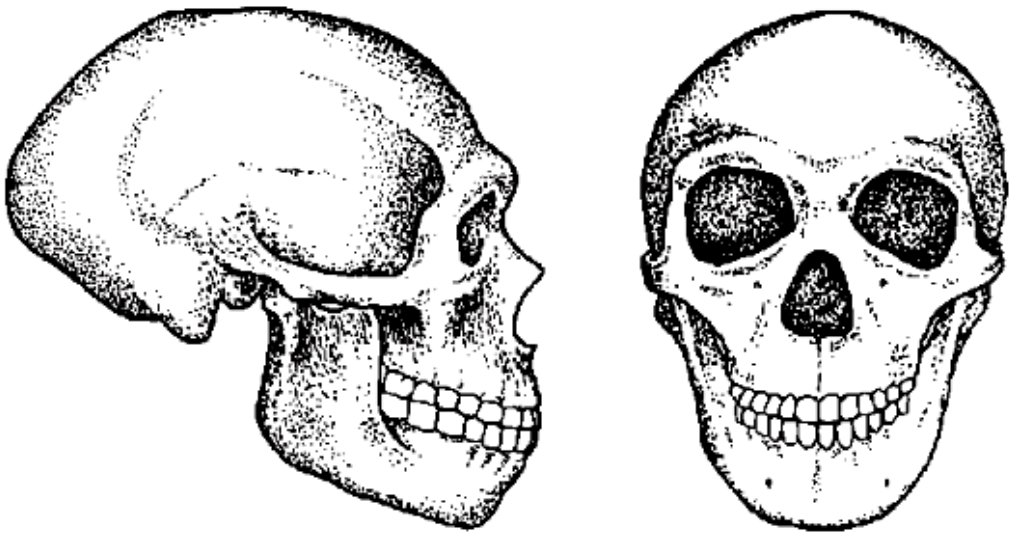
- **Includes a phase, from 90,000 to 30,000 years ago, when Neandertal man occupied much of Europe from Russia to Spain and from Turkey to southern**

Dinosaurs and Mammals

The European story

- **Neandertals had large brains (on average, 1400 cm3), heavy brow ridges and stocky powerful bodies.**
- **Adapted to living in the continuous icy cold of the last ice ages, and**

Dinosaurs and Mammals



Skull of fossil humans in front and side views:

H. sapiens, Neandertal type;

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=16&fig=Fig16-16&img=c17f021

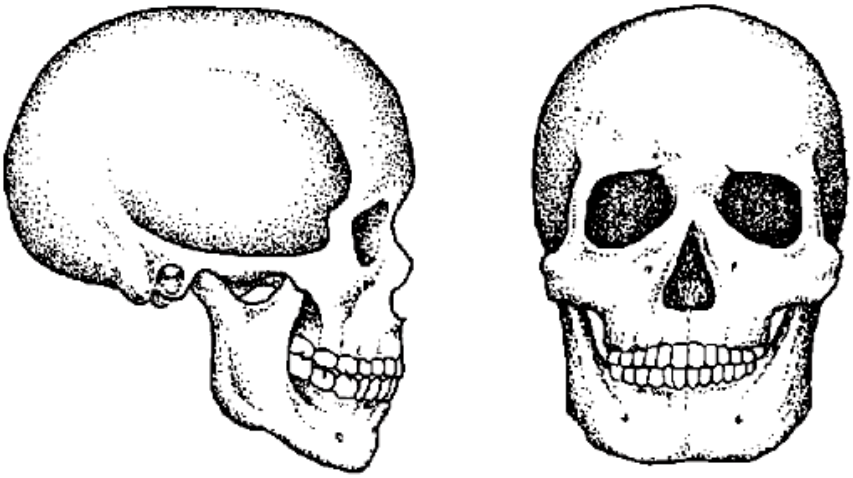
Dinosaurs and Mammals

Modern humans

- **Advanced across Europe from the Middle East**
- **Spread over the rest of the world,**
- **Asia to Australasia: before 40,000 years ago.**
- **A unique small-sized human species. *H. fl***

END-1

Dinosaurs and Mammals



Skull of fossil humans in front and side views:

H. sapiens

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=16&fig=Fig16-16&img=c17f021

Fossil Plants

Fossil Plants

Fossil Plants

Fungi & Algae

- **Fungi have a long fossil record, perhaps dating back to the end of the Precambrian, but they are not true plants.**
- **Green algae,**

Fossil Plants

Plants on Land

- **Plants moved onto land in the Ordovician and Silurian, a move enabled by the evolution of vascular tissues, waterproof cuticles and**

Fossil Plants

Non-seed-bearing plants

- **Arose during the Devonian, but tree-like lycopsids, equisetopsids**
- **Groups such as ferns became established by the Carboniferous. These formed the great "coal**

Fossil Plants

Plant Fossils

- **Paleobotany, which concentrates on macroscopic (visible with the naked eye) plant remains**
- **Palynology, the study of fossil pollen and spores, gives remarkable insights into**

Fossil Plants

The Gymnosperms

- **Seed-bearing plants radiated in several phases:**
  - **During the Carboniferous-Permian (medullosans, cordaites, cycads) and Mesozoic (conifers, ginkgos, bennettitalean**

Fossil Plants

The Angiosperms

- **Flowering plants radiated dramatically during the Cretaceous,**
- **Fully enclosed and protected seeds, flowers and double fertilization**

END

Trace Fossils

Trace Fossils
An Introduction

Trace Fossils

Trace fossils

- **Represent the activities of organisms.**
- **Trace fossils may be treated as fossilized behavior, or as biogenic sedimentary structures.**

Trace Fossils

Types

- **Trace fossils include**
- **Tracks and trails,**
- **Burrows and borings,**
- **Fecal pellets and coprolites,**
- **Root penetration structures**
- **Other kinds of pellets.**

Trace Fossils

Naming

- **Trace fossils are named on the basis of shape and ornamentation, not on the basis of the supposed maker, environment or stratigraphy**

Trace Fossils

Origins

- **One animal may produce many different kinds of trace fossils, and one trace fossil type can be produced by many**

Trace Fossils

Shapes

- **Trace fossils may be produced within a sedimentary layer, or on the surface;**
- **Trace fossils may be preserved in the round, and may be seen as molds and casts on the**

Trace Fossils

Classification

- **Trace fossils may be classified according to the mode of behavior represented:**
- **Movement**
- **Feeding**
- **Farming**
- **Dwelling**
- **Escape**
- **Resting**

Trace Fossils

Ichnofacies

- **Certain trace fossil assemblages (ichnofacies) appear to repeat through time, and may give clues about the environment of deposition.**

Trace Fossils

Tiers

- **Trace fossils often occupy particular levels (tiers) in the sediment column,**
- **the depth of tiering has apparently increased through time.**
- **Limited use in stratigraphy,**

END

Trace Fossils

Understanding
Trace Fossils

Trace Fossils

Trace fossils

- **The study of trace fossils, often called ichnology (from the Greek ichnos, a trace).**
- **German paleontologist Adolf Seilacher established a classification of trace fossils based on**

Trace Fossils

A. Traces on Bedding Planes

- **Tracks: sets of discrete footprints, usually formed by arthropods or vertebrates**
- **Trails: continuous traces, usually formed by the whole body, either**

Trace Fossils

B. Structures within the sediment

- **Burrows: structures formed within soft sediment, either for locomotion, dwelling, protection or feeding, by moving grains out of the way**

Trace Fossils

- **Borings: structures formed in hard substrates, such as limestone, shells or wood, for the purpose of protection, Includes bioerosion feeding traces, such as drill**

Trace Fossils

C. Excrement

- **Fecal pellets and fecal strings: small pellets, usually <10 mm in length, or strings of excrement**
- **Coprolites: discrete fecal masses, usually >10 mm in length, and usually the**

Trace Fossils

D. Others

- **Root penetration structures: impressions of the activity of growing roots**
- **Non-fecal pellets: regurgitation pellets of birds and reptiles, excavation pellets of crustaceans**

Trace Fossils

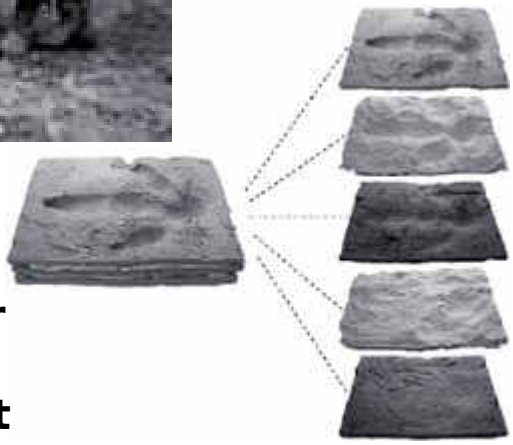
Naming

- **Given formal names,**
- **Often based on Latin and Greek, just like living and fossil plants and animals**
- **Trace fossil genera: ichnogenera**
- **Trace fossil species:**

END-1

Trace Fossils





Experimental Ichnology:

(Left) graduate student Jesper Milàn, trying to persuade an emu to walk where he wants it to walk, and (Right) the tracks and undertracks of the emu

http://www.blackwellpublishing.com/pbb/biology/figure.asp?chap=19&fig=Fig19-7&img=c19f007

Diversification of Life

Diversification of Life

Diversification of Life

Diversity of life

- **5–50 million species**
- **Logistic model: Diversity reached a global equilibrium level,**
- **Exponential model: diversity continues to expand**

Diversification of Life

Evolution

- **Many examples of evolutionary trends, one-way changes in a feature or features, are in reality more complex.**
- **The idea of progress in evolution, change with improvement in**

Diversification of Life

Patterns

- **It is important not to confuse pattern with process; too often scientists and the public assume such processes as competition, adaptation and progress without testing**

Diversification of Life

Major steps in Evolution

- **Major steps in evolution (e.g. evolution of wings and feathers in birds, evolution of limb loss in snakes) are well documented by fossils and**

Diversification of Life

END

Major steps in Evolution

- **An alternative, biological, view of the major steps focuses on fundamental subcellular systems, replicators and genetic systems.**

Diversification of Life

Diversity of Life

Diversification of Life

Diversity of life

- **Onward and upward**
- **An accepted principle of evolution**
- **All modern and ancient life on Earth is part of a single great phylogenetic tree**
- **A Precambrian common**

Diversification of Life

Diversity of life

- **A plot of species numbers through time must show a pattern of phenomenal increase over the past 3500 myr**
- **It is impossible**
- **Many species were never**

Diversification of Life

Valentine (1969)

- First serious effort
- He plotted the numbers of families of skeletonized shallow marine invertebrates through the Phanerozoic
- The pattern showed a jerky Increase, with several declines

Diversification of Life

Raup (1972)

- Argued that the graph showed more about the sources of error in the fossil record than it did about the true pattern of the diversification of life
- The low diversity

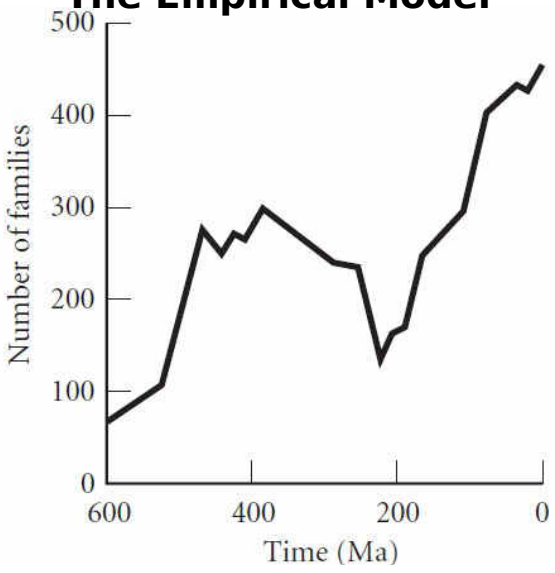
Diversification of Life

Raup (1972)

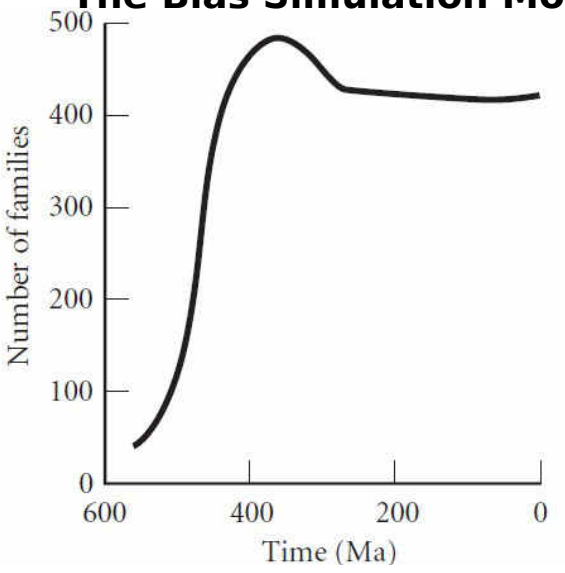
- **The true pattern of diversification of marine invertebrates had been a rapid rise to modern diversity levels during the Cambrian and Ordovician, and a steady equilibrium level since then.**
- **Many**

Diversification of Life

The Empirical Model



The Bias Simulation Model



Two models for the diversification of marine invertebrate life over the past 600 myr of good-quality fossil records.

(Based on information in Valentine 1969; Raup 1972)

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=20&fig=Fig20-3&img=c20f001

Diversification of Life

Global Diversification Patterns

- **Three mathematical models**
- **The linear model : A straight line**
- **The exponential model: An exponential curve**
- **The logistic model: Logistic**

Diversification of Life

The linear model

- **The linear model represents additive increase, the addition of a fixed number of new species in each unit of time**
- **Such a model has generally**

Diversification of Life

Exponential model

- **More consistent with a branching mode of evolution.**
- **If speciation and extinction rates remain roughly constant, then there will be regular doubling of**

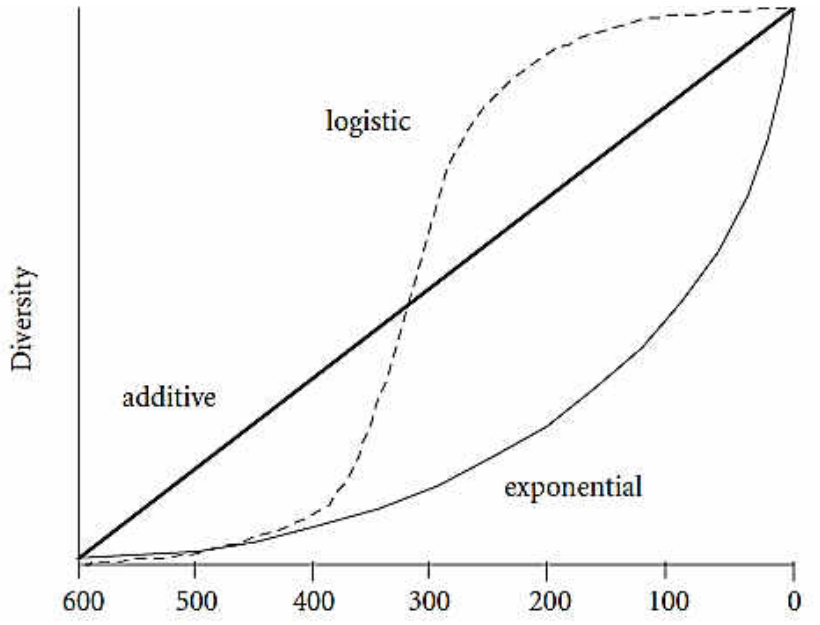
Diversification of Life

The logistic model

- **Involves one or more classic S-shaped curves**
- **Each consisting of an initial period of slow diversity increase, a rapid rise, a slowing of the rate of increase as a result of diversity-**

END-1

Diversification of Life



Theoretical models for the diversification of life plotted as if for the last 600 myr in the absence of major perturbation

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=20&fig=Fig20-3&img=c20f003

Diversification of Life

Equilibrium or Expansion?

Diversification of Life

Equilibrium or Expansion?

- **If the logistic model is correct, life has diversified in a controlled manner, reaching one or more equilibria, each of which is probably density**

Diversification of Life

Equilibrium or Expansion?

- **If the exponential model is correct, life has diversified in a less controlled manner**
- **Rising continually and never reaching an equilibrium**

Diversification of Life

Equilibrium or Expansion?

- **Eight observations**
- **For distinguishing equilibrium and expansion models of diversification of life.**
- **The first four: in favor of**

Diversification of Life

Observation 1

- **An evolutionary explosion of marine animals during the Early Cambrian, and diversification rates slowed after this initial exponential rise.**
- **This strongly suggests a logistic/equilibri**

Diversification of Life

Observation 2

- **There were rapid rebounds after mass extinctions, in which local and global diversity recovered to pre-extinction levels during relatively short spans of time**
- **Suggesting the refilling of**

Diversification of Life

Observation 3

- **Late phases of diversification cycles are associated with declining rates of origination and increasing rates of extinction, as the logistic curve approaches the equilibrium**

Diversification of Life

Observation 4

- **The Paleozoic plateau in marine animal diversity is strong evidence for equilibrium.**
- **But note that the plateau appears clearly only in the family-level data**

Diversification of Life

Observation 5

- **A single equilibrium level is easier to understand in terms of a global equilibrium model; otherwise each equilibrium level has to be justified as representing a complete overhaul of the**

Diversification of Life

Observation 6

- **There is no evidence for a global carrying capacity for species, and so a fundamental assumption behind the equilibrium model has yet to be demonstrated independently**

Diversification of Life

Observation 7

- **The radiation of life on land, and of certain major marine clades, appears to have followed an exponential pattern**
- **There is no sign of slowing down in the rate of**

Diversification of Life

Observation 8

- **The Modern "fauna" radiated dramatically over the last 100 myr and shows no sign of reaching an equilibrium level**
- **Conclusion: no point in seeking an overarching mathematical model to explain the**

END

Diversification of Life

Trends and Radiations

Diversification of Life

Progress & Trend

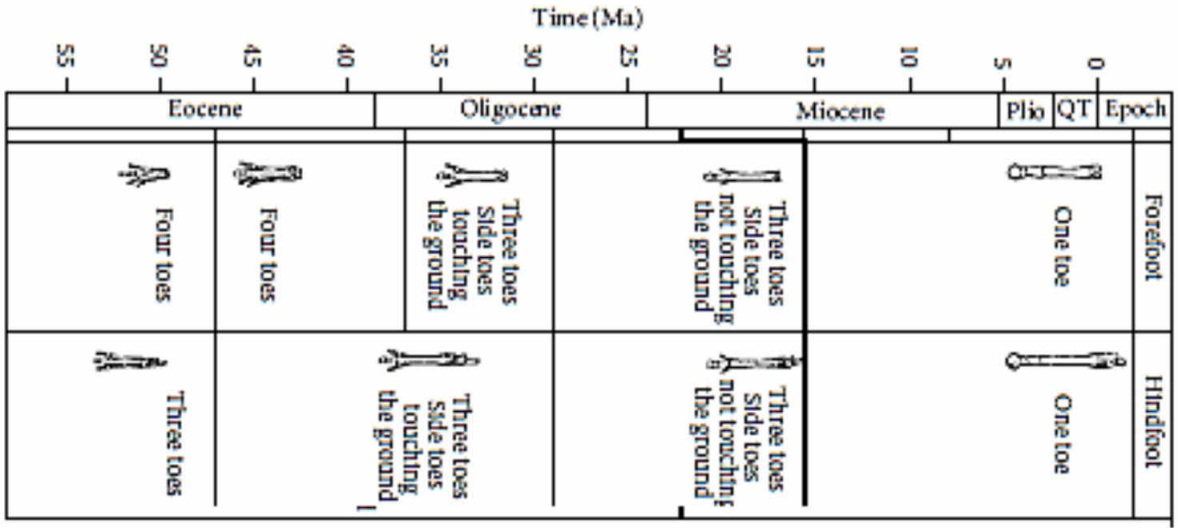
- **Progess means change with improvement.**
- **The later forms have to be demonstrably better than their predecessors.**
- **An evolutionary trend is a one-way change in**

Diversification of Life

Trend in Humans

- **A trend in human evolution has been for increasing brain size,**
- **Classed as progress if it is assumed that a larger brain means higher intelligence and so greater**

Diversification of Life



A Trend in Horse Evolution

for increasing size and loss of toes among horses

http://www.blackwellpublishing.com/paleobiology/figure.asp?chap=20&fig=Fig20-6&img=c20f006

Diversification of Life

Progress?

- **Does horse evolution show progress?**
- **Harder to argue:**
- **Small camouflaged, forest-dwelling *Hyracotherium* of the Eocene was "better" than the plains-dwelling, larger,**

Diversification of Life

Idea of Progress

- **A long and checkered history.**
- **Evolution is progressive only in that advantageous adaptations may be inherited by the offspring of successful**

Diversification of Life

Adaptive Radiation

- **One of the classic observations of large-scale evolution**
- **A radiation is when a clade expands relatively rapidly.**
- **The adjective "adaptive": happening because of some**

Diversification of Life

Patterns and Processes

- **Patterns are observations of the appearance and disappearance of species.**
- **Processes are hypotheses that seek to explain the**

Diversification of Life

Biotic replacements

- **An obvious feature of the history of life.**
- **These are times when one group of plants or animals replaces another.**
- **The replacement of**

END

Diversification of Life

Ten Major Steps

Diversification of Life

Major Steps

- **The study of paleontology reveals a great deal about how life has achieved its present astonishing diversity.**
- **Some major events in the history of life may be identified**

Diversification of Life

Adaptation 1

- **The origin of life**
- **The biochemical model**
- **Complex organic molecules were synthesized naturally in the Precambrian oceans.**
- **First living organisms**

Diversification of Life

Adaptation 1

- **Prokaryotic cells, small and lacking nuclei.**
- **Operated in the absence of oxygen, and they caused one of the most significant changes in the history of the planet – the raising of**

Diversification of Life

Adaptation 2

- **Eukaryotes and the origin of sex**
- **In marked contrast to the prokaryotes, eukaryote cells are usually large, with organelles and membrane-bounded nuclei containing the**

Diversification of Life

Adaptation 3

- **Multicellularity**
- **Clusters of eukaryote cells organized into different tissue types and organs, where different parts of the organism are responsible for particular functions and tasks**

Diversification of Life

Adaptation 3

- **Oldest multicellular eukaryotes: reported from rocks 1200 Ma in Canada**
- **These red algae were one of nearly 20 multicellular eukaryote lineages**
- **Some 400 myr**

Diversification of Life

Adaptation 4:

- **Skeletons**
- **During an interval of a few million years in the earliest Cambrian, a variety of mineralized skeletons appeared**
- **These are seen spectacularly**

Diversification of Life

Adaptation 4

- **Advantage: by providing protection, support and areas for the attachment of muscles.**
- **Predator pressure may have been the main driving force behind the acquisition**

END

Diversification of Life

Ten Major Steps (Part 2)

Diversification of Life

Adaptation 5

- Predation
- The Late Precambrian Ediacara fauna was soft-bodied, and it appears likely that predators and scavengers were absent.
- This changed during the Early Cambrian

Diversification of Life

Adaptation 5

- During the Early Cambrian Predation was an important part of the ecosystem.
- The rapid diversification of armored and protective strategies was a feature of the Cambrian

Diversification of Life

Adaptation 6

- **Biological Reefs**
- **Marine equivalents of tropical rain forests.**
- **Modern reefs are highly diverse, colorful frameworks of brain, horn and staghorn**

Diversification of Life

Adaptation 6

- **Throughout the Phanerozoic, the main reef builders have changed, with major changes punctuated by mass extinctions.**
- **The first reefal frameworks appeared during the**

Diversification of Life

Adaptation 7

- **Terrestrialization**
- **The colonization of the land added major new environments to those previously occupied by life.**
- **It is hard to**

Diversification of Life

Adaptation 7

- **Soils reported from Mid Precambrian sequences**
- **Microbial life extended a greenish scum around the water's edge.**
- **Ordovician soils suggest that larger plants and animals**

Diversification of Life

Adaptation 8

- **Trees and forests**
- **Next major expansion of living space on land took place during the Carboniferous, with the development of forests.**
- **The first tree sized plants:**

Diversification of Life

Adaptation 8

- **Significance: It created a vertically tiered range of new habitats.**
- **Trees, with their long roots, gained access to nutrients that were not available to smaller plants**

Diversification of Life

Adaptation 9

- **Flight**
- **Expansion of land life was into the air.**
- **Evolution of trees led to this**
- **Having insect groups to move off the ground in search of edible leaves and fruits, gliding and true**

Diversification of Life

Adaptation 9

- **Insects arose in the Early Devonian, but the first true fliers are Carboniferous in age**
- **Flight has doubtless been the clue to the vast success of insects**
- **Flight has**

Diversification of Life

Adaptation 10

- **Consciousness**
- **Human beings probably have to feature somewhere in a list of major biotic advances,**
- **How to view the role of humans in evolution has been a question that has dogged philosophers for**

END

Diversification of Life

An Alternative Top Eight Steps

Diversification of Life

Major Steps

- **In a biologically-oriented presentation, John Maynard Smith and Eörs Szathmáry (1997) identified eight major steps from the origin of life to human**

Diversification of Life

Step1

- **Replicating molecules.**
- **The first objects with the properties of multiplication, variation and heredity were probably replicating molecules, similar to RNA but perhaps**

Diversification of Life

Step 2

- **Independent replicators.**
- **In existing organisms, replicating molecules, or genes, are linked together end to end to form chromosomes**

Diversification of Life

Step 3

- **RNA as gene and enzyme.**
- **In modern organisms there is a division of labor between two classes of molecule: nucleic acids (DNA and RNA) that store and transmit information**

Diversification of Life

Step 4

- **Eukaryotes and organelles**
- **Prokaryotes lack a nucleus and have (usually) a single circular chromosome.**
- **Eukaryotes have a nucleus containing rod-shaped chromosomes**

Diversification of Life

Step 5

- **Sexual reproduction.**
- **a process of sexual reproduction in which a new individual arises by the fusion of two sex cells, or gametes, produced by**

Diversification of Life

Step 6

- **Differentiated cells**
- **Composed of many different kinds of cells – muscle cells, nerve cells, epithelial cells and so on.**
- **Each individual, therefore, carries not one copy of the genetic**

Diversification of Life

Step 7

- **Colonial living.**
- **Most organisms are solitary, interacting with others of their species, but not dependent on them. Other animals, notably ants, bees, wasps and termites, live in colonies in which only a few**

Diversification of Life

Step 8

- **Primate societies – human societies, and the origin of language and consciousness.**
- **The decisive step in the transition from ape to human society was probably the origin of language, which led in turn to**

END

The History of Biogeography

Biogeography

The History of Biogeography

Biogeography

Biogeography is the study of the distribution of species and ecosystems in geographic space and through geological

The History of Biogeography

Biogeography

- **Organisms and Biological communities often vary in a regular fashion along**

1. **Geographic gradients of latitude**
2. **Elevation**
3. **Isolation**
4. **Habitat area**

The History of Biogeography

Biogeography

- **Biogeography is an integrative field of inquiry that unites concepts and information from**
  1. **Ecology,**
  2. **Evolutionary biology**
  3. **Geology**
  4. **Physical**

The History of Biogeography

Modern Biogeography

- **Combines info & ideas from many fields**
- **The physiological & ecological constraints on organismal dispersal**
- **Geological & climatological phenomena operating at global spatial scales &**

The History of Biogeography

Biogeography

- **The patterns of species distribution across geographical areas can usually be explained through a combination of historical factors such as: speciation,**

The History of Biogeography

Geographic Information Systems

- **To predict future trends and understand the factors affecting organism distribution**
- **Often mathematical models and GIS are employed to solve ecological problems that**

The History of Biogeography

Island Biogeography

- **Islands are also ideal locations because they allow scientists to look at habitats that new invasive species have only recently colonized and can observe how they disperse throughout the**

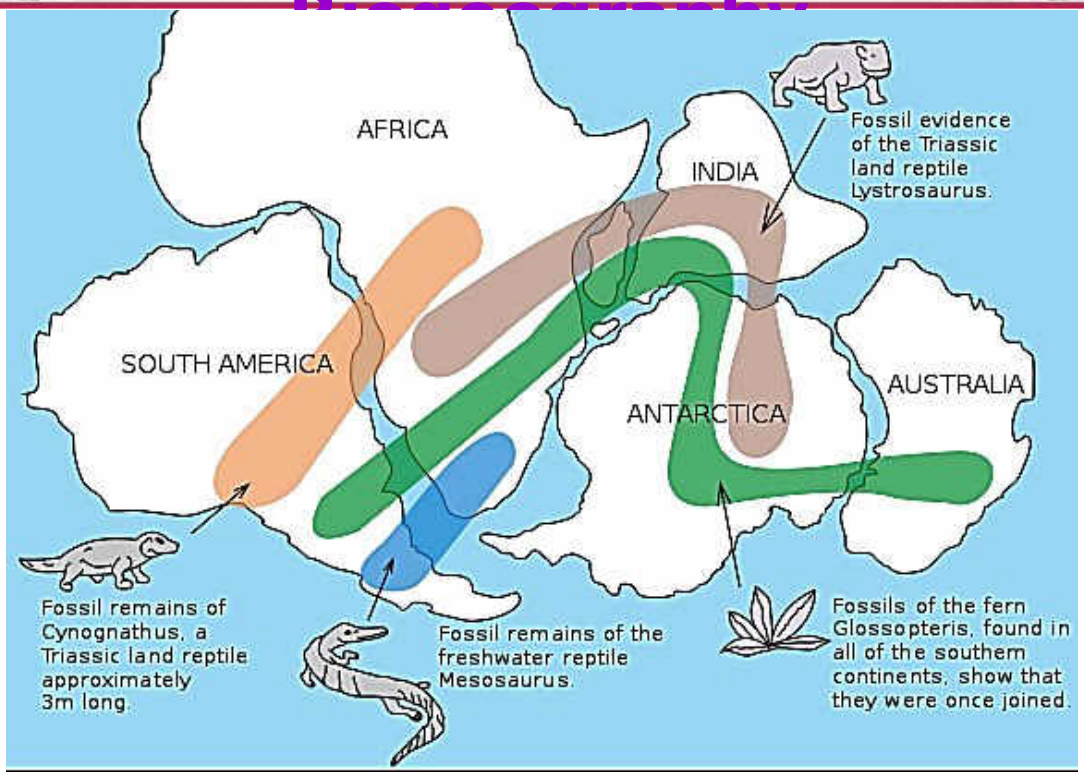
The History of Biogeography

Darwin

- **Recognized the importance of geographic locations**
- **"The Zoology of Archipelagoes will be well worth examination".**
- **Two chapters in On the Origin of Species were devoted to geographical**

END-1

The History of Biogeography



Schematic Distribution of Fossils on Pangea According To Wegener

https://en.wikipedia.org/wiki/Biogeography#/media/File:Snider-Pellegrini_Wegener_fossil_map.svg

The History of Biogeography

Ecological vs. Historical Biogeography

The History of Biogeography

Biogeography

The most fundamental split in biogeography is that between the ecological and historical aspects of the subject

The History of Biogeography

Ecological Biogeography

- **Concerned with species confinement to its present range in space**
- **What enables it to live where it does, and what prevents it from expanding into other areas?**
- **Roles of soil, climate, latitude,**

The History of Biogeography

Ecological Biogeography

- **Concerned with short-term periods of time, at a smaller scale; with local, within-habitat or intracontinental questions; and primarily with species or subspecies of living animals or**

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Historical Biogeography

- **Concerned with**
- **How did the taxon come to be confined to its present range in space?**
- **When did distribution come to have its present boundaries?**
- **How have**

The History of Biogeography

Historical Biogeography

- **Concerned with long-term, evolutionary periods of time; with larger, often sometimes global areas; and often with taxa above the level of the species and with taxa that may**

The History of Biogeography

Plant Biogeography

- **Plants are static**
- **Their form and growth much more closely conditioned by their environmental, ecological conditions**
- **It is also far easier to collect and preserve**

The History of Biogeography

Biogeography

- **The biogeography of the more distant past was, until recently, largely the preserve of zoologists, whereas plant scientists were far more concerned with ecological**

END

The History of Biogeography

Biogeography and Creation

The History of Biogeography

Biogeography

- **Began in the mid-18th century.**
- **At that time, most people accepted the statements in the Bible as the literal truth, that the Earth and all living things that we see today had been created in a**

The History of Biogeography

The Realization

- **Both the living world and the planet that it inhabits are continually changing**
- **Driven by two great processes – the biological process of evolution and the geological process of**

The History of Biogeography

Linnaeus in 1735

- **Swedish naturalist**
- **Started to name and describe the animals and plants**
- **Assumed organisms as unchanging species, created by God.**
- **But he soon**

The History of Biogeography

Noah's Ark

- **The different environments to be found at different altitudes had been colonized in turn by different animals and plants from the Ark as the floodwaters receded,**

The History of Biogeography

Georges Buffon

- **French naturalist**
- **The first person to realize that "similar environments, found in different regions of the world, contained different**

The History of Biogeography

Georges Buffon

- **He noted many of the mammals of North America, such as bears, deer, squirrels, hedgehogs and moles, were found also in Eurasia**
- **Travelled via Alaska, when**

The History of Biogeography

Georges Buffon

- **Most of the mammals of South America are quite different from those of Africa, even though they live in similar tropical environments.**
- **Accepting that all were originally**

The History of Biogeography

Georges Buffon

- **Buffon strongly felt that one had to be guided by study of the facts, and this conviction drove him to accept that geography, climate and even the nature of the species**

The History of Biogeography

Georges Buffon

- **His observations on the differences between the mammals of the two regions were soon extended to land birds, reptiles,**

END

The History of Biogeography

The Distribution of Life Today

The History of Biogeography

18th-century

- **Explorers and naturalists revealed more and more of the world, they also extended the horizons of biogeography itself, discovering a greater diversity of**

The History of Biogeography

Discoveries

- **British botanist *Joseph Banks* and the German *Johann Reinhold Forster*, together with his son *Georg Forster* who collected thousands of species of plants, many of**

The History of Biogeography

Forster's Findings

- **Forster found that *Buffon's* Law applied to plants as well as to animals, and also applied to any region of the world that was separated from others by barriers of**

The History of Biogeography

Forster's Findings

- **There are gradients of diversity**
- **There being more plant species closer to the equator and progressively fewer as one moves towards the poles,**
- **First**

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18th Century Concepts

- **The concepts of ecological biogeography, botanical regions and island biogeography had, then, all been recognized by the end of the 18th century**

The History of Biogeography

Question of Naturalists

- **How all these different floras had come into existence, widely scattered over the Earth's surface?**
- **German botanist *Karl Willdenow***

The History of Biogeography

Karl Willdenow

- **German botanist**
- **suggested that, although there had been only one act of creation, it had taken place simultaneously in many places.**
- **In each area, the local flora had been able**

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Other Scientists

- ***German Alexander von Humboldt*: the founder of plant geography**
- ***Humboldt* believed that the world was divided into a number of natural regions, each with its own distinctive**

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Other Scientists

- ***Augustin de Candolle*** **of Geneva who, in 1805 together with *Lamarck,* published a map showing France divided into five floristic regions with different ecological conditions.**
- **coined the word**

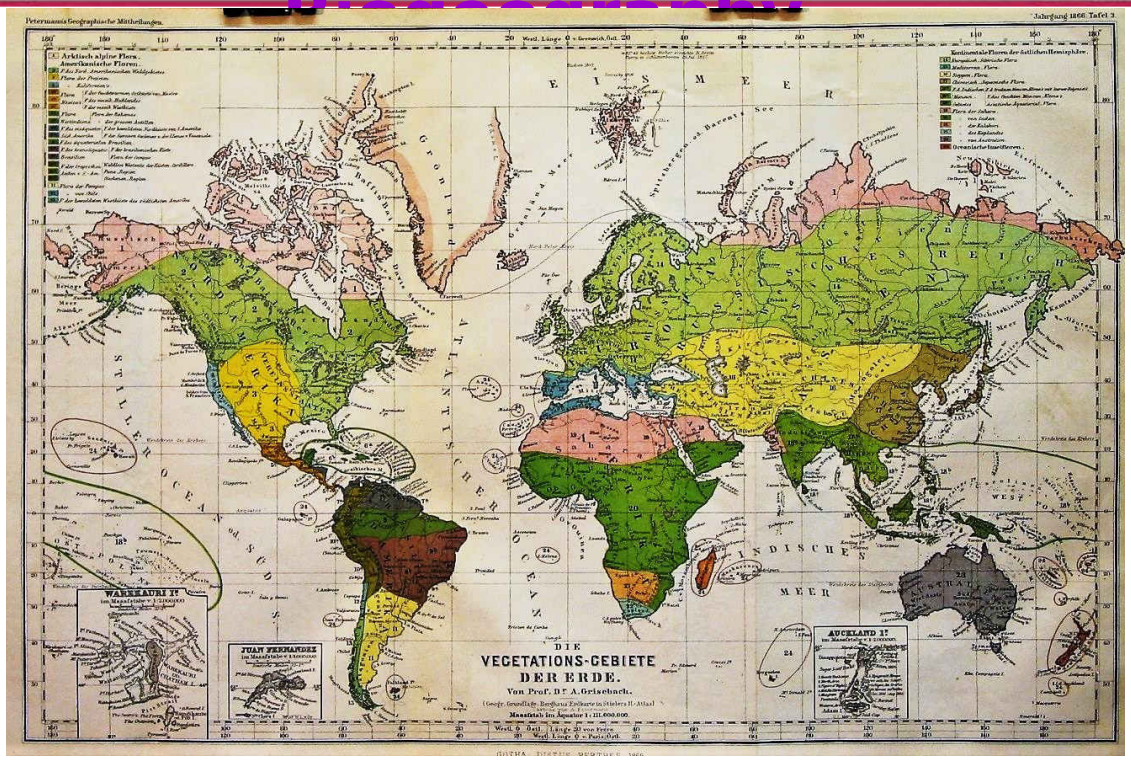
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Vegetation Maps

- **Danish botanist *Joakim Schouw* was the first to classify the world's flora and show the results on maps**
- **The distribution maps of particular groups of plants, rather than maps of regional floras**
- ***Grisebach's***

END-1

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Grisebach's more detailed, Coloured map of 1866

was similarly a vegetation map

https://www.abebooks.com/maps/1866-Map-Vegetation-Types-World-Prof/22575572506/bd

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Evolution – A Dangerous Idea!

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18th century Europe

- **Leading work on biological and geological subjects had been carried out in Prussia,**
- **French Revolution of 1789 led to a flowering of French science**
- **Power of the Church was**

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18th century Europe

- **New National Museum of Natural History, became a powerhouse of ideas and debate in Europe.**
- **One of those employed in this new museum was *Jean-Baptiste***

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Jean-Baptiste Lamarck.

- **He believed that there was some underlying pattern and structure to every aspect of the physical and biological world**
- **A mind-set common in18th-century**

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Jean-Baptiste Lamarck.

- **In 1802, Lamarck suggested that**
- **‘Lower’ organisms might also be found earlier in time and that they might gradually change into the ‘higher’ forms**
- **Due to an**

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Georges Cuvier

- **The science of comparative anatomy.**
- **Used this new branch of science to prove that such great fossil mammals belonged to quite different species from those of today**

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Georges Cuvier

- **So, to *Cuvier, Lamarck's* theory of continual transformation was deeply unacceptable**
- **Rejected Evolution**
- **So throwing out the baby of evolution with the bathwater**

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Geoffroy St Hilaire

- **1818–1828**
- **Geoffroy suggested evolutionary homologies and links between such widely different animals as fish and cephalopods**
- **Evolutionary record**

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Case for Evolution

- **Further damaged in 1844**
- **Scottish journalist *Robert Chambers* published a book, *Vestiges of the Natural History of Creation*.**

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Robert Jameson

- **Translated *Cuvier's* ideas into English in 1813,**
- **Suggesting that *Cuvier's* continent- wide catastrophes as the biblical Flood**
- ***Cuvier* accepted that science and**

END

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Enter Darwin – and Wallace

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Early 19th century:

- **Evolution: a slightly disreputable, anarchic and Nihilistic idea for the structure of society**
- **Young *Charles Darwin* was cautious, secretive and reluctant to**

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Darwin's Voyage

- **Interested in geology & natural history**
- **In 1831 joined the crew of a *HMS Beagle*, to act as a companion to the captain and also as a naturalist for**
- **6-year voyage to survey the coasts of *South***

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Darwin's Voyage

- **Mocking Bird, Finches and fossils mammals**
- **Idea that the living species were descended from the fossil species that had existed in the same part of the world**

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Alfred R. Wallace

- **Organisms were related to one another by evolution**
- **Thinking along exactly the same lines as Darwin**
- **First to publish that closely related species were often also found close to**

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A letter from Wallace

- **To *Darwin* then working in the East Indies, stimulated *Darwin* to publish his ideas after many years of agonizing over its possible hostile reception by the vociferously antievolutionary**

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Natural Selection

- **In the case of both workers, it was observation of the patterns of distribution of individual species of animals, i.e. their biogeography, that led them to consider the possibility of evolution.**

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Natural Selection

- **The idea of natural selection was announced by short papers from both Darwin and Wallace, read at a meeting of the *Linnean Society of London* on 30 June 1858**
- **Darwin quickly went on to**

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Natural Selection

- **"On the Origin of Species."**
- **Darwin had spent the 40 years after his voyage in detailed research on many other areas of biology that provided evidence for evolution**

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Charles Lyell

- **British geologist argued that many lines of evidence suggested that the Earth must be many millions of years old**
- **Discovered in the 20th century, leading to the eventual realization that**

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Two Paradigms

- **Plate tectonics is the central paradigm of the earth sciences and Theory of evolution is of the biological sciences**
- **Biogeography provides a striking example of the concordance of**

END

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World Maps: Biogeographical Regions of Plants and Animals

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Darwin and Wallace

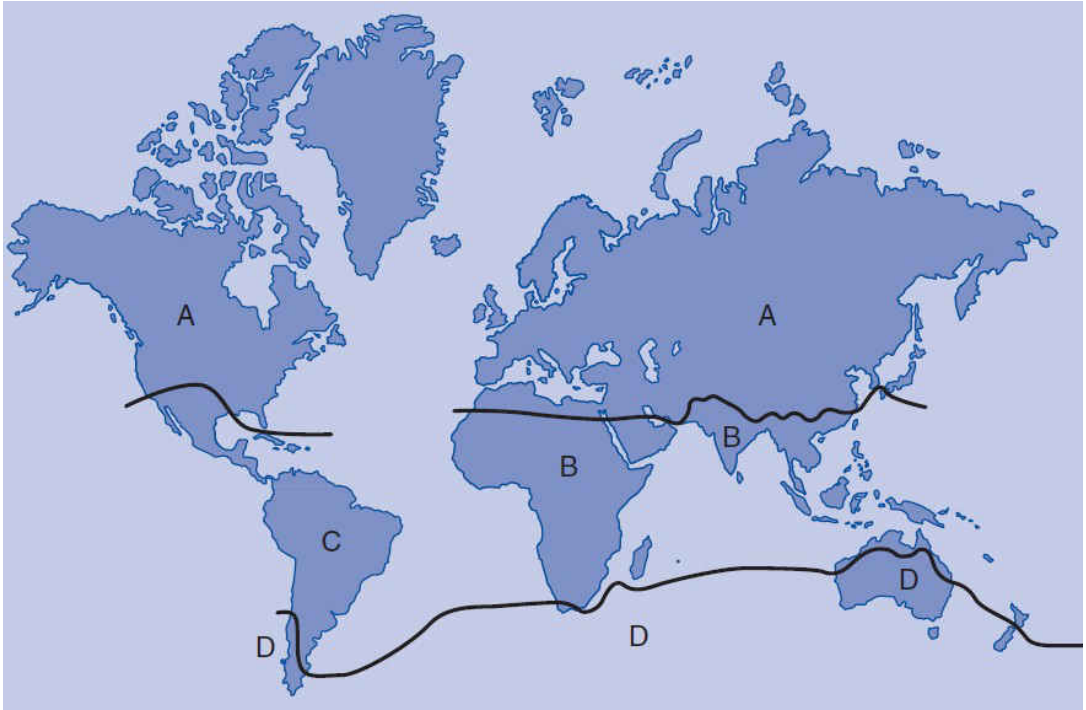
- **Evolution: the living world's reactions to changes in the physical world**
- **Genetics was yet to be identified**
- **Mechanisms of the geological process responsible for those changes**

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Adolf Engler (1879)

- **Differences between the floras and faunas of the separate continents resulted from their having had separate evolutionary histories.**
- ***Engler:*** **first to make a world map**
- **four major floral regions, or 'realms'**

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The world's botanic realms according to Engler

A, The Northern Extratropical Realm; B, the Palaeotropical Realm; C, the South American Realm; and D, the Old Ocean Realm

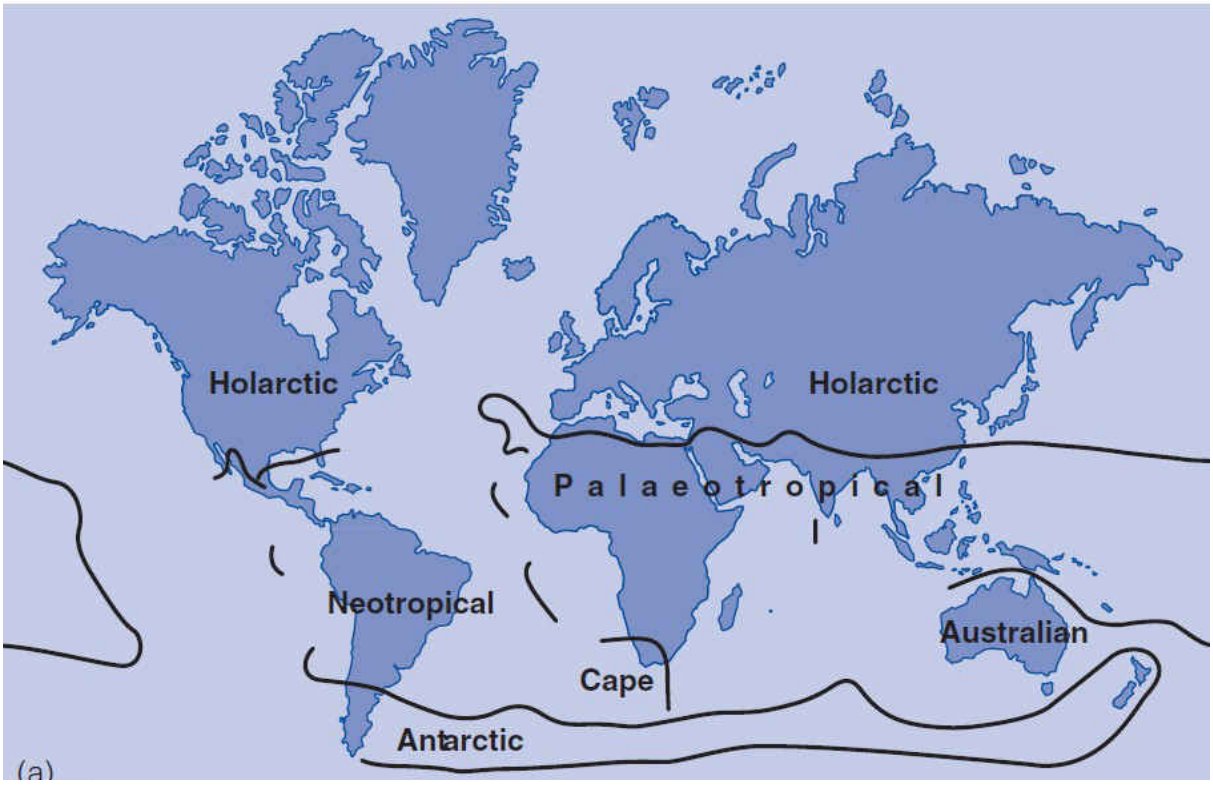
https://tinyurl.com/yd8umccm

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Floras of Engler

- **The system of plant regions accepted today is very similar to that of Engler**
- **No systematic comparison and contrast of the composition of the floras of these different realms**

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Floral kingdoms, according to *Good* and *Takhtajan*

https://tinyurl.com/y8ylaqps

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Old Ocean Realm

- Joseph Hooker
- Floras of the continents and islands of the Southern Hemisphere, and had suggested that these might be explained partly by the dispersal of floating seeds.

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Zoogeography

- Developing from early 19th cen onward with a different emphasis
- Birds and Mammals
- Do not show a close correlation to local ecology
- Early Zoogeographer: *Prichard* in 1826 and *Swainson* in 1835
- Six regions

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Zoogeography

- **This was first formalized in 1858 by the British ornithologist *Philip Sclater***
- **He believed that all species had been created within the area in which they are found today.**

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Alfred Wallace

- **Made his living by collecting bird skins, butterflies and beetles in the East Indies, and selling them to naturalists**
- **His travels and collections led him to be interested in their patterns of distribution just like *Darwin***

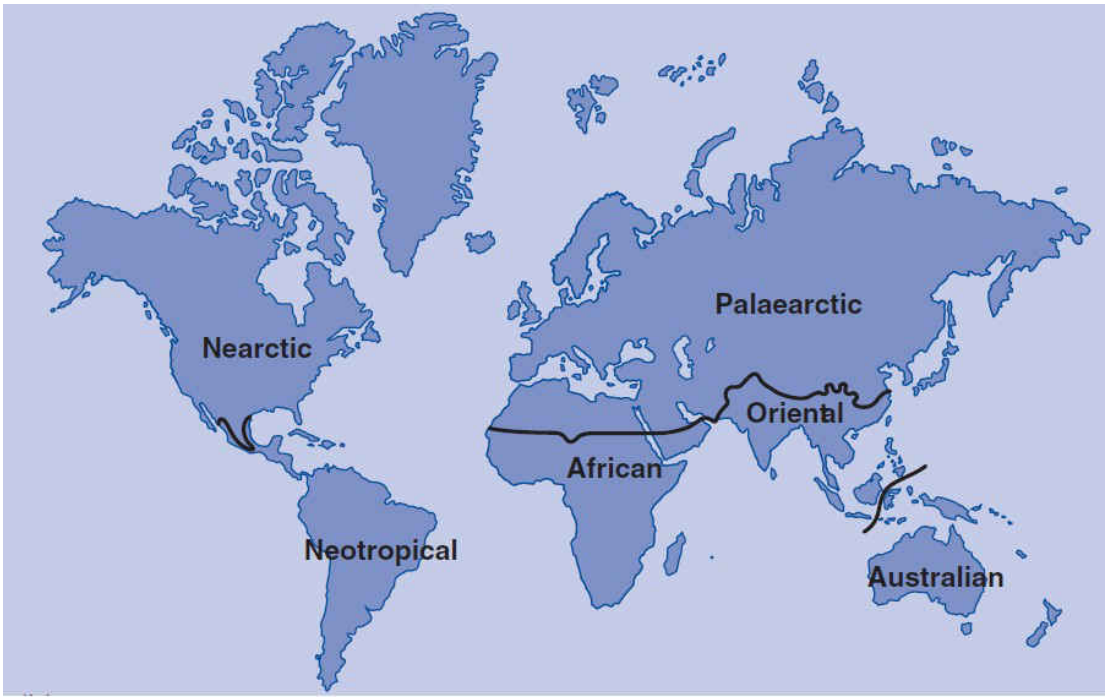
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Alfred Wallace

- **He immediately accepted *Sclater's* scheme, including his names for the regions, and expanded it to include the distribution of mammals and other vertebrates**
- **Identified/ commented on many aspects of biogeography**

END-1

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Zoogeographical Regions,
According to *Sclater* and *Wallace*

https://tinyurl.com/y8ylaqps

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Getting Around the World

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Biogeography

- **Acceptance of evolution gave a new importance to biogeography**
- **Posed new problems**
- **Until mechanics of continental drift or plate tectonics, were revealed.**

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Dispersalism

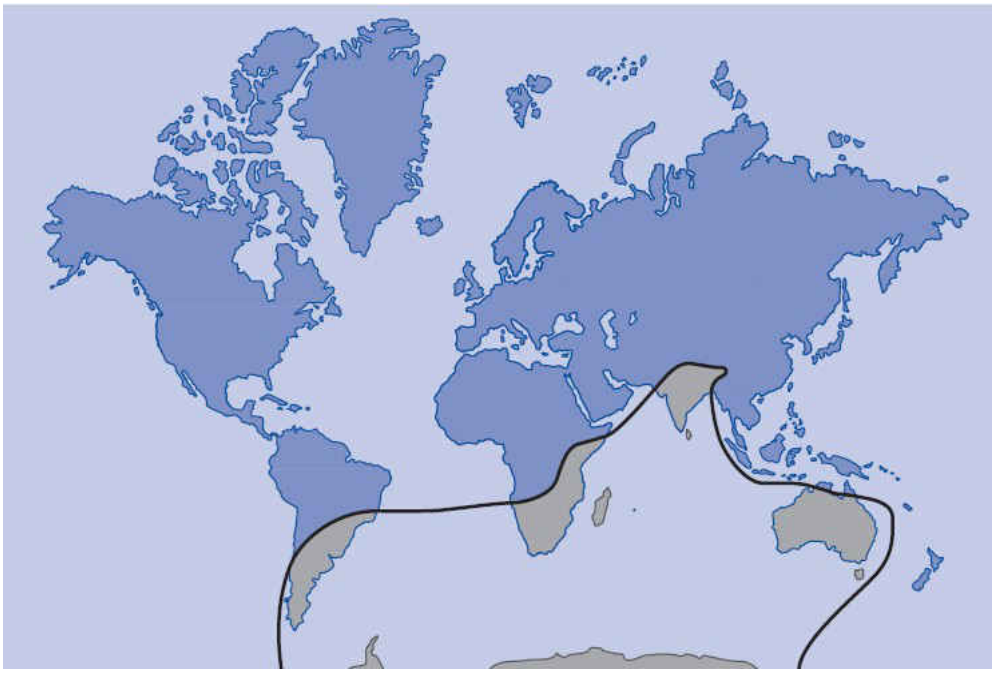
- **Where a taxon or two related taxa are found on either side of a barrier to their spread, this is because they had been able to cross that barrier after it formed**
- **Inadequate to explain the patterns of distribution of past**

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Dispersalism

- ***Joseph Hooker*, found these explanations quite unconvincing**
- **Instead, Narrow land bridges, or by wider tracts of dry land across the present South Atlantic and Indian Oceans**

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Distribution of the *Glossopteris* Flora (shaded area). 300 million years ago, existed in *Africa, Australia, Antarctica, southern South America* and, most surprisingly of all, *India*

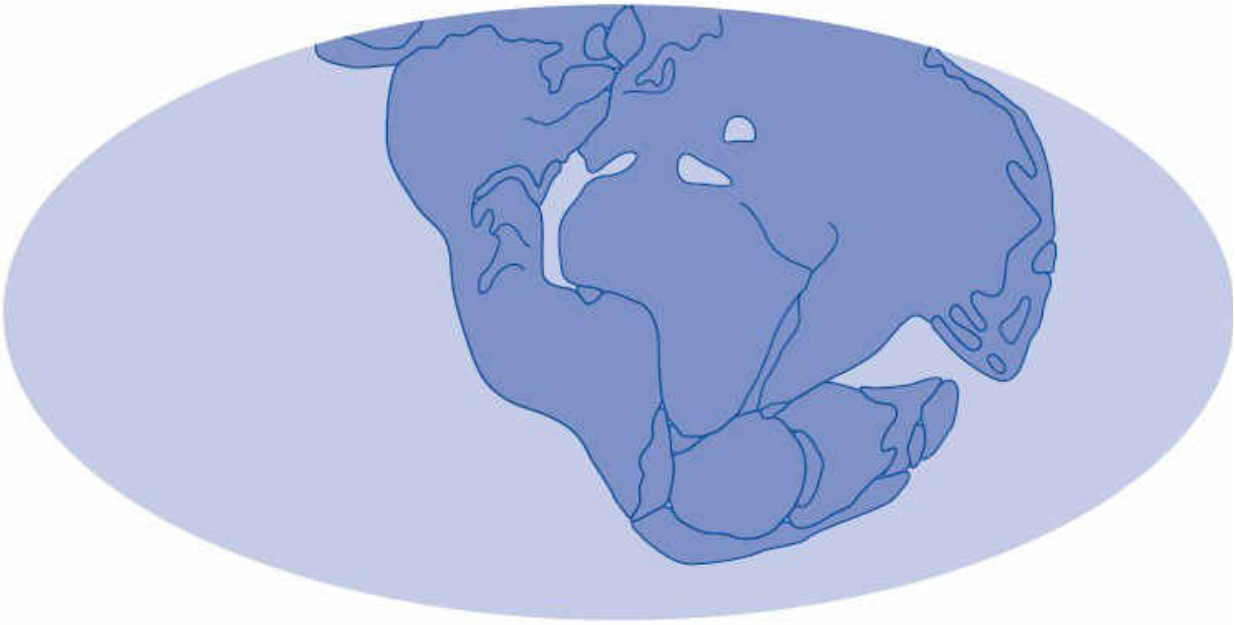
https://tinyurl.com/ycg63ned

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Alfred Wegener

- German meteorologist (1912)
- Presented his theory of continental drift in
- Wegener suggested that all of today's continents had originally been part of a single supercontinent, *Pangaea*

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How today's landmasses were originally linked together to form a single supercontinent, Pangaea, according to Wegener.

https://tinyurl.com/yb4ptrda

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END

Dispersalism

- ***Walter Matthew.*** **In his 1924 paper** ***'Climate and Evolution'***
- ***George Simpson***
- ***Karl Schmidt,***
- ***George Myers*** **(who worked on freshwater**
- **fishes)**
- **The zoogeographer** ***Philip Darlington***

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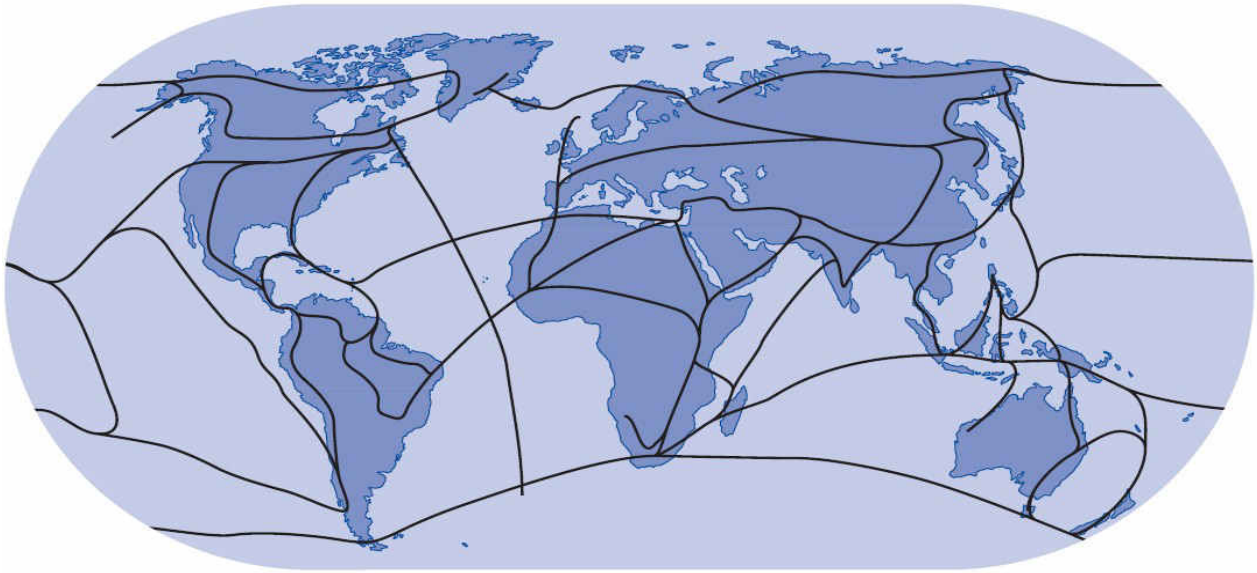
Leon Croizat

The History of Biogeography

Leon Croizat

- **He amassed a vast array of distributional data, representing each biogeographical pattern as a line, or track, connecting its known areas of distribution.**

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Croizat studied the distribution patterns of many unrelated taxa, and for each he drew lines or 'tracks' on the map linking the areas in which they are found. In many cases, these lines were similar enough in position to be combined as 'generalized tracks', shown here.

https://tinyurl.com/y8rzoz9f

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Leon Croizat

- **He found that the tracks of many taxa, belonging to a wide variety of organisms, could be combined to form a generalized track that connected different regions of the world**

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Panbiogeograph

- **Argued that all of the areas connected by one of these tracks had originally formed a single, continuous area that was inhabited by the groups concerned**

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Vicariance

- ***Croizat*** **believed that any barriers that exist today within the pattern of distribution of the taxa had appeared after that pattern had come into existence, so that these taxa had never needed to cross them**

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Coizat

- *Croizat* published his ideas in the 1950s and 1960s, his major presentation being his 1958 book *Panbiogeography*
- *Croizat* was correct, and ahead of time
- 'Dispersal explains everything', vs 'Vicariance explains everything

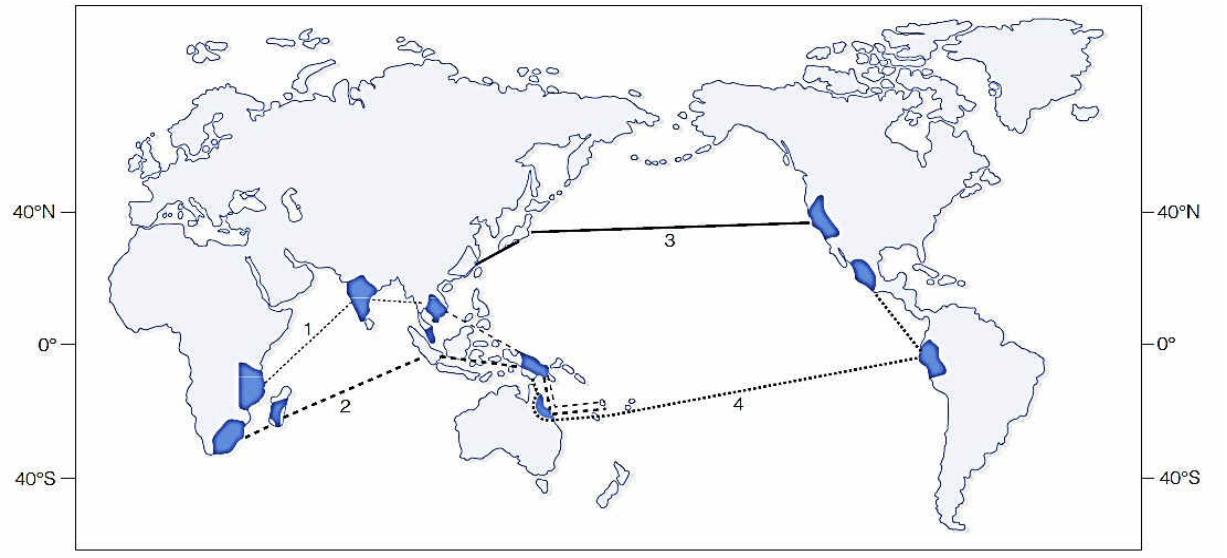
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Croizat's Supporters

- Biogeographers, most of whom worked in New Zealand
- These panbiogeographers accepted his generalized tracks running across the ocean basins, referring to them as *Ocean Baselines*

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Craw's panbiogeographical method.

The tracks link areas (dark blue) where related taxa are found. Tracks 1 and 2 are examples of an Indian Ocean baseline, and tracks 3 and 4 similarly are examples of a Pacific Ocean baseline.

https://tinyurl.com/y7dscn7t

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The Origins of Modern Historical Biogeography

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Dispersal of Life?

- **Could organisms have dispersed across oceans to reach these scattered locations?**
- ***Wegener's* theory of continental drift had provided an explanation to**

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Plate Tectonics

- **The 1960s**
- **Strong new evidence of the mechanism for Wegener's theory, now renamed *plate tectonics*, led to the acceptance of the reality of this**

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Plate Tectonics

- **It was only now that geologists were able to provide a series of palaeogeographic maps that showed, from the *Silurian Period* onward, the changing patterns of association of**

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Palaeobiogeography

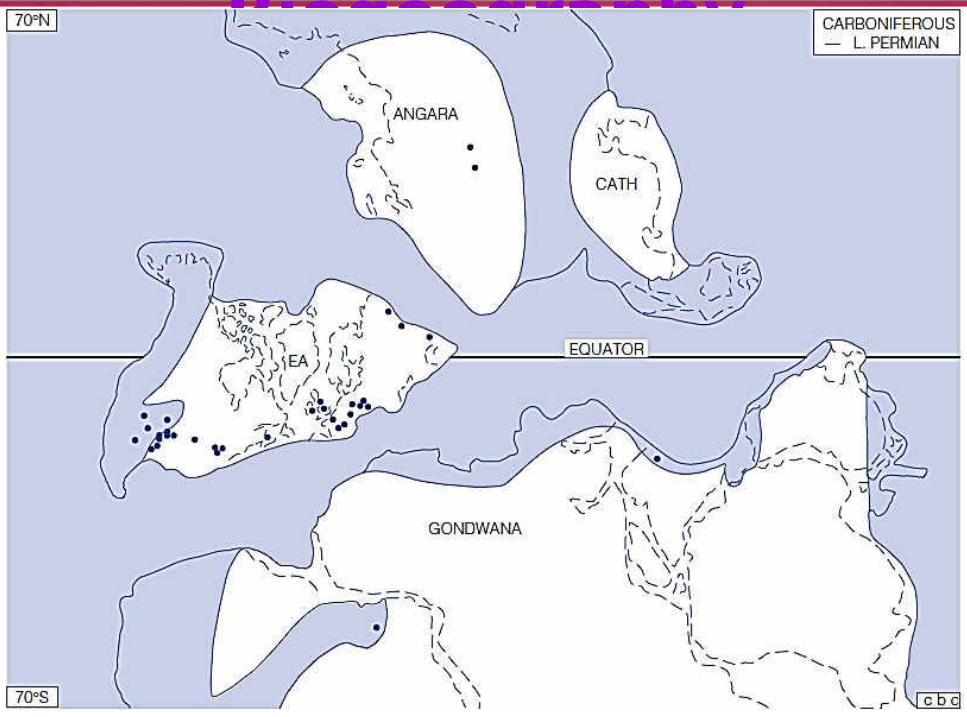
- **Biogeographers had tried to analyze the biogeography of the past according to the different geological periods**
- **The new maps identify stretches of time within**

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Palaeobiogeography

- **Palaeobiogeographer had to summate the faunas and floras from every locality within each of the resulting Palaeocontinents.**
- **Elements of these faunas and floras**

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Palaeogeographical map of the Carboniferous–Lower Permian period of time,

https://tinyurl.com/yavvb4o8

as reconstructed in 1973. The seas and oceans are

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Palaeobiogeography

- **At long last, biogeographers could build up a coherent, increasingly detailed set of pictures of the geography of the world over many millions of years.**

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Cladistics

- **Provides a rigorous methodology for analysing the patterns of evolutionary relationship between the different members of a group**
- **Characters used in this**

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Molecular Systematics

- **DNA and Proteins Provides confidence in accuracy of reconstructions of the patterns of evolutionary divergence of group under study**
- **Indicates the times at which**

END

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The Development of Ecological Biogeography

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Ecological biogeography

- ***Linnaeus*: simple observations**
- **Recorded, what type of environment each plant was found**
- ***Forster:* recognized latitudinal gradients of diversity,**
- ***Humboldt*: altitudinal**

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Ecological biogeography

- **Developed In the 20th century**
- **It depended on the rise of modern science with its techniques of experimental, physiological studies.**
- **Its history was not complicated**

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Ecological biogeography

- **The development was strongly dependent on the increasing application of chemical and physical concepts and techniques to the understanding of plant and animal function**

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Early Botanists

- **Distribution of plants was closely linked to climate.**
- **To structure the results of this relationship**
- **They focused either on the demands of environment on physiology of plants, or on type of vegetation**

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Candolle(1855)

- **Three physiologically different types of plant that resulted from their adaptations to different levels of heat and moisture**
- **Megatherms: High, Mesotherms: Moderate and Microtherms: Low**

The History of Biogeography

Candolle(1855)

- ***Hekistotherms*: live in the polar regions.**
- ***Xerophytes:* tolerate low levels of moisture**
- **Botanists soon also started to analyse the effects of the geology of the area in which**

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E.W. Hilgard (1860)

- **How climate and plant life combined to gradually break down the native rock into smaller fragments and provide an increasing component of soil as a product of the *biological***

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V.V. Dokuchaev

- **Analysed the mineralogical and physical attributes of the soils that resulted from the breakdown of different types of rocks**
- **The alternative focus: *Engler's* map**

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Categorizing Vegetation

- **The first clear and simple system of categorizing the different types of vegetation was produced by the German botanists *Hermann Wagner* and *Emil von Sydow***

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Categorizing Vegetation

- ***Clements and Shelford*** **in 1916, were plant formation or, with the addition of its animals, a biome.**
- ***Tansley*** **in 1935 added the climatic and soil aspects of the complex, calling it an ecosystem, which became the basic unit of**

END

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Living Together

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Julius von Sachs

- **German botanist and plant physiologist**
- **Physiological approach**
- **Environmental stresses: limiting factors in plant distribution patterns,**
- **Morphology, anatomy & physiology:**

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Plant Form

- **These features were recognized as a more effective way of defining the formations and biomes than any taxonomic or evolutionary system of classification**
- ***Christen Raunkiaer:***

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Community

- **Plant ecologist *Frederic Clements***
- **Communities resemble individual organisms in their degree of internal organization, and may similarly behave as units in their**

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Succession & Climax

- **The linked concepts of succession and climax, first developed by *Henry Cowles***
- **Alternative approach*: chaos theory***
- **A concept: the outcome of a process is highly dependent on**

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The Ecosystem Concept

- **One of the most influential ideas of ecological studies**
- **Useful in biogeographical studies.**
- **Work of *Raymond Lindemann*, who in 1942 put forward a formal account of**

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The Ecosystem Concept

- **Expanded by the work of American ecologists *Howard and Eugene Odum*, and named by the British botanist *Arthur Tansley.***
- **Any selected portion of nature is an**

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The Ecosystem Concept

- **In the early 1960s, the first landscape- scale ecosystem was subjected to monitoring and manipulative management at *Hubbard Brook*, a forested mountainside in New Hampshire**

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Ecophysiology

- **Examines how plants and animals vary in their physiological processes in response to the environment**
- **Subtle differences in organism's systems provide some species**

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Neutral Theory of Biodiversity

- **The assemblage of species in a site is entirely a matter of chance**
- **The arrival of a species is a stochastic process**
- **The best predictive models are**

END

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Marine Biogeography

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Marine biogeography

- **Biogeography of the oceans is similar to that of the continents**
- **Concerned with the biota of vast areas of the surface of the globe**
- **Different: because of the nature of the environment**

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Marine biogeography

- ***James Dana*: (1853), divided the surface waters into several different zones based on mean minimum temperature.**
- ***Edward Forbes*: (1856) published Five depth zones and 25 faunal provinces along the coasts**

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Marine biogeography

- **In 1880, *Albert Günther* published a book on fishes in which he recognized 10 different regions in the distribution of shore fishes,**
- ***Arnold Ortmann* published work based on the distribution of**

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Atlas of Zoogeography

- **1911: Assembled by three British zoologists (*John Bartholomew, William*
- ***Clark and Pery Grimshaw*).**
- **30 maps of the distributions of fishes based on the patterns of distribution of 27 families.**

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An Influential Review

- **Carried out by the Swedish worker Sven Ekman;**
- **German in 1935,**
- **English translation in 1953.**
- **This divided the faunas of the shallow seafloors into seven (mainly climatic) areas**

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An Influential Review

- **Carried out by the Swedish worker Sven Ekman;**
- **German in 1935,**
- **English translation in 1953.**
- **This divided the faunas of the shallow seafloors into seven (mainly climatic) areas**

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Sven Ekman

- ***Panama barrier* must have been absent**
- **Island-free *East Pacific* acted as a barrier to dispersal of organisms**
- **Phenomenon of 'bipolarity', where a species is found on either side of the equatorial**

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Jack Briggs (1974)

- ***Marine Zoogeography***
- ***Briggs* used the patterns of endemicity of coastal faunas to identify locations where there appears to be a zone of unusually rapid faunal change, and then used this to**

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Recent Advances

- **Ability to explore the**
- **Depths of the sea**
- **Sensing & recording satellites in space**
- **Deepest part of the oceans– *the strange hydrothermal vent faunas.***
- **Nimbus: Monitor**

END

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Island Biogeography

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Georg Forster

- **First biologist to identify particular features of island biogeography**
- **Fewer species than the mainland, but that the number of species varies according to the size and**

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Candolle

- **Pointed out that the age, climate and degree of isolation of an island, and whether or not it was volcanic, would also affect the diversity of its flora.**
- **Sheer variety and volume of the works**

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Philip Darlington (1943)

- **Larger islands contain a greater number of individuals, and a greater diversity of species, than smaller islands,**
- **The species diversity increasing by a factor of 10 for every doubling of island area.**

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Mathematical Analyses

- ***The Theory of Island Biogeography***
- **Published 1967 written by two American biologists**
- **The mathematical ecologist *Robert MacArthur***
- **The taxonomist–biogeographer *Edward Wilson***

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Area and The Number

- **Swedish worker *Olof Arrhenius in 1921*, and the Americans *Eugene Munroe* in 1948 and *Frank Preston* in 1962, had noted the relationship between the area of an island and the number of species that it**

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Area and The Number

- ***The Song of the Dodo* – *Island Biogeography in an Age of Extinction*, by the American science writer *David Quammen***
- **Story of the rise of the theory and of the later mounting wave of criticism has**

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Island Biogeography

- ***MacArthur and Wilson* nevertheless revolutionized the study of island biogeography, for they led the way in introducing mathematical techniques, and in providing a**

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Island Biogeography

- **The ecology of island faunas and floras is far more fragile than that of the continents.**
- **Natural laboratories for evolutionary change**
- **Contain a high proportion of the biotic diversity that**

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Island Biogeography

- **New Guinea contributes only 3% of the world's land area, it contains some 10% of its species of terrestrial organism**

END

Patterns of Distribution

Finding a Home

Patterns of Distribution

Aim of Biogeography

- **To understand underlying patterns of distribution of organisms on our planet,**
- **Such studies must be based on an appreciation of the nature of the species with which one is**

Patterns of Distribution

Subspecies

- **Some species, for example, exist in a number of different forms that are sufficiently stable to be termed subspecies, and these often have different distribution patterns**

Patterns of Distribution

Polytypic and Monotypic

- **A species that exists as a series of subspecific forms is termed *A Polytypic Species***
- **As opposed to a less variable species that exists in just one form – called a**

Patterns of Distribution

Genetic Analyses

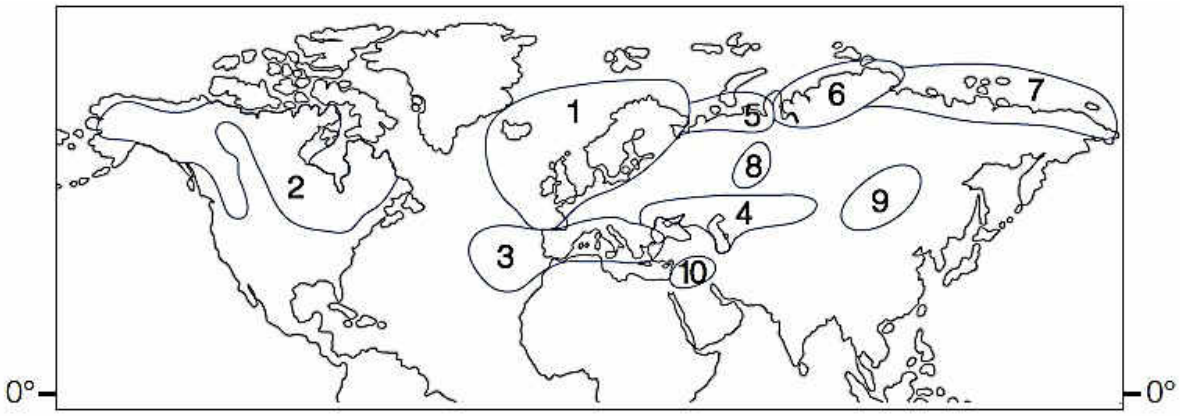
- **Biologists apply these more widely**
- **The complex relationships within species are becoming increasingly evident**
- **Such complexity is reflected in distribution patterns**

Patterns of Distribution

Larus argentatus

- **An example of a polytypic species**
- **The Herring Gull**
- **Was regarded as polytypic with about a dozen subspecies spread around the entire Northern Hemisphere**

Patterns of Distribution



Approximate Breeding Distributions of Various Taxa Within the Herring Gull Complex

(1) European herring gull (Larus argentatus)
(2) American herring gull (L. smithsonianus);
(6) Taymyr gull (L.taimyrensis);
(7) Vega gull (L. vegae);
(8) steppe gull (L. barabensis);
(9) Mongoliangull (L. mongolicus);
(10) Armenian gull (L. armenicus)

Patterns of Distribution

Gradual Change

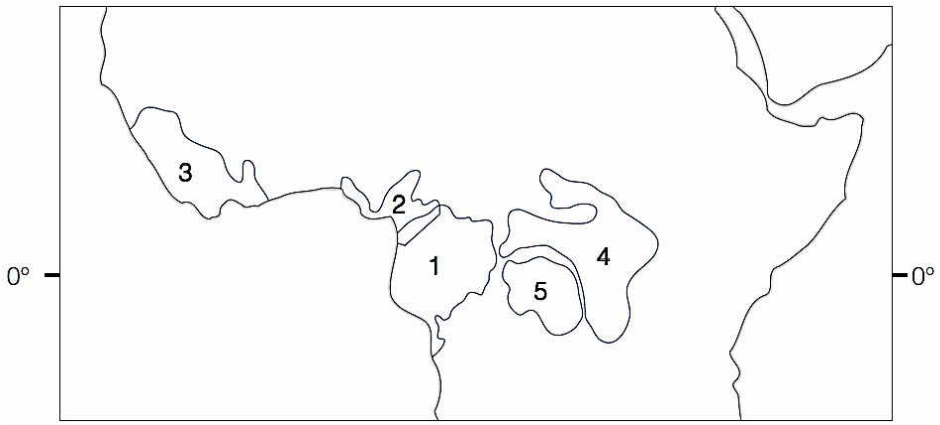
- **Where there is gradual change in genetics and form along a gradient, taxonomists refer to a *cline*, and the variation is said to be *clinal.***

Patterns of Distribution

Evolution of Bonobo

- **A consequence of separate genetic development resulting from the presence of a major barrier to interbreeding (River Congo).**
- **All chimpanzee subspecies lie to the north or east of this**

Patterns of Distribution



Distribution Patterns of chimpanzee subspecies and bonobo in Central and West Africa

(1–4) the subspecies of chimpanzee, Pan troglodytes;
(5) the bonobo or pygmy chimpanzee, Pan paniscus.
More specifically:
(1) the nominate Pan troglodytes troglodytes; (2) Pan troglodytes vellerosus;
(3) Pan troglodytes verus; (4) Pan troglodytes schweinfurthii.
The bonobo is found south of the River Congo and is hence

Patterns of Distribution

Microhabitats

- **Such as forest canopies or forest floors.**
- **New Zealand forest**
- **Brown Kiwi *Apteryx australis* forest floor**
- **The Fantail *Rhipidura fuliginosa* nests in canopy**
- **Occupy**

END

Patterns of Distribution

Limits of Distribution

Patterns of Distribution

Aim of Biogeography

- **There are limits within which distribution of an organism is spatially confined.**
- **Beyond these limits, it is unable to sustain its population.**
- **Determined by barriers, but the**

Patterns of Distribution

Physical Barriers

- **There are physical barriers that may prevent the spread of an organism.**
- **High mountain chains, expanses of water or areas of arid desert may confine a species to one**

Patterns of Distribution

Climatic barriers

- **Frost can prove fatal to many tropical plants because the formation of ice within the cells of the plant, followed by melting, disrupts the cell membranes and results in death.**
- **Drought can cause problems**

Patterns of Distribution

Geological Barriers

- **Geology, and its effect on soil chemistry and structure, is often limiting for plants and for soil-inhabiting invertebrate animals and microbes.**
- **Overcoming demands effective**

Patterns of Distribution

Nature of the Habitat

- **At a lower level: can impose limits to a species.**
- **A forest species may be deterred from crossing an area of grassland; or a marsh organism may fail to travel across dry habitats to**

Patterns of Distribution

Biological Barriers

- **Increased predation, parasitism, disease or competition from more robust species if it were to move beyond specific area limits.**
- **Insect that leaves its forest-floor log, is**

Patterns of Distribution

Historical Factors

- **Create barriers that confine species to a limited area.**
- **Changes in the pattern of land masses over the surface of the Earth have resulted in the creation of physical barriers, sometimes**

Patterns of Distribution

Chance

- **Sheer chance in the distribution of organisms.**
- **The arrival of a wind-borne insect or a seed at a particular point in space cannot be predicted with certainty, and the first arrival may well be at an advantage**

Patterns of Distribution

Endemic

- **Some plants and animals are confined in their distribution, within the areas in which they evolved; these are said to be endemic to that region.**
- **Palaeoendemics**
- **recently evolved (neoendemics).**

END

Patterns of Distribution

The Niche

Patterns of Distribution

Niche

- **The demands that an organism places on its environment in terms of physical and chemical conditions, space and food supply help to define what**

Patterns of Distribution

Niche

- **Covers all aspects of the basic physics and chemistry of habitat and how the organism makes a living.**
- **Includes the food an animal requires, but also encompasses the way in**

Patterns of Distribution

Niche Partitioning

- **The subdivision of resources**
- **Plants: similar requirements for water and chemical elements from soil**
- **Roots at different depths, or flower at different times,**
- **Tap slightly**

Patterns of Distribution

Kleptoparasitism

- **A very widespread duck in the gadwall (*Anas strepera*).**
- **Coots (both Eurasian coot, *Fulica atra*, and the American coot, *Fulica americana*)**
- **Dive for their food and bring**

Patterns of Distribution

Kleptoparasitism

- **The coots are messy eaters, and it is not difficult for gadwall to move in and collect some of the loot.**
- **This behavior is called kleptoparasitism, and it is an effective way of**

Patterns of Distribution

Fundamental Niche

- **There is the theoretical or ideal type of niche, usually called the fundamental niche, which is the sum of all the niche requirements under ideal conditions when the species is**

Patterns of Distribution

The Realized Niche

- **Species compete for resources (i.e. have overlapping niches)**
- **Perform better in their efficiency of acquisition.**
- **The result is that the observed distribution of**

Patterns of Distribution

Importance

- **These concepts are important in biogeography, especially when attempts are made to model potential niches as an aid to predicting distribution patterns**

END

Patterns of Distribution

Topographical
Limits
and
Endemism

Patterns of Distribution

Distribution Patterns

- **Confined to a specific range by topographical factors, such as expanses of ocean or, areas of lowland forest between mountain habitats.**
- **Such isolation may lead to the evolution of new**

Patterns of Distribution

Endemism

- **Species may evolve in one region, spread to other locations and then become extinct in all but a restricted area where it survives**
- **Species restricted in this way are said to**

Patterns of Distribution

Endemism

- **In general, there are two major factors influencing the degree of endemism in an area:**

1. **Isolation**
2. **Stability**

- **Isolated islands and mountains**

Patterns of Distribution

Australia

- **The island of Australia, for example, has long been isolated from outside influences, until the arrival of European people with their associated**

Patterns of Distribution

Australia

- **Although not particularly stable in its climate, Australia covers a very considerable area, so on a simple area basis it should be expected to have an**

Patterns of Distribution

Australia

- **Australia also contains few physical barriers to movement during times of change, so extinction by local isolation has not been an important factor.**

Patterns of Distribution

Australia

- **Australia is indeed rich in endemics, many of which have a long geological history.**
- **This kind of 'fossil endemism' is called palaeoendemism, in contrast to**

END

Patterns of Distribution

Physical Limits

Patterns of Distribution

Physical Limits

- **Often, a species' distribution is limited by a particular factor in the environment that influences its ability to survive or reproduce adequately.**
- **Physical factors such as**

Patterns of Distribution

Biotic factors

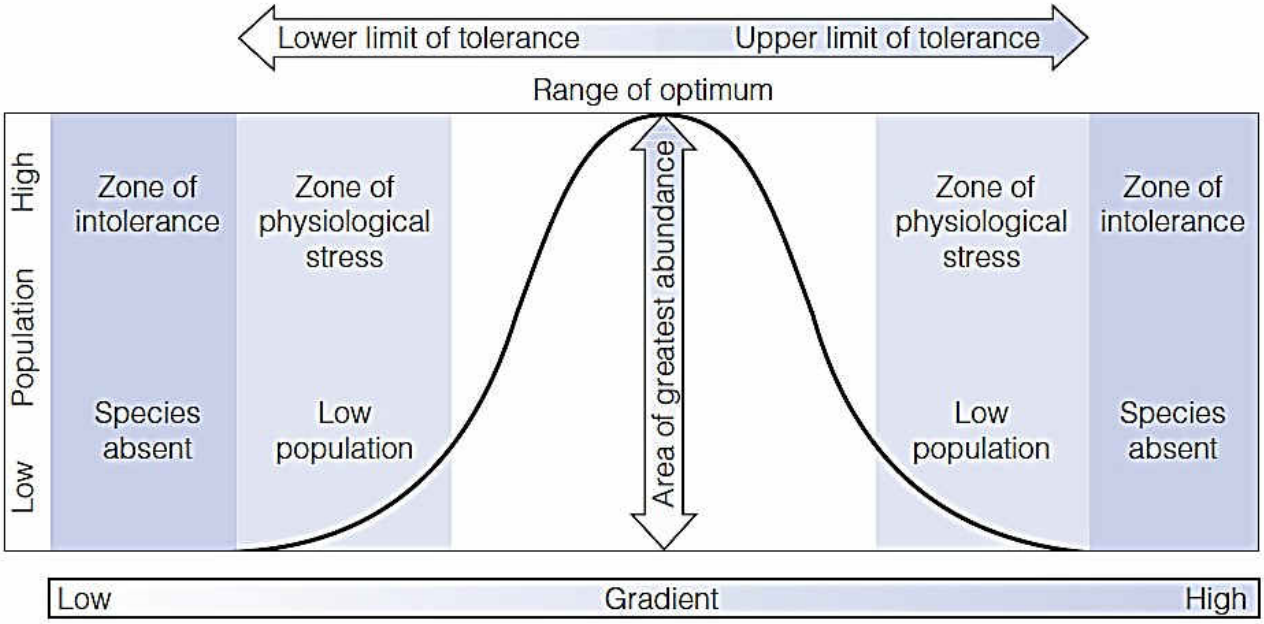
- **Biotic factors such as competition, predation, parasitism or the presence or absence of suitable food.**
- **All of these factors contribute to the niche of the organism**

Patterns of Distribution

Environmental Variable

- **Taking a single environmental variable**
- **Any species will have certain limits along a gradient of that factor**
- **Optimum for that factor, at which it populations will grow most effectively**

Patterns of Distribution



Graphic model of the population abundance maintained by a species of animal or plant along a gradient of a physical factor in its environment

Cox, C. Barry, Peter D. Moore, and Richard Ladle. *Biogeography: an ecological and evolutionary approach*. John Wiley & Sons, 2016.

Patterns of Distribution

Limiting Factor

- **Of these factors, there is often one that is particularly important and that may be over-riding in determining survival and hence distribution.**
- **This is called**

Patterns of Distribution

Limiting Factor

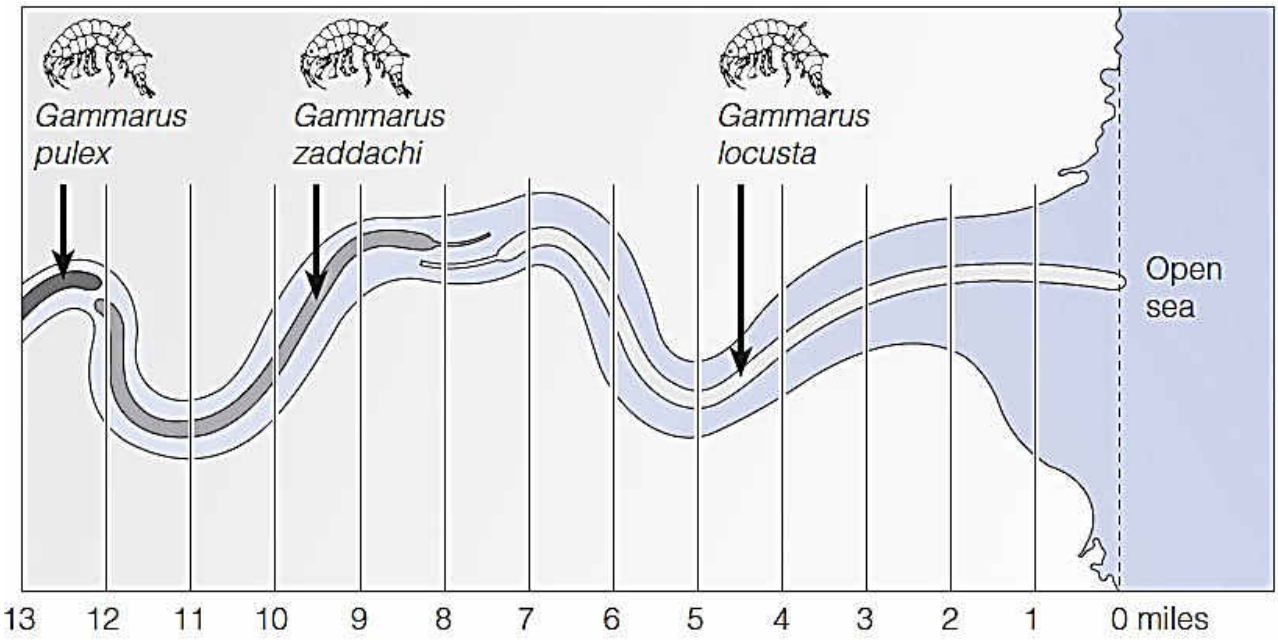
- **Anything that tends to make it more difficult for a species to live, grow or reproduce in its environment may prove to be a limiting factor for the species in that environment.**

Patterns of Distribution

Zonation

- **Any regular change in physical or chemical conditions through space thus creates a sequence of replacement of one species by another, among both animals and plants.**
- **This is known**

Patterns of Distribution



Distribution along a river of three closely related species of amphipod (Crustacea), relative to the concentration of salt in the water

Cox, C. Barry, Peter D. Moore, and Richard Ladle. *Biogeography: an ecological and evolutionary approach*. John Wiley & Sons, 2016.

Patterns of Distribution

Studying Distribution

- **Potential distributions of species cannot be fully understood without reference to the influence of other organisms and their respective distribution**

END

Patterns of Distribution

Competition

Patterns of Distribution

Competition

- **When two species are attempting to tap a resource in the same way, and when that resource is in short supply, the two are said to be in competition.**
- **Weaker species may be excluded**

Patterns of Distribution

Competitive Exclusion

- **When a species is prevented from occupying an area by the presence of another species in this way, it is termed competitive exclusion.**
- **Not easy to observe this ousting of one species by**

Patterns of Distribution

Example

- **The barnacle species that occupy the rocky seashores of western Europe and northeastern North America.**

Patterns of Distribution

Reducing Competition

- **An organism may find considerable advantage in avoiding competition**
- **With other species or other members of its own species.**
- **Many different ways of reducing competition**

Patterns of Distribution

Reducing Competition

- **Sometimes, species with similar food or space requirements exploit the same resources at different seasons of the year, or even at different times of day.**
- **Owl hunt at**

Patterns of Distribution

Temporal Separation

- **Many bats are night-active insectivores, avoiding competition for prey with insectivorous birds during the day, and also avoiding the predatory attention of day-active hawks and falcons**

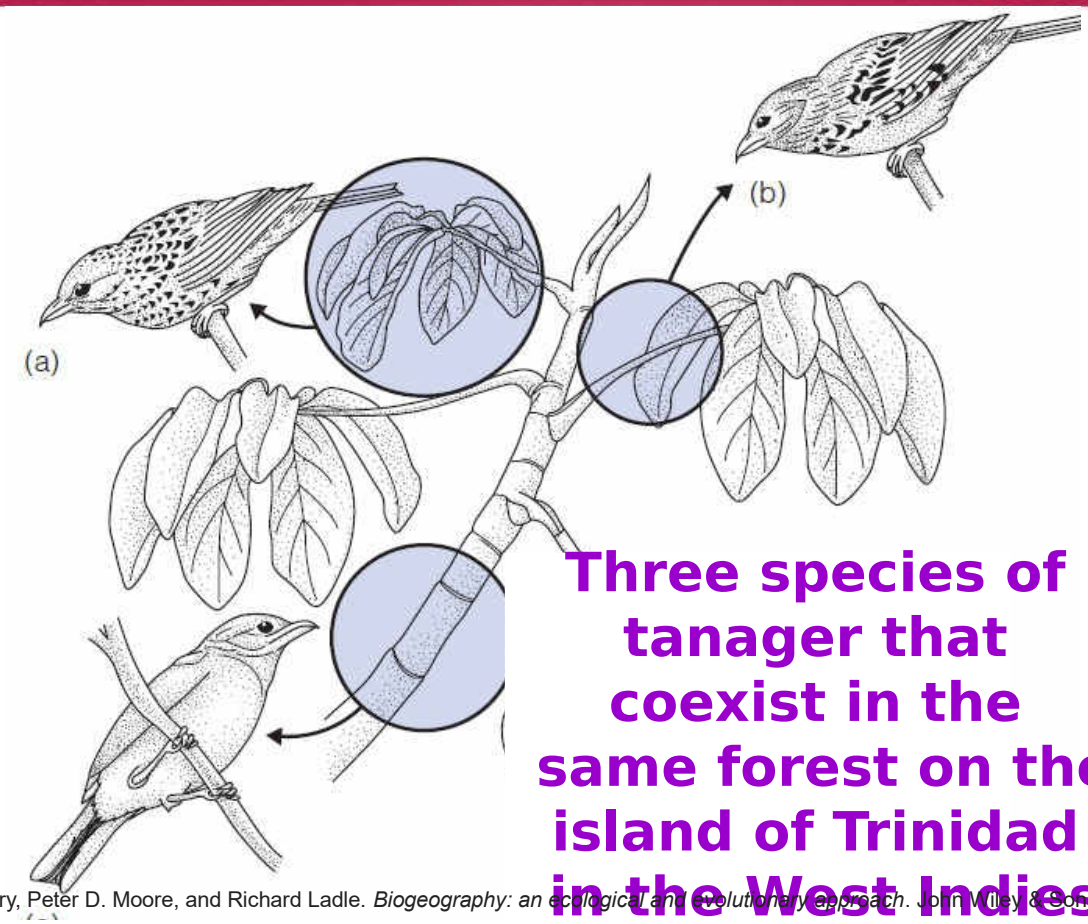
Patterns of Distribution

Spatial Separation

- **Each species must be adapted to live within the fixed set of physical conditions of its particular microhabitat.**
- **Bird species have different preferences for the available feeding areas.**

END-1

Patterns of Distribution



Three species of tanager that coexist in the same forest on the island of Trinidad in the West Indies

Cox, C. Barry, Peter D. Moore, and Richard Ladle. *Biogeography: an ecological and evolutionary approach*. John Wiley & Sons, 2016.

Patterns of Distribution

Predators and Prey, Parasites and Hosts

Patterns of Distribution

Predators

- **Predators may be another biological factor influencing the distribution of species, as may the presence and abundance of parasites in a habitat, but their effects have been much less studied than those of**

Patterns of Distribution

Predators

- **The simplest influences that predators might have is to eliminate species by eating them or, alternatively, to prevent the entry of new ones into a**

Patterns of Distribution

Prey Switching

- **Species is preyed upon too heavily, and the predators can always turn to alternative food species if the numbers of their usual prey should be reduced by climatic or other influences.**
- **This is termed**

Patterns of Distribution

Parasites

- **Parasites reduce the rate of growth of populations because of their negative influence on general fitness, survival and fecundity.**
- **Rarely cause the complete extinction of the host species;**

Patterns of Distribution

Species Diversity

- **A parasite may increase diversity, but it may also reduce it.**
- **The presence of predators is likely to increase rather than reduce the numbers of species present**
- **Predators**

Patterns of Distribution

Species Diversity

- **In a grassland, the complicated sets of interactions between predator, grazer and plant can lead to the development of a finely balanced and**

Patterns of Distribution

Keystone Species

- **The removal of certain species could create effects far in excess of what may originally have been expected. Influential species of this kind are known as keystone**

Patterns of Distribution

Keystone Species

- **Identifying the keystone species in an ecosystem is clearly a very important task, especially if biodiversity is to be maintained.**
- **The loss of a keystone species can cause an**

END

Patterns of Distribution

Migration

Patterns of Distribution

Migration

- **Environmental conditions alter with seasons, especially in the higher latitudes, and some animals alter their distribution patterns in concert with the seasons.**
- **This is called**

Patterns of Distribution

Migration

- **Not to be confused with range expansion, or spread, of a species,**
- **Consists of the temporary occupation (usually seasonal) of a region and then mass movement**

Patterns of Distribution

Migration

- **Motile organisms**
- **Microscopic plankton are capable of changing the depth at which they live, depending on conditions, and this can be regarded as a form of vertical migration**

Patterns of Distribution

Migration

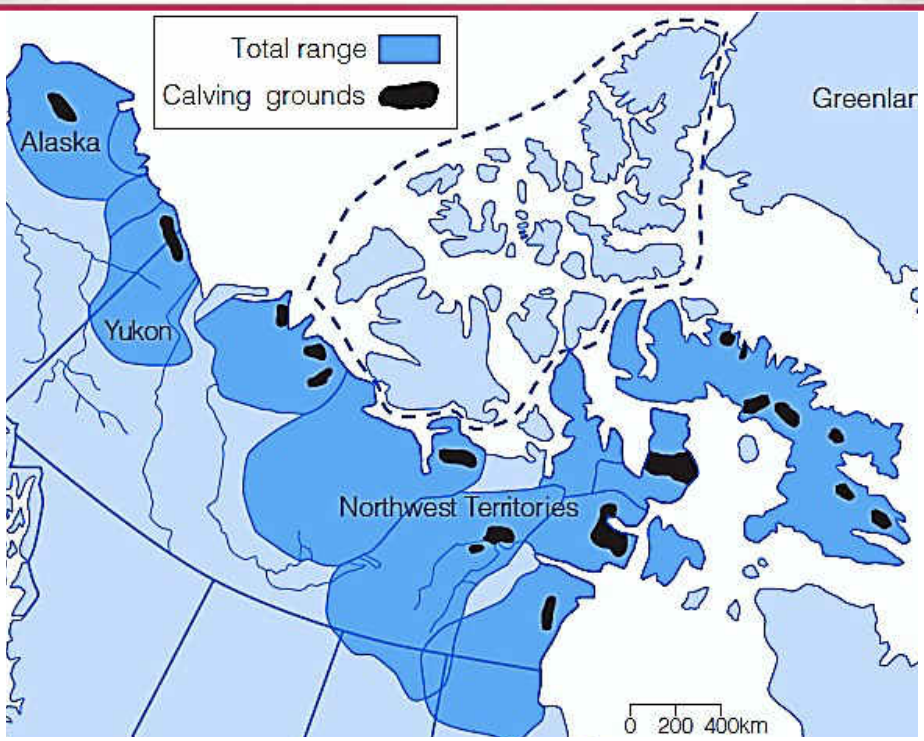
- **Migration often takes the form of latitudinal movements of animals in order to take advantage of long summer days and high productivity in the high latitudes, and then to retreat to lower**

Patterns of Distribution

Migration

- **Energetically expensive and also exposes animals to the risks of predation,**
- **In the case of caribou by wolves that follow the herds.**
- **But the benefits of migration in terms of food availability and**

Patterns of Distribution



Ranges of caribou herds in North America, also showing their calving grounds to which they migrate each spring

Cox, C. Barry, Peter D. Moore, and Richard Ladle. *Biogeography: an ecological and evolutionary approach*. John Wiley & Sons, 2016.

Patterns of Distribution

Migration

- **Birds are among the most mobile of animals, and many species resort to migration in order to maximize food supply, especially during the**

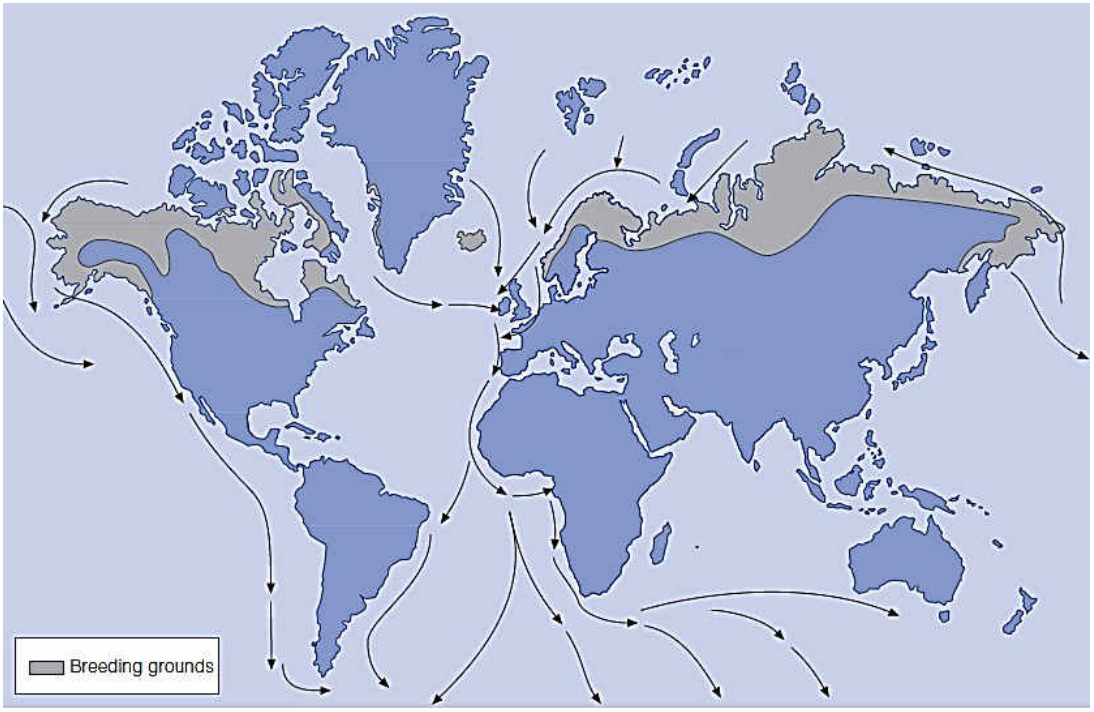
Patterns of Distribution

Migration

- **Most extraordinary of all migrant birds, is the Arctic tern (*Sterna paradisaea*) which, nests in the Arctic and travels to the Antarctic during the northern hemisphere winter.**
- **This bird must enjoy more**

END-1

Patterns of Distribution



Breeding grounds, migration routes and wintering area of the Arctic tern (*Sterna paradisaea*).

Cox, C. Barry, Peter D. Moore, and Richard Ladle. *Biogeography: an ecological and evolutionary approach*. John Wiley & Sons, 2016.

Patterns of Distribution

Invasion

Patterns of Distribution

Invasion

- **The capacity to spread is important to all organisms.**
- **Success of a species can be measured by its geographical distribution, and the ability to move into new areas is one of the attributes**

Patterns of Distribution

Invasion

- **Habitats may alter or be lost, so a species needs to be capable of moving to more appropriate sites.**
- **Climate may change, and species will then need to alter their ranges to cope with the**

Patterns of Distribution

Invasion

- **All organisms need to disperse to ensure survival.**
- **Many of the animals that have failed to survive and have become extinct have failed in this respect.**
- **The flightless birds, such as**

Patterns of Distribution

Invasion

- **Species need to be able to move to new areas if local conditions deteriorate for them.**
- **But range expansion for organisms with little or no mobility of their own presents problems, and these have been**

Patterns of Distribution

Ecological Imperialism

- **Greatly assisted by humans**
- **Ecological imperialism is a term sometimes used to describe the wave of biological invasions that has occurred in the wake of human invasions, by either accidental**

END

Communities and Ecosystems

Living Together

Communities and Ecosystems

Living Together

- **No organism lives in total isolation from all others.**
- **Different organisms interact with one another in both the long and the short term, competing for resources and sometimes excluding one**

Communities and Ecosystems

Living Together

- **Over evolutionary time, this can lead to populations specializing in certain ways, perhaps in the way they obtain food, or the type of food they eat or the type of microclimate in**

Communities and Ecosystems

The Community

- **Species rarely occur as single populations; usually they occur in a mixture of different species, and such an assemblage is termed a community**

Communities and Ecosystems

The Guild

- **The term guild is used for animals that play a particular role in the community, such as plant-sucking insects or insectivorous birds**
- **Some plants and animals occur together and are associated with specific habitats**

Communities and Ecosystems

Co-evolution

- **Species adapt**
- **To cope with the physical demands of their environment,**
- **To cope with the presence of other species.**
- **Co-evolution: species tolerating one another, or becoming**

Communities and Ecosystems

Phytosociology

- **Discipline of vegetation science**
- **Summarized by the views of the two American ecologists,**
- **Frederic Clements**
- **Henry Gleason**
- **Who began the discussion in the**

Communities and Ecosystems

Clements

- ***Clements*** **regarded the plant community as an organic entity in which the positive interactions and interdependencies between plant species led to their being found in distinct associations**

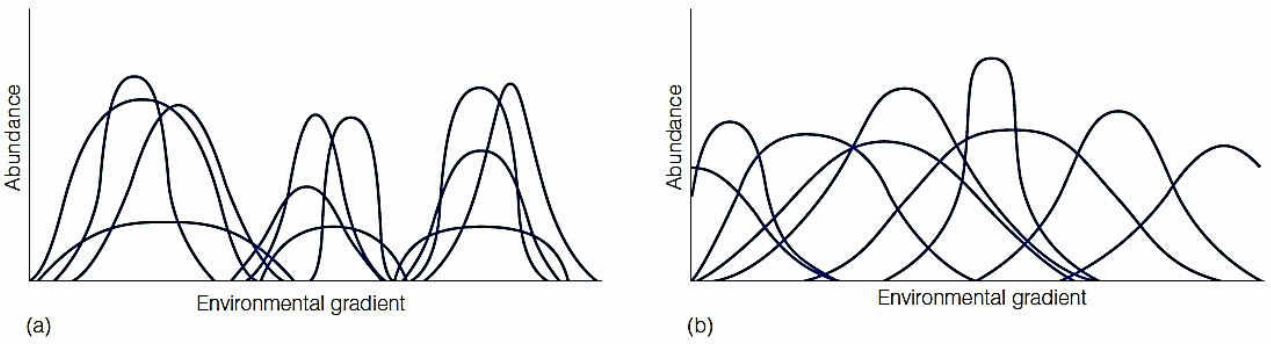
Communities and Ecosystems

Gleason

- **Individualistic concept**
- **Pointing out that no two species have quite the same needs.**
- **Very rarely do the distributional or ecological ranges of any two species**

END-1

Communities and Ecosystems



Diagrammatic representation of two models of vegetation.

(a) The model of Clements in which species' requirements coincide, leading to the separation of distinct 'communities'.

(b) The 'individualistic' model of Gleason in which each species is distributed independently and no clear 'communities' are apparent.

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Communities and Ecosystems

The Ecosystem

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Ecosystem

- **If we include environmental features, including the underlying soil, the water, and the atmosphere and surrounding vegetation**
- **More complex, interactive system that is called the**

Communities and Ecosystems

Ecosystem

- **The concept of the ecosystem can be applied at various levels.**
- **The entire Earth can be viewed as an enclosed ecosystem, but so can a lake, a forest, a stream or even a clump of grass.**

Communities and Ecosystems

Ecosystem

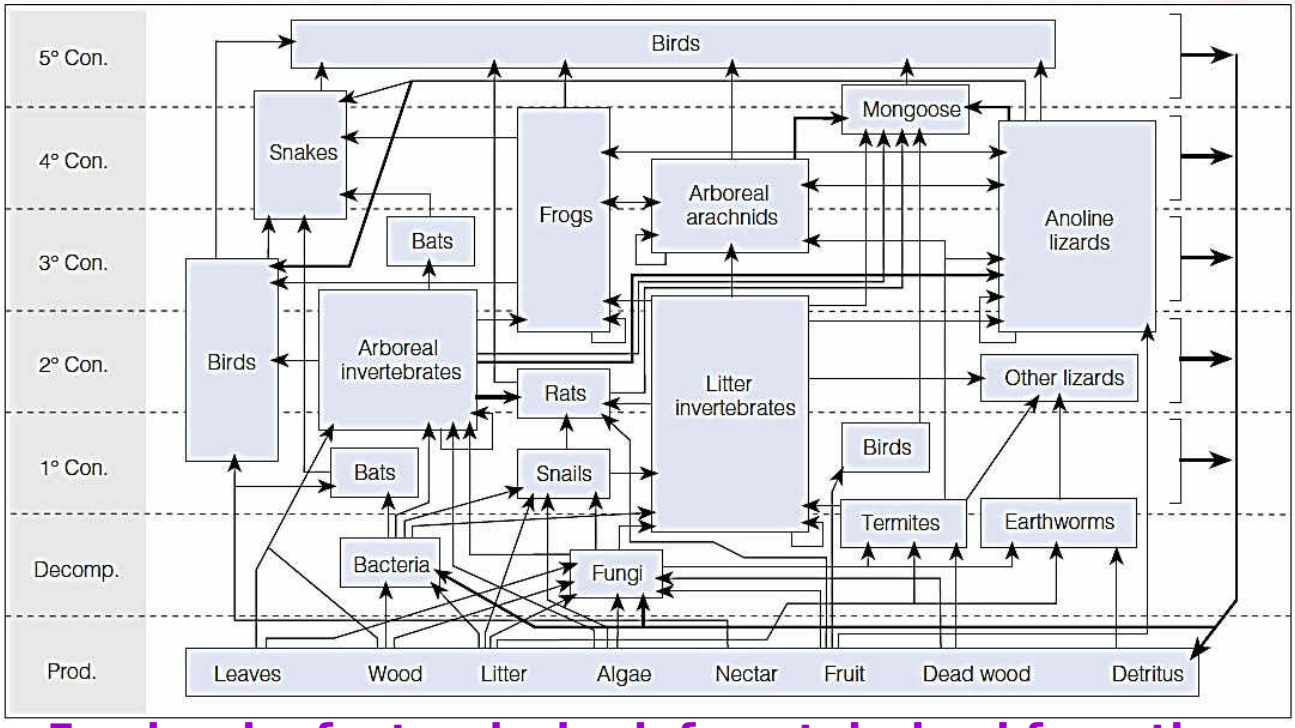
- **Two fundamentals underlying the ecosystem concept**
- **Energy flow and nutrient cycling.**
- **Energy is fixed from solar radiation into a chemical form by green plants**

Communities and Ecosystems

Feeding Relationships

- **We can classify all the organisms in any community in terms of their feeding relationships.**
- **In practice, a series of complex feeding webs are usually formed, relating each species to many others**

Communities and Ecosystems



Food web of a tropical rainforest derived from the observations of *Reagan* and *Waide* at El Verde, PuertoRico

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Movements of Elements

- **Occurs between ecosystems**
- **Hydrological cycle plays a major role in both delivering and removing elements to and from ecosystems.**
- **Gradual degradation of rocks, weathering**

Communities and Ecosystems

The Ecosystem Concept

- **Involves all the complexity of species interactions within the system, but views these in relation to the processes in which the ecosystem is engaged, including**

Communities and Ecosystems

The Ecosystem Concept

- **Very useful in the assistance it provides in understanding the relationships between organisms and the interactions with the environment**
- **Gives us a basis for the rational use of natural resources for**

END

Communities and Ecosystems

Ecosystems and Species Diversity

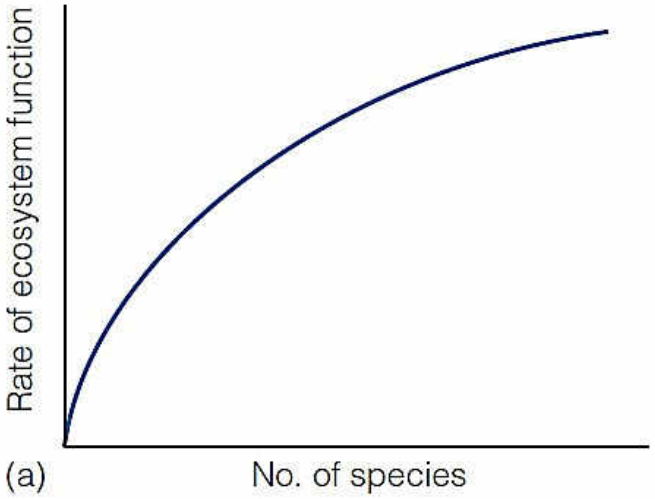
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Redundant Species Hypothesis

- **Removal of certain species from an ecosystem would have little or no effect on the functioning of that ecosystem**

Communities and Ecosystems

The possible relationships between the number of species in an ecosystem and its rate of function



(a) Redundant species hypothesis, where at high species density some species can be lost without affecting ecosystem function.

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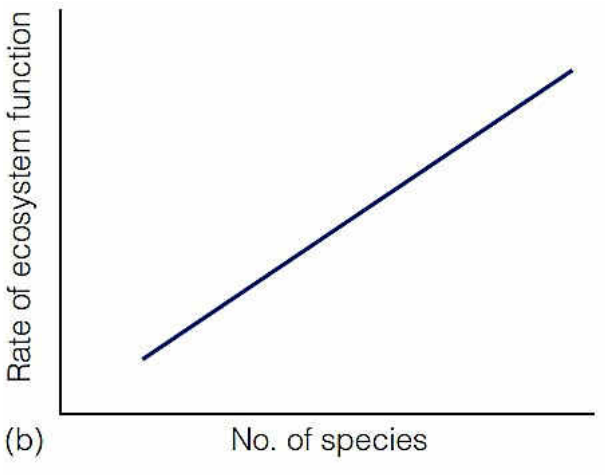
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Linear Relationship Model

- **A possible alternative model is based on the supposition that all species are equally important to ecosystem function,**
- **In which case the loss of each species renders it a little less**

Communities and Ecosystems

The possible relationships between the number of species in an ecosystem and its rate of function



(b) Linear model, in which every species is equal in functional importance and the loss of any species reduces the efficiency of ecosystem function accordingly.

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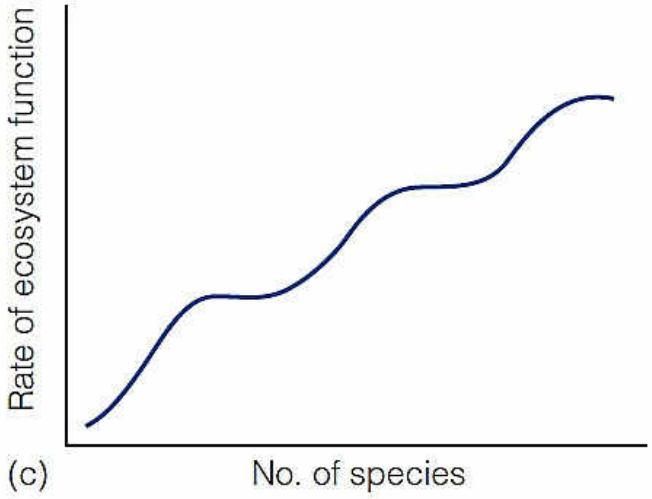
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The Rivet Hypothesis

- **A third option, is that certain species play key roles in the ecosystem, and when they are lost there is a sudden drop in the capacity of the ecosystem to function.**
- **This is sometimes referred to as**

Communities and Ecosystems

The possible relationships between the number of species in an ecosystem and its rate of function



Rivet hypothesis, in which certain species are critical in supporting ecosystem function (rivets). Loss of these species has a disproportionate effect on ecosystem function.

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Functional Types

- **The roles that species play within an ecosystem can vary in importance to general ecosystem function, and it is possible to divide species into functional types according to their**

Communities and Ecosystems

Stability

- **British ecologist *Charles Elton* first proposed (in the 1950s) that a more complex and rich ecosystem should also be more stable,**
- **Less prone to violent fluctuations such as those caused by**

Communities and Ecosystems

Stability

- **Defined in terms of inertia, or resistance to change.**
- **A stable ecosystem could be defined as one which rapidly returns to its original state following disturbance.**
- **The concept of**

END

Communities and Ecosystems

Biotic Assemblages on a Global Scale

Communities and Ecosystems

Biotic Assemblages

- **A general classification of terrestrial, large-scale ecosystems**
- **First based simply on vegetation, called formations,**
- **Animal life: included in descriptions**

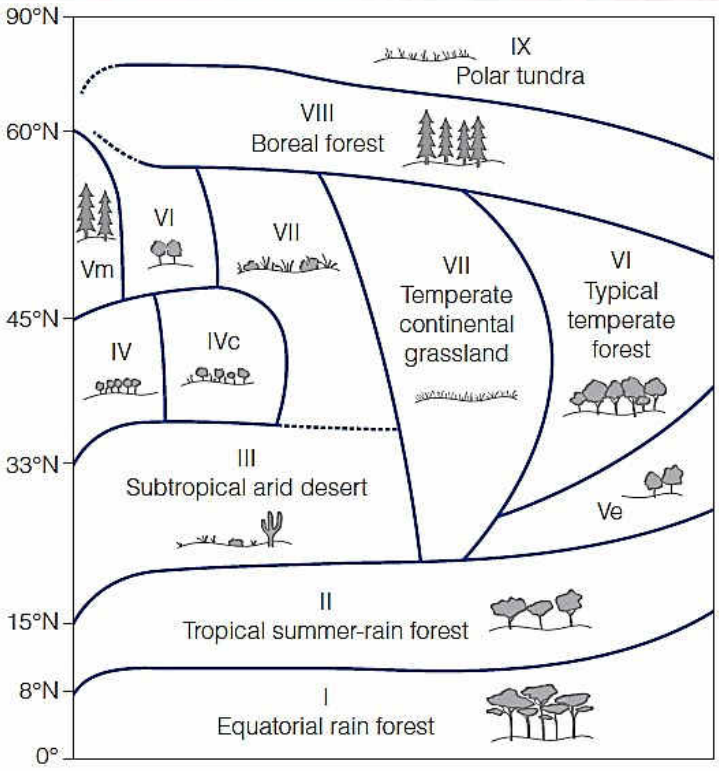
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Raunkiaer

- **The concept of a life form among plants,**
- **He analyzed the flora of different parts of the world into component functional types and found that each region had its own distinctive**

Communities and Ecosystems

An idealized Northern Hemisphere continent showing the pattern of climate and biome types over its surface.



IV, Mediterranean forest/scrub (maritime and continental forms). Vm, (West coast) temperate rainforest. Ve, (East coast) warm temperate forest. VI, Temperate forest.

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Climatic Envelope

- **Each biome is said to fit within a certain climatic envelope, i.e. the sum of all the climatic variables that limit that biome.**
- **A refinement of conventional biome**

Communities and Ecosystems

Ian Woodward

- **Proposed the classification of these vegetation types**

1. **Evergreen needleleaf forests – tall (over 2 m high), dense (over 60% cover) forests of evergreen trees with narrow**

Communities and Ecosystems

2. **Evergreen broadleaf forests – tall, dense forests of evergreen trees with broad leaves (e.g. tropical rainforests).**
3. **Deciduous needleleaf forests – tall, dense forests of narrow-leaved**

Communities and Ecosystems

4. Deciduous broadleaf forests – tall, dense forests of broad-leaved trees that seasonally lose their leaves (e.g. beech, maple, some oaks).
5. Mixed forests – tall, dense forests with an

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6. Woody savannas – trees > 2 m high, cover only 30–60% of the land surface; with herbaceous vegetation.
7. Savanna – trees >high, widely scattered, covering only 10%-30% of the surface, rest is

Communities and Ecosystems

8. **Grasslands – land with herbaceous cover and with less than 10% tree or shrub cover.**
9. **Closed shrublands – lands with woody vegetation less than 2 m tall and with a**

Communities and Ecosystems

10. **Open shrublands – lands with woody vegetation (evergreen or deciduous) less than 2 m tall and with a shrub cover of between 10% and 60%.**

END

- **Objective advantage:**

Communities and Ecosystems

Global Patterns of Climate

Communities and Ecosystems

Climate

- **The climate of an area consists of the whole range of weather conditions experienced within that area, including temperature, rainfall, evaporation, sunlight and**

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Factors Determining Climate

- **Particularly latitude, altitude and location in relation to oceans and land masses.**
- **The climate is a very important factor in determining the species of plants and animals, and even the life**

Communities and Ecosystems

Latitude

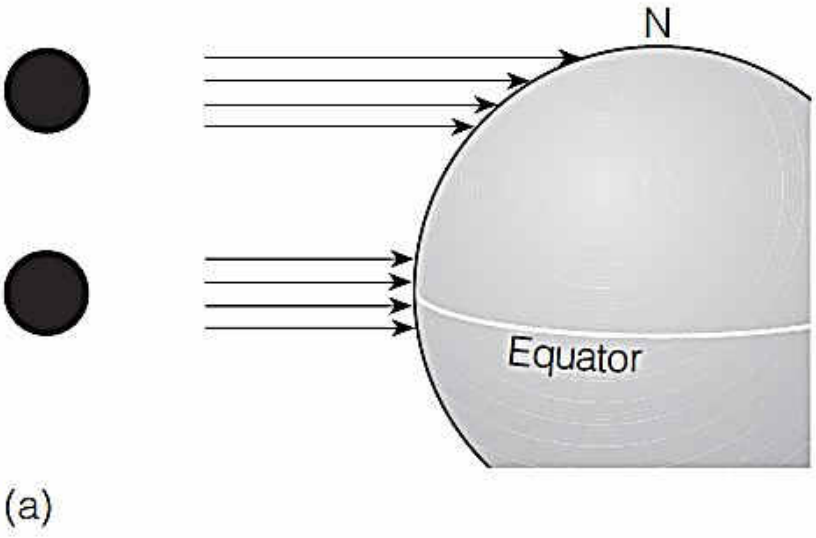
- **Climate varies with latitude**
- **The spherical form of the Earth results in an uneven distribution of solar energy with respect to latitude.**
- **In the high latitudes, energy is spread over a**

Communities and Ecosystems

Latitude

- **As the angle of incidence of the sun's rays approaches 90°, the area over which the energy is spread becomes smaller, so that there is an increased heating effect.**

Communities and Ecosystems



Causes of global patterns of climate.

(a) Due to the spherical shape of the Earth, polar regions receive less solar energy per unit area than the equatorial regions.

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Communities and Ecosystems

Latitude

- **The precise latitude that receives sunlight at 90° at noon varies during the year; it is at the equator during March and September, at the Tropic of Cancer (23°28′N) during June and at the Tropic of**

Communities and Ecosystems

Latitude

- **The effect of this seasonal fluctuation is more profound in some regions than in others, with the greatest contrasts experienced at high latitudes.**

Communities and Ecosystems

Movement of Air Masses

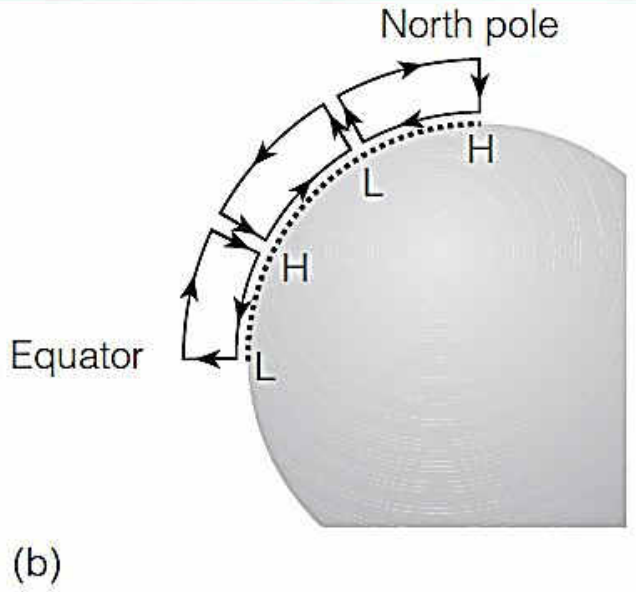
- **Variations in climate also result from the pattern of movement of air masses**
- **Air heated most strongly over the equator and therefore rises (causing a low-pressure area) and moves**

Communities and Ecosystems

Movement of Air Masses

- **Air moves towards the pole & gradually cools & increases in density until it descends, where it forms a subtropical region of high pressure, known as the Horse Latitudes.**
- **Air then either**

Communities and Ecosystems



Causes of global patterns of climate.

(b) The major patterns of circulating air masses (cells) in the Northern Hemisphere: H, high pressure; L, low pressure.

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Communities and Ecosystems

END

Movement of Air Masses

- **This simplified and idealized picture is complicated by the *Coriolis effect* (named in honour of the French mathematician Gaspard Coriolis, who analyzed it), which is a consequence of the west- east**

Global Patterns of Climate Part 2

Communities and Ecosystems

Movement of Air Masses

- **The simplified and idealized picture is complicated by the *Coriolis effect* (named in honour of the French mathematician Gaspard Coriolis, who analysed it), which is a consequence of**

Communities and Ecosystems

Movement of Air Masses

- **This spinning force tends to deflect any freely moving object to the right of its course in the Northern Hemisphere and to the left in the Southern Hemisphere.**

Communities and Ecosystems

Movement of Air Masses

- **As a result, the winds moving toward the equator in both hemispheres are deflected and consequently blow from east to west.**

Communities and Ecosystems

Movement of Air Masses

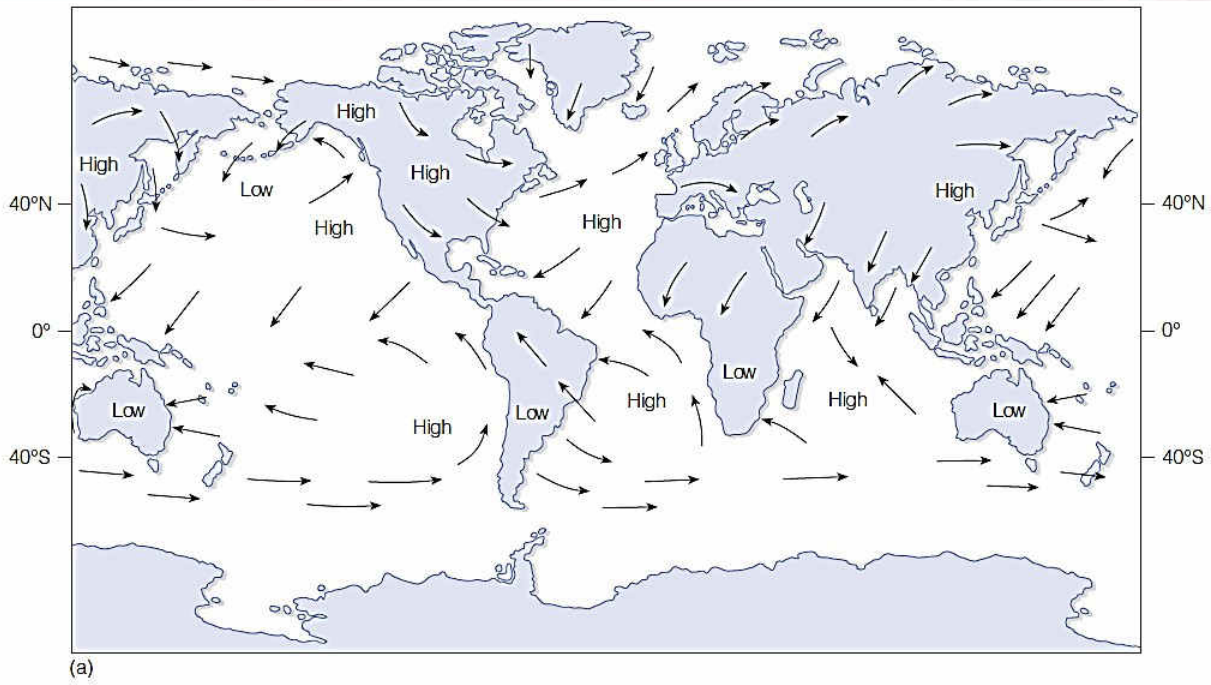
- **The ‘trade winds’, found in both the Northern and Southern Hemispheres, meet in the region of the equator, and this is known as the intertropical convergence zone (ITCZ).**

Communities and Ecosystems

Movement of Air Masses

- **In the Northern Hemisphere summer, strong southerly winds are generated in the Indian Ocean, carrying warm, moist air into India and East Africa.**
- **These winds bring the monsoon rains**

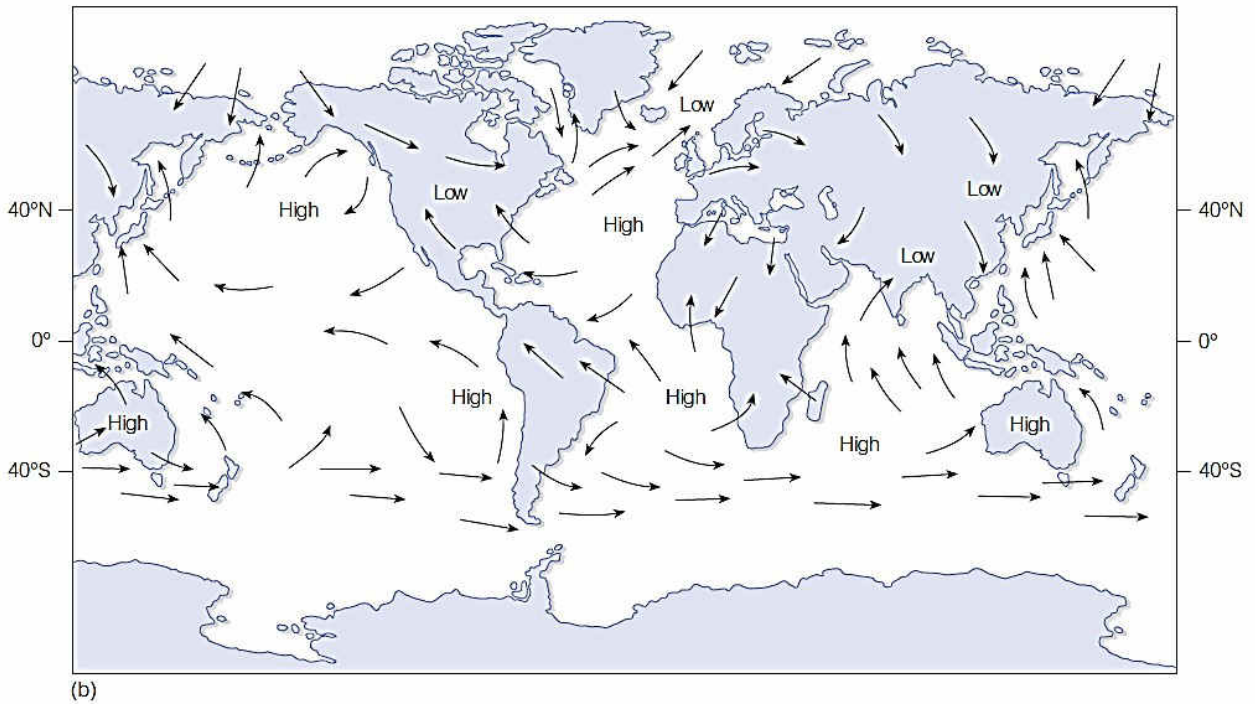
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General pattern of areas of high and low pressure across the Earth's surface, and the consequent patterns of movement of air masses: in January

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General pattern of areas of high and low pressure across the Earth's surface, and the consequent patterns of movement of air masses: in July.

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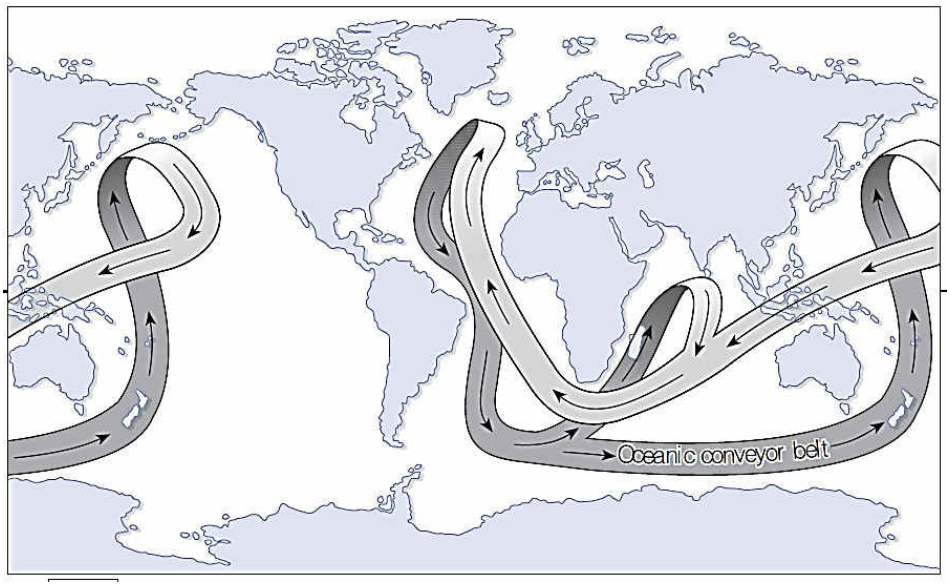
Communities and Ecosystems

Global Pattern of Oceans And Land Masses

- **Modifies the climatic patterns yet further.**
- **The global circulation patterns of water within the oceans are also of great importance in determining**

END-1

Communities and Ecosystems



The oceanic conveyor belt. carrying warm, low-salinity surface waters northwards into the North Atlantic and deep, higher salinity cold waters from west to east into the Indian Ocean and the Pacific. From here, water receives a renewal of its heat content, rises to the surface and returns westward into the Atlantic.

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Patterns of Biodiversity

Biodiversity

Patterns of Biodiversity

Biodiversity

- **Biodiversity is an expression of the great variety of living things on our planet, but it is far more than a simple count of species.**
- **We take a species and analyze its composition, we find that it**

Patterns of Biodiversity

Metapopulation

- **A fragmented population**
- **Isolated populations are genetically distinct and can be classified as subspecies, but even within single populations there is often great variation**

Patterns of Biodiversity

How many Species?

- **Many species are difficult to identify**
- **The numbers of expert scientists in the field of taxonomy are relatively few**
- **The task of counting species is much more difficult to**

Patterns of Biodiversity

How many Species?

- **The convenient idea that two species cannot interbreed is not actually workable because it is often found that interbreeding is possible between several animal and plant species that are morphologically**

Patterns of Biodiversity

How many Species?

- **Undoubtedly many species yet to be discovered,**
- **Approximately 1.8 million species of organism that have been described**
- **Many may have been described and named**

Patterns of Biodiversity

How many Species?

- **The diversity of microbes (bacteria, fungi, viruses etc.) is difficult to estimate,**
- **Not as well known as the mammals or the flowering plants.**
- **Of the bacteria, only about 4000 species have so**

Patterns of Biodiversity

Group	Number of described species	Likely total	%
Insects	950 000	8 000 000	12
Fungi	70 000	1 000 000	7
Arachnids	75 000	750 000	10
Viruses	5000	500 000	5
Nematodes	15 000	500 000	3
Bacteria	4000	400 000	1
Vascular plants	250 000	300 000	83
Protozoans	40 000	200 000	20
Algae	40 000	200 000	20
Molluscs	70 000	200 000	35
Crustaceans	40 000	150 000	27
Vertebrates	45 000	50 000	90

The numbers of described species in selected groups of organisms, together with the likely total numbers on Earth, and the percentage of the group that is currently known. Data from Groombridge.

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How many Species?

- **Extinction is occurring all around us.**
- **The biologist Edward O. Wilson has calculated that the loss of species from the tropical forest area alone could currently be as high as 6000 species per year**

END

Patterns of Biodiversity

Latitudinal Gradients of Diversity

Patterns of Biodiversity

Latitudinal Gradients

- **The distribution of biodiversity over the land surface of the planet is far from even.**
- **The tropics contain many more species, of both plants and animals, than an equivalent area of the higher**

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Numbers of breeding birds and mammal species in different parts of Central and North America.



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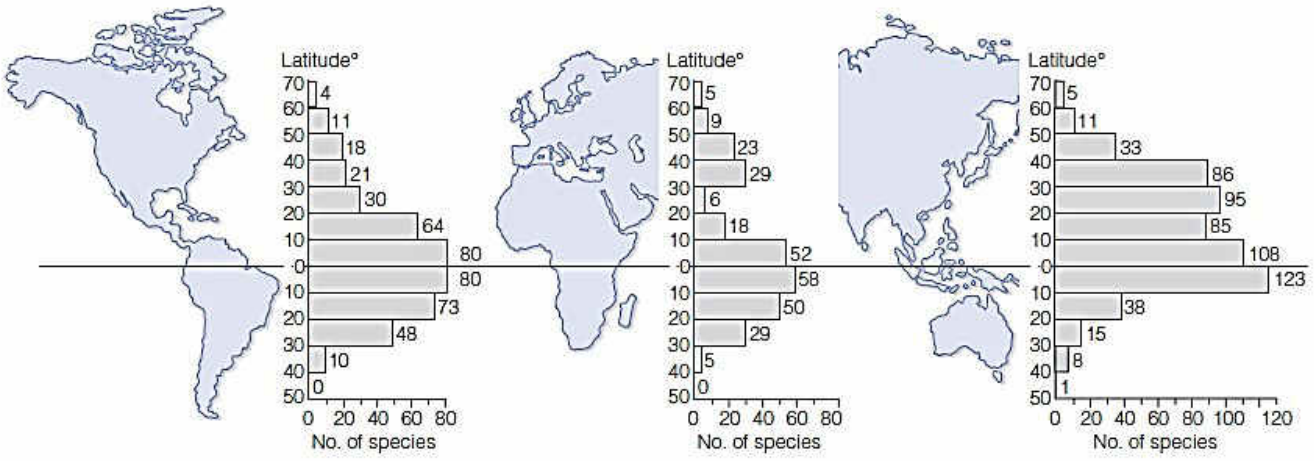
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Numbers of species of frog in different parts of Central and South America. Data from Groombridge

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Latitudinal gradients of species richness for swallowtail butterflies in three different parts of the world. Data from Collins and Morris

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Latitudinal Gradients

- **Regions with the highest evapotranspiration are able to support the highest diversity of tree species.**
- **Evapotranspiration itself also correlates closely with the potential productivity of a**

Patterns of Biodiversity

Latitudinal Gradients

- **In general, the equatorial regions are the areas in which highest productivity is possible because of the prevailing climate, which is hot, wet and relatively free from seasonal**

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Energy Hypothesis

- **Latitudinal gradient of species diversity suggests that the critical factor is how much energy is captured by the vegetation.**

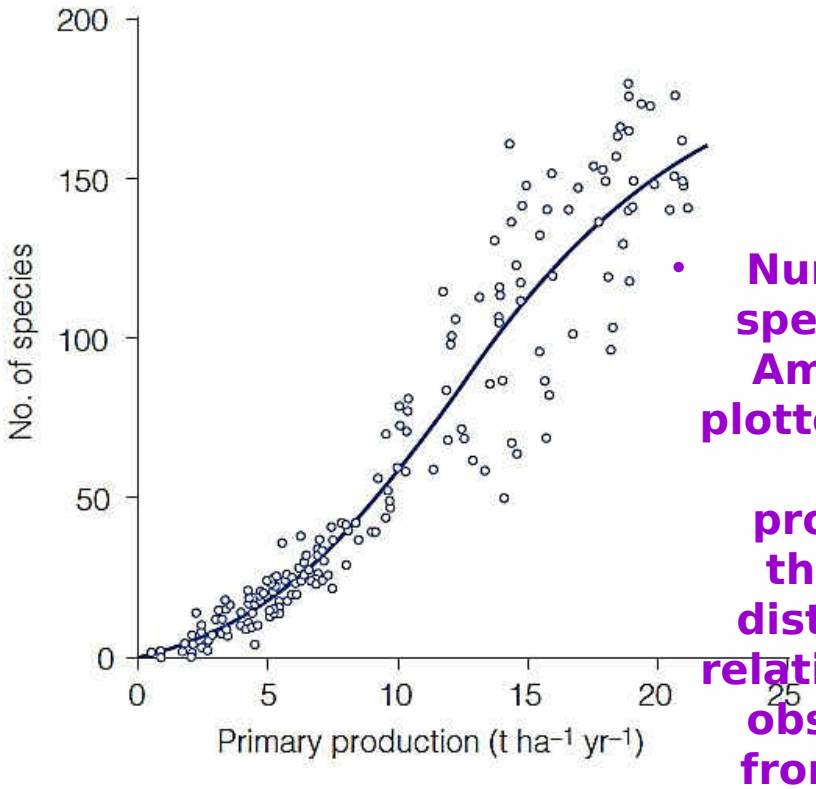
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Metabolic theory

- **Higher biomass and more complex vegetation architecture to host more animals.**
- **Warm moist climates in which high productivity occurs can also lead to greater**

END-1

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- **Number of tree species in North American sites plotted against the primary productivity of those sites. A distinct positive relationship can be observed. Data from Currie and Paquin**

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Is Evolution Faster in the Tropics?

Patterns of Biodiversity

Evolution

- **Evolution, the process by which new species are generated**
- **It essentially involves genetic variation and subsequent selection of the most suitable genetic combinations within a**

Patterns of Biodiversity

Evolution

- **Whether evolution proceeds more rapidly under tropical conditions.**
- **If it does, then the richness of the tropics could simply be due to the continual**

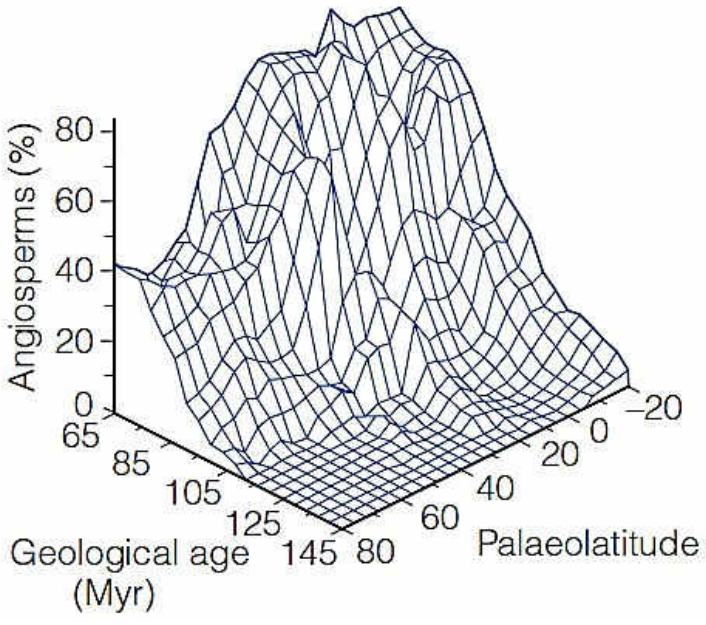
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Evolution

- **Whether the tropics have acted as a centre of evolution for groups of organisms in the past?**
- **Plants and their fossils provide a useful group in which to investigate this**

Patterns of Biodiversity

Estimated percentage representation of flowering plants (angiosperms) at different times in geological history and at different latitudes. Angiosperms have always been most abundant in the low-latitude (tropical) regions. From Crane and Lidgard



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Metabolic Theory

- **In an environment where energy is abundant and temperature is consistently high, such as the tropics, metabolic rates in organisms tend to be faster. Fecundity is**

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Ultraviolet Radiation

- **Generally greater in the tropics, and this can increase mutation rates.**
- **There is a positive feedback in that the new varieties are in competition with one another, leading to an**

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High Diversity

- **Regions with high diversity exhibit a faster rate of diversification.**
- **Argument is circular**
- **External factors likely to create the required environment for enhanced diversification**

Patterns of Biodiversity

High Biomass

- **Jonathan Davies & his colleagues from I.College London and from Kew Gardens**
- **Accumulation of species was indeed faster in regions of high biomass**
- **Either of speciation being**

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END

Energy–biomass Model

- **Energy–biomass model remains the most robust explanation currently available for latitudinal gradients in diversity.**
- **There remain, however, additional factors that**

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Regards : Zarva Chaudhary

Admin:

* Zarva Chaudhary *

Chaudhary Moazzam

* Laiba Mahi *

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The Legacy of Glaciation

Patterns of Biodiversity

Extinctions Rates

- **Fast rate of speciation in the tropics : increased biodiversity, less extinction rates**
- **Greater extinction rates in the higher latitudes is the instability of climatic conditions over**

Patterns of Biodiversity

Earth's Climate

- **Constantly changing**
- **Considerably colder over the past 2 million years than was the case for the previous 300 million years**
- **A high amplitude of variation between warm and cold**

Patterns of Biodiversity

Earth's Climate

- **During cold episodes, the high latitudes have been disrupted by the development of glaciers over the land surface.**
- **Biogeographical patterns of plants and animals were**

Patterns of Biodiversity

Stable Tropics

- **This idea of a climatically stable tropical belt, if it is indeed true, could account for some of the diversity still found in the tropics as the plants and animals could be a relic accumulation**

Patterns of Biodiversity

Equatorial Forests

- **Had to endure less disturbance than their temperate counterparts,**
- **Maintained themselves in a forested form during the period of stress**
- **Their species composition and architectural**

Patterns of Biodiversity

Equatorial Forests

- ***Uninterrupted forest hypothesis of Colinvaux.***
- **It is reasonable to conclude, therefore, that many factors contribute to the species richness of the tropical regions and the lower**

END

Patterns of Biodiversity

Latitude and Species Ranges

Patterns of Biodiversity

Ranges & Latitudes

- **High-latitude organisms have broader geographical ranges than those from the low latitudes.**
- **General feature of biogeography first pointed out by *E.H. Rapoport* in the 1970s**

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Ranges & Latitudes

- **There remains doubt as to whether this is a local effect that only makes itself felt in more northerly latitudes (above about 40–50°N), or whether it continues to be**

Patterns of Biodiversity

Ranges & Latitudes

- **Klaus Rohde of Armidale, Australia, considers that *Rapoport's rule* is of local application only and cannot be applied in the tropical regions.**
- **Broad-range species in the high latitudes: successive**

Patterns of Biodiversity

Ranges & Latitudes

- **Greater seasonal fluctuations of the high latitudes will select for wide-tolerance organisms.**
- **Detailed testing has failed to support a global relationship between latitude or**

Patterns of Biodiversity

Ranges & Latitudes

- **Katherine Smith and James Brown examined the diversity of fish as one proceeds deeper**
- **Species of greater depth have wider tolerance**
- **species tolerating more extreme conditions tend**

Patterns of Biodiversity

Ranges & Latitudes

- **Although the Rapoport effect has proved more restricted in its application than was originally anticipated, it provides an excellent example of the kind of question that biogeographers**

Patterns of Biodiversity

Ranges & Latitudes

- **Ecological questions within a much larger scale framework of space and time.**
- **James Brown of the U. of New Mexico has coined the term macroecology to cover this approach to biogeographical**

END

Patterns of Biodiversity

Diversity and Altitude

Patterns of Biodiversity

Altitude

- **Patterns of vegetation and hence of biomes are generally related to latitude, and these are broadly repeated with respect to altitude, with higher altitudes often bearing biome types**

Patterns of Biodiversity

Altitude

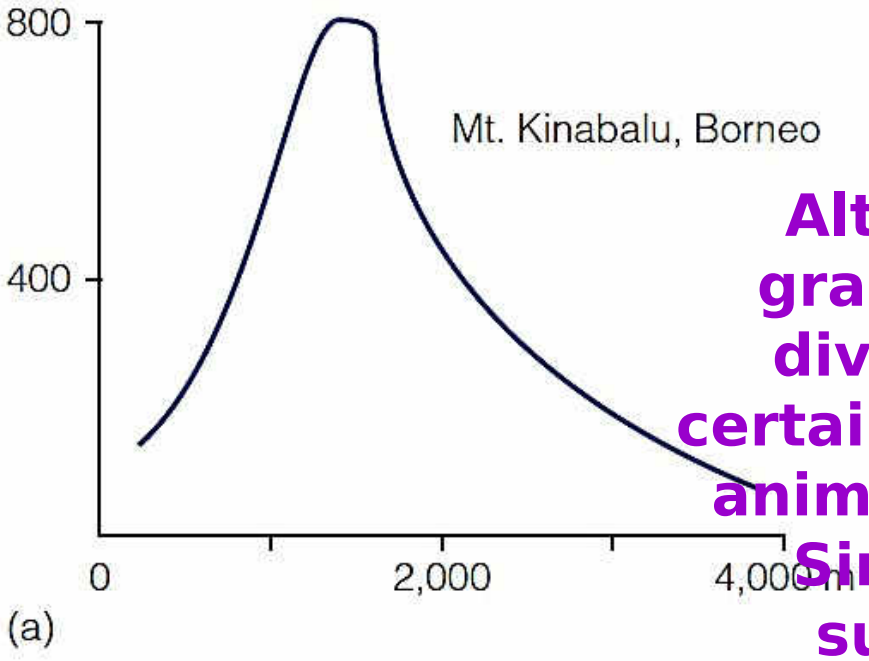
- **Many studies investigated the changes in species richness with altitude.**
- **Concentrated on tropical mountains, where the full range of climatic variation is found.**
- **Not generally conformed with**

Patterns of Biodiversity

Altitude

- **Many studies have demonstrated that the richness of species, particularly plants, increases with altitude, reaches a peak and then declines again**

Patterns of Biodiversity

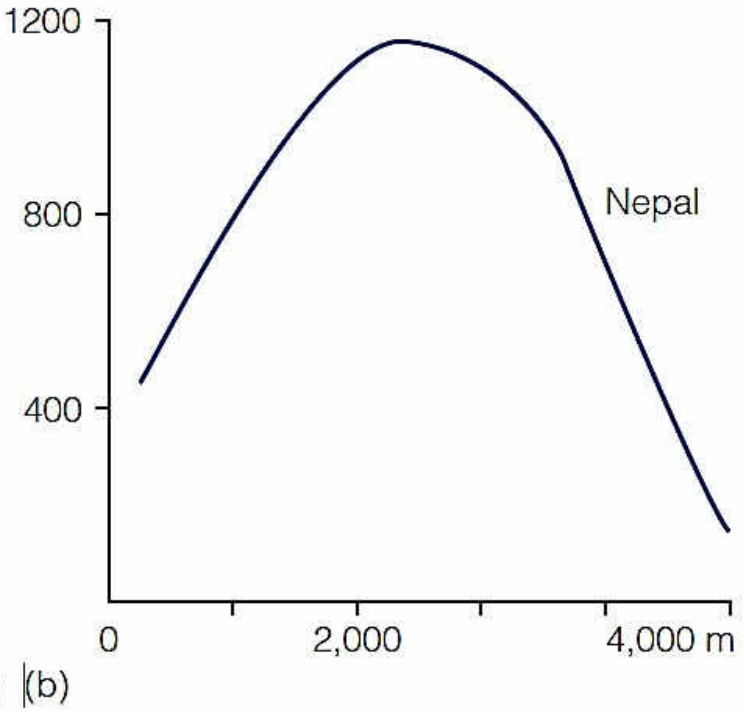


Altitudinal gradients of diversity in certain plant and animal groups. Simplified summary

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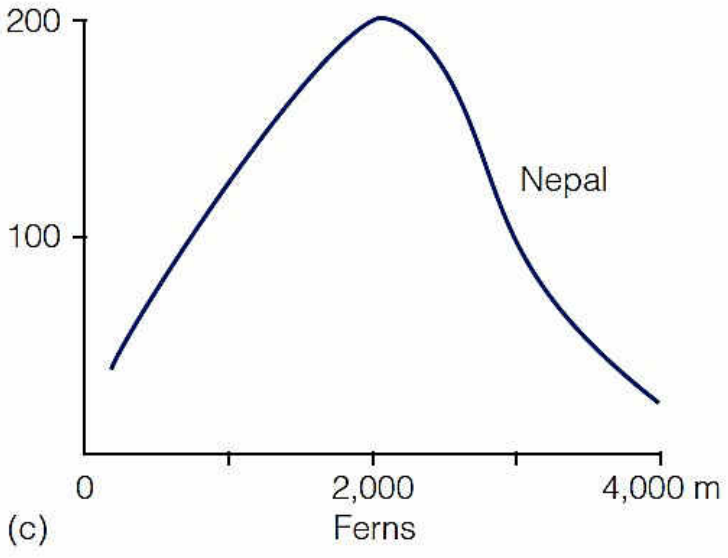
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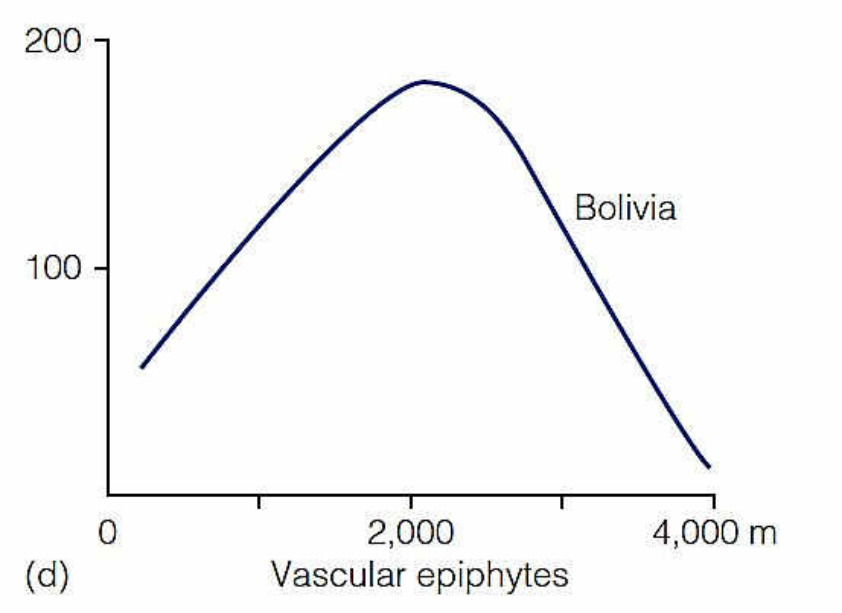
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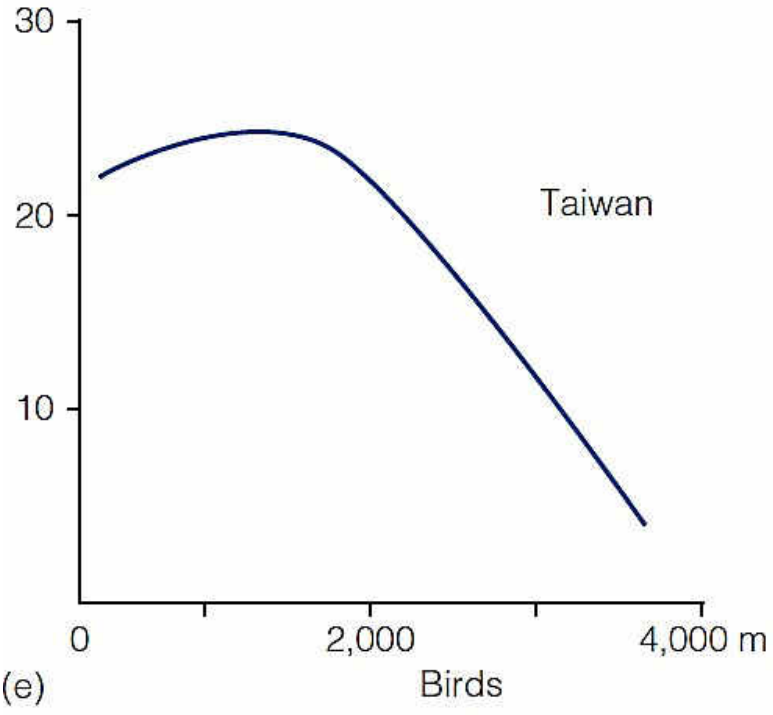
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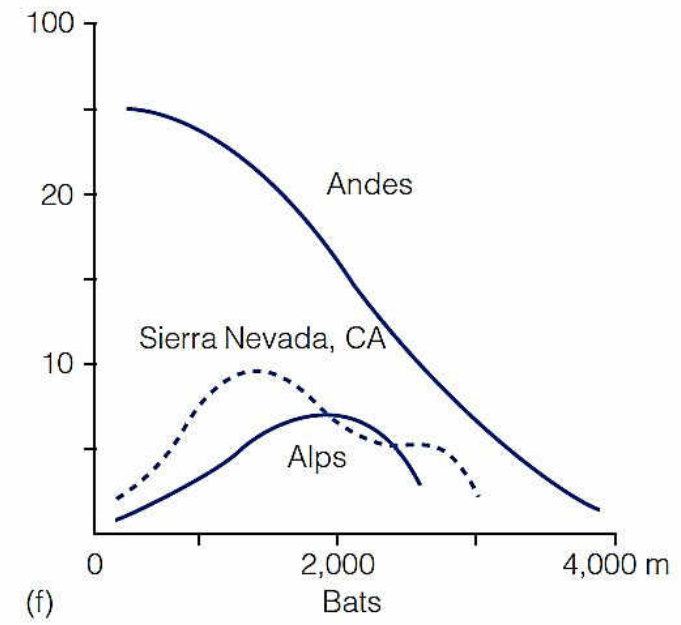
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Altitudinal gradients of diversity in certain plant and animal groups. Simplified summary



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Altitude

- **The overall conclusion regarding patterns of diversity with altitude, is that the energy model used in latitudinal studies probably holds good for many types of**

Patterns of Biodiversity

Altitude

- **The complications found in altitude patterns of diversity probably largely relate to the peculiarities of local climates in mountain regions.**

END

Patterns of Biodiversity

Biodiversity Hotspots

Patterns of Biodiversity

Species Richness

- **The Amazon basin contains approximately 90 000 flowering plant species, whereas equivalent areas in Africa and in South-East Asia contain only about 40,000 each.**

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Biodiversity Hotspots

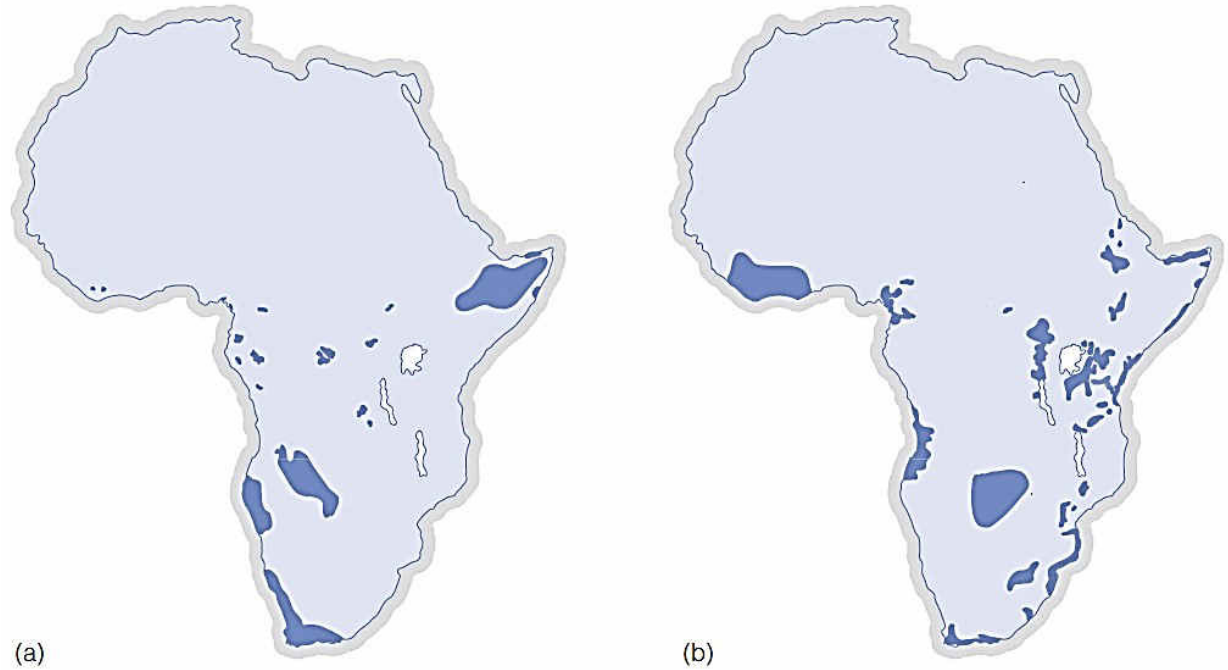
- **There appear to be certain areas of the world that are exceptionally rich in species, termed biodiversity hotspots by the conservationist *Norman Myers***
- **Originally**

Patterns of Biodiversity

Norman Myers

- **Largely identified on the basis of plant diversity, based on the idea that if vegetation is diverse all else will follow.**
- **Not always true**
- **The areas of high plant diversity in Africa compared with areas of**

Patterns of Biodiversity



The areas of Africa that are particularly rich in (a) plant species, compared with those areas that are rich in (b) endemic birds. As can be seen, the two do not always correspond

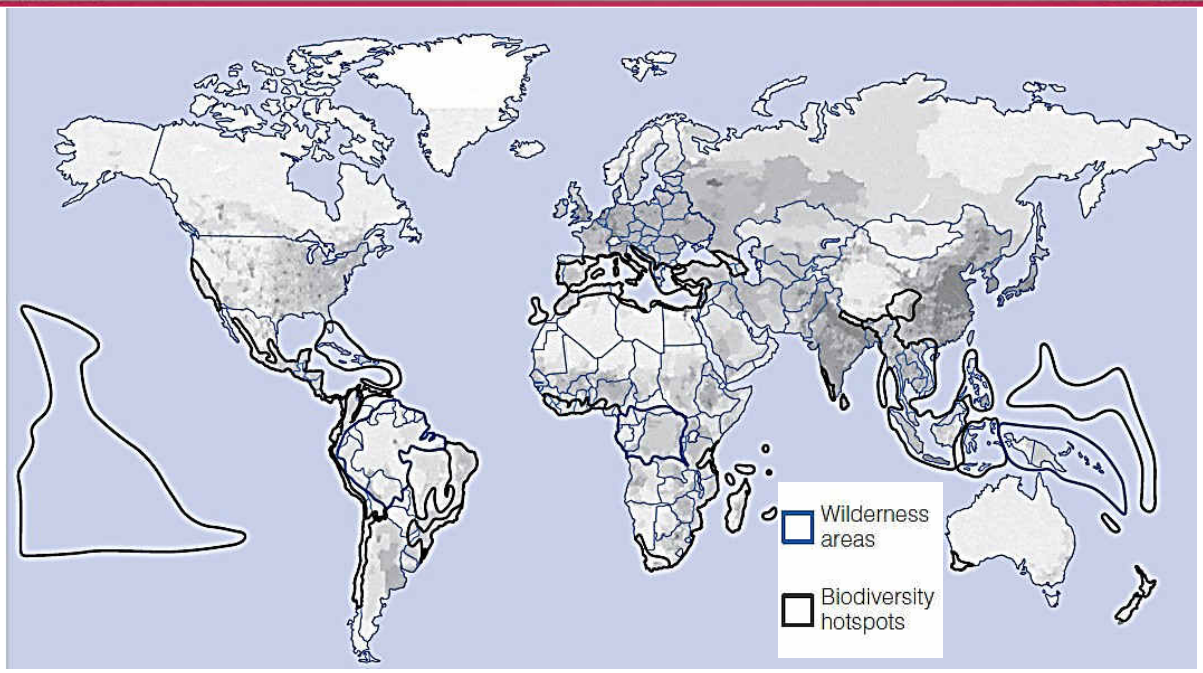
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Biodiversity Hotspots

- **The original work of Myers has been developed and expanded**
- **The location of 25 of the hottest spots for biodiversity on Earth based on a consideration of many of the better known groups of**

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The location of areas of exceptionally high biological richness (biological hotspots) in relation to human population density. From Cincotta et al.

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Biodiversity Hotspots

- **All the land surface area of the hotspots together comprise only about 1.4% of the Earth's terrestrial total**
- **Contain about 44% of the world's vascular plants and 35% of the**

Patterns of Biodiversity

Biodiversity Hotspots

- **Stuart Pimm & Peter Raven: research conservationists calculated that even if the 25 hotspots were given protection the likely extinction rate of species would be about 18%.**
- **If protection is**

Patterns of Biodiversity

Biodiversity Hotspots

- **Global richness pattern of bird species showed no significant correlation between overall richness and the richness of endemic species**
- **Biological diversity & human population**

END

Plate Tectonics

The Evidence for Plate Tectonics

Plate Tectonics

Plate Tectonics

- **The idea that continents could fragment and move across the face of the planet was first suggested by the German meteorologist *Alfred Wegener* in 1912**
- **In the 1960s, new discoveries**

Plate Tectonics

First Breakthrough

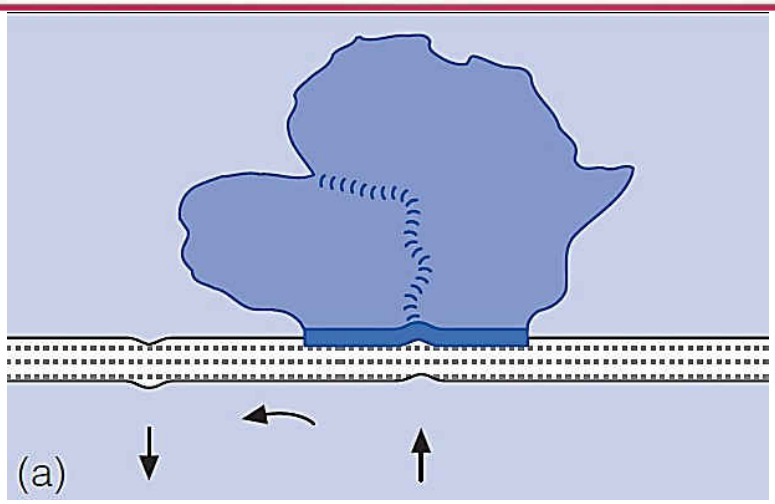
- **The invention of techniques that used the phenomenon of Palaeomagnetism.**
- **Used the presence of magnetized particles in many rocks to trace the movements of**

Plate Tectonics

Harry Hess (1962)

- **American geophysicist**
- **Suggested that the Volcanic chains were spreading ridges, where new seafloor is being formed**
- **The trenches are where old ocean floor is consumed, downward into**

Plate Tectonics

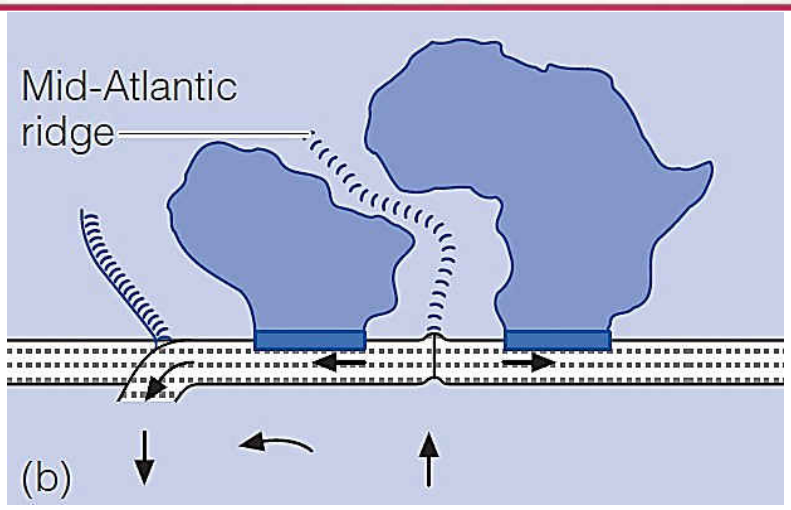


How and why South America and Africa drifted apart.

(a) The two continents were originally part of a single continent, Gondwana (the rest of which is not shown). An upward convection current from the deeper layers of the Earth appeared under them, with the corresponding downward current further to the west, in the Pacific Ocean.

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Plate Tectonics

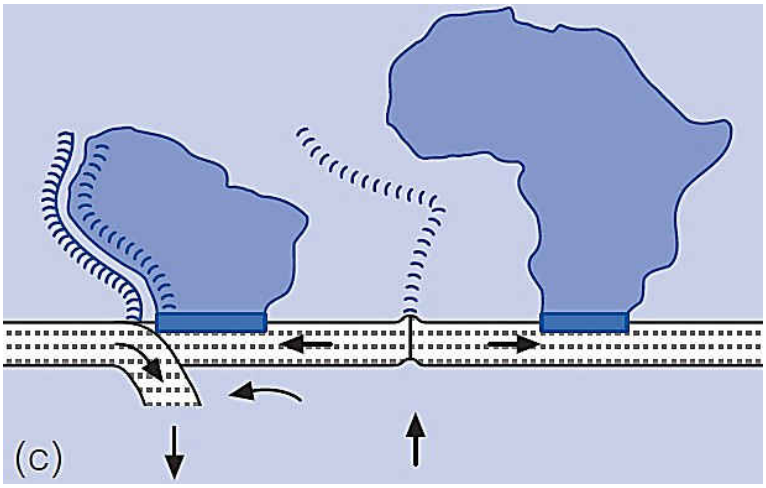


How and why South America and Africa drifted apart.

(b) The two continents moved apart, separated by the new South Atlantic Ocean. Down the centre of this runs the mid-Atlantic spreading ridge, on either side of which new ocean crust is continually created. This extension movement is balanced by the appearance, in the Pacific, of an ocean trench where old ocean crust disappears into the Earth.

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Plate Tectonics



How and why South America and Africa drifted apart.

(c) South America has moved westwards until it is adjacent to the ocean trench. To continue to balance the still-widening South Atlantic Ocean, the ocean crust that disappears into the trench is now derived from the west. This old crust now disappears below western South America, causing earthquakes and the rise of the volcanic Andes Mountains.

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Plate Tectonics

Lithosphere

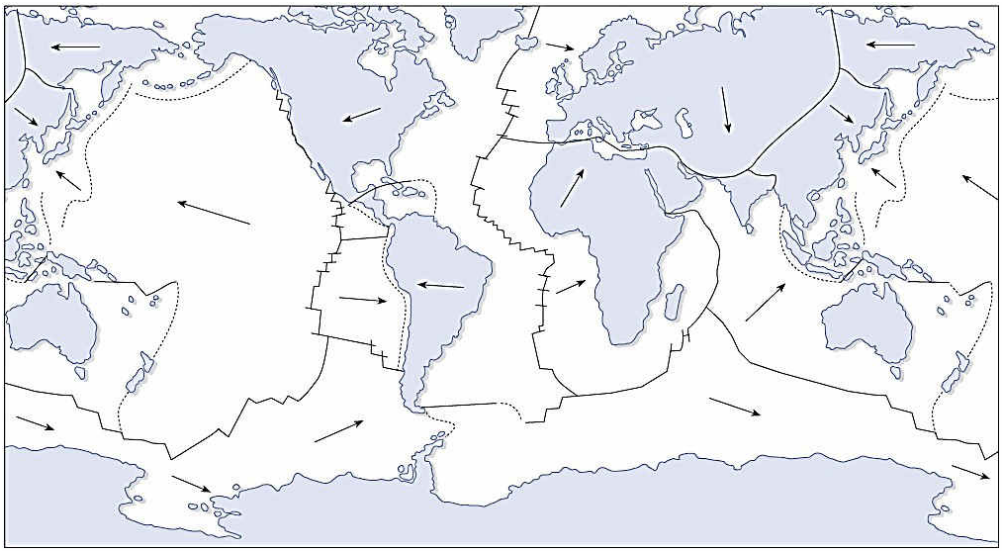
- **The surface of the Earth, known as the lithosphere, is occupied by a number of areas known as tectonic plates, which may contain continents and parts of oceans, or may consist**

Plate Tectonics

Plate Tectonics

- **The ocean floors move as well as the continents, the study of their movements is known as plate tectonics rather than continental drift.**
- **The different plates may also move past one another at**

Plate Tectonics



The major tectonic plates.

Lines within the oceans show the positions of spreading ridges: dotted lines indicate the positions of trenches. Lines within the continents show the divisions between the different plates. Arrows indicate the directions and proportionate speeds of movement of the plates. The Antarctic plate is rotating clockwise

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Plate Tectonics

END

Plate Tectonics

- **All this evidence for the theory of plate tectonics was so overwhelmingly convincing that it quickly gained general acceptance by biogeographers during the**

Plate Tectonics

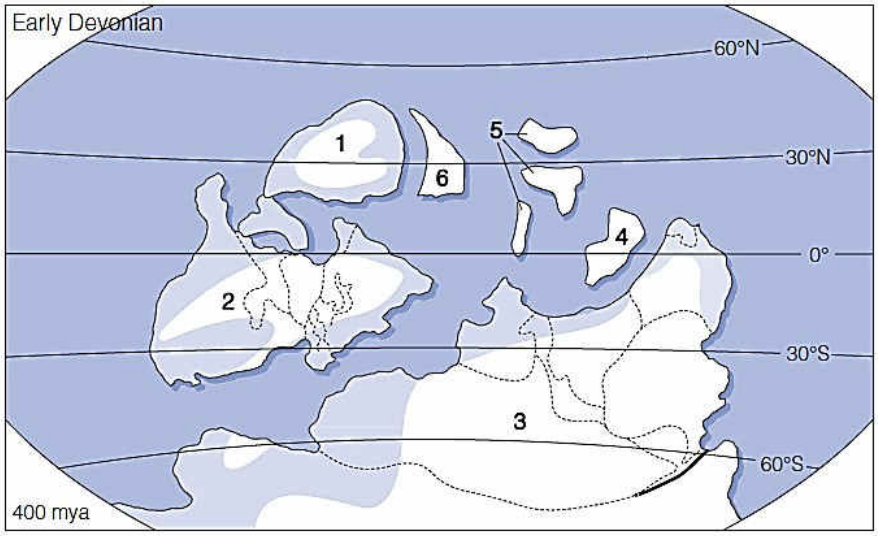
Changing Patterns of Continents

Plate Tectonics

Gondwana

- **In the middle of the Palaeozoic, 400 mya, a large landmass that we call Euramerica, lay across the equator.**
- **To its south lay a great continent known as Gondwana, a huge area of**

Plate Tectonics



World geography at Early Devonian Tripel–Winkel projection.

Dark tint indicates ocean; epicontinental seas (light shading) after Smith et al. Dotted lines indicate modern coastlines. Continental positions after Metcalfe (1)Siberia; (2) Euramerica; (3) Gondwana; (4) southern China; (5) northern China; (6) Kazakhstan.

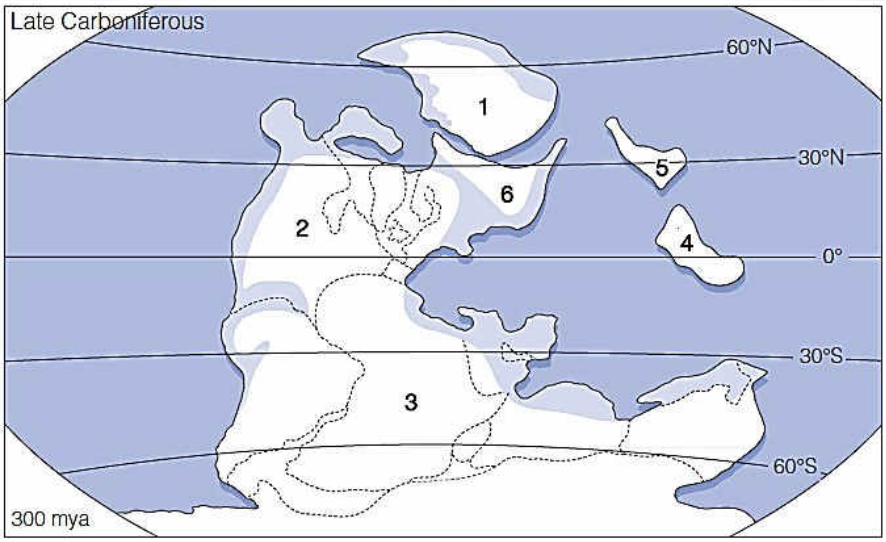
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Plate Tectonics

Gondwana

- **Antarctica ,Sout h America, Africa, Australia and India.**
- **Gondwana and Euramerica, joined together (340 mya)**
- **About 295 mya, the resulting supercontinent was joined by two other Northern**

Plate Tectonics



World geography at Late Carboniferous Tripel–Winkel projection.

Dark tint indicates ocean; epicontinental seas (light shading) after Smith et al. Dotted lines indicate modern coastlines. Continental positions after Metcalfe (1)Siberia; (2) Euramerica; (3) Gondwana; (4) southern China; (5) northern China; (6) Kazakhstan.

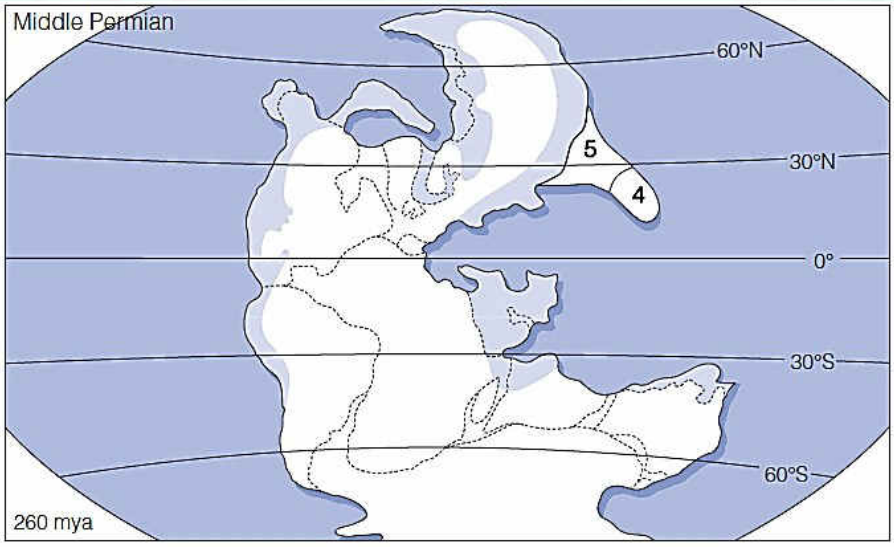
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Plate Tectonics

Pangea(260 mya)

- **Joined by a number of smaller fragments (including north China, south China, Tibet, Indochina and South-East Asia) that had split off from the northern edge of Gondwana and moved**

Plate Tectonics



World geography at Middle Permian: Tripel–Winkel projection.
Dark tint indicates ocean; epicontinental seas (light shading) after Smith et al. Dotted lines indicate modern coastlines. Continental positions after Metcalfe (1)Siberia; (2) Euramerica; (3) Gondwana; (4) southern China; (5) northern China; (6) Kazakhstan.

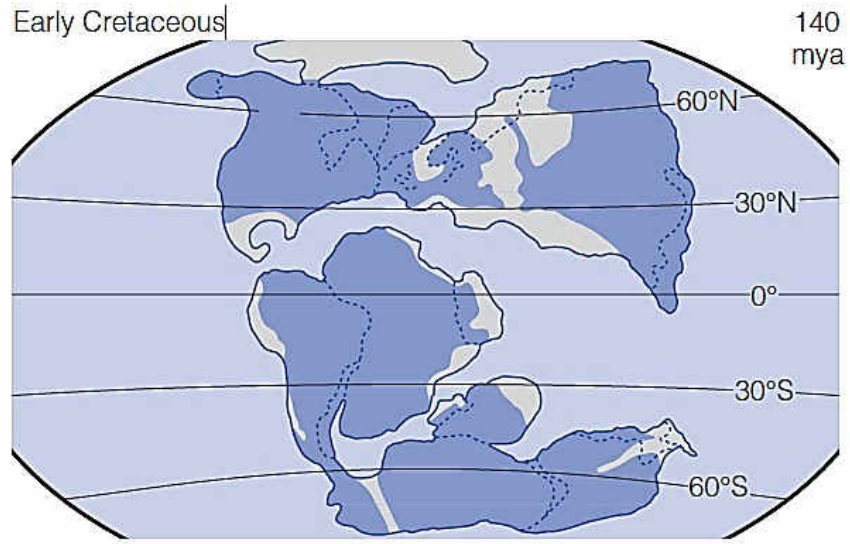
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Plate Tectonics

Pangea(160 mya)

- **Pangaea started to become divided.**
- **Gondwana separated from the northern landmass, now made up of North America and Eurasia, that we call Laurasia.**
- **The new ocean**

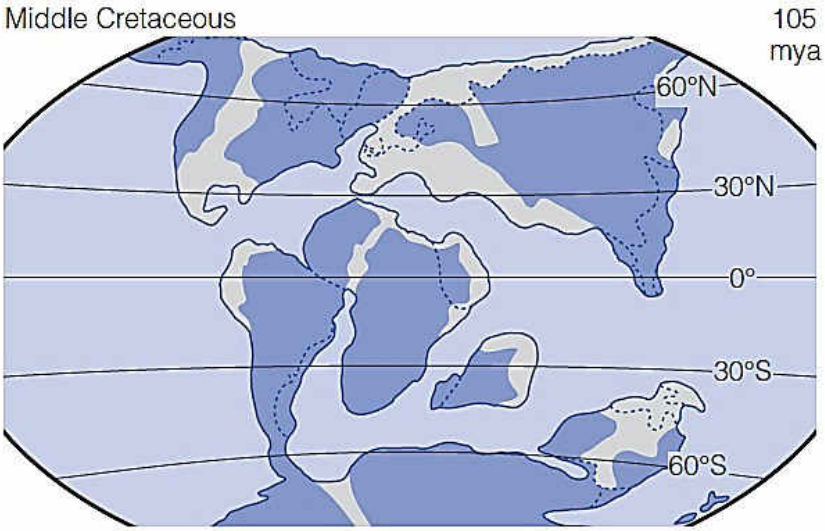
Plate Tectonics



World geography at Early Cretaceous: Tripel-Winkel projection;
outlines of epicontinental seas (light shading) after Smith et al. Dotted lines indicate modern coastlines. Continental positions after Cambridge Palaeomap Services

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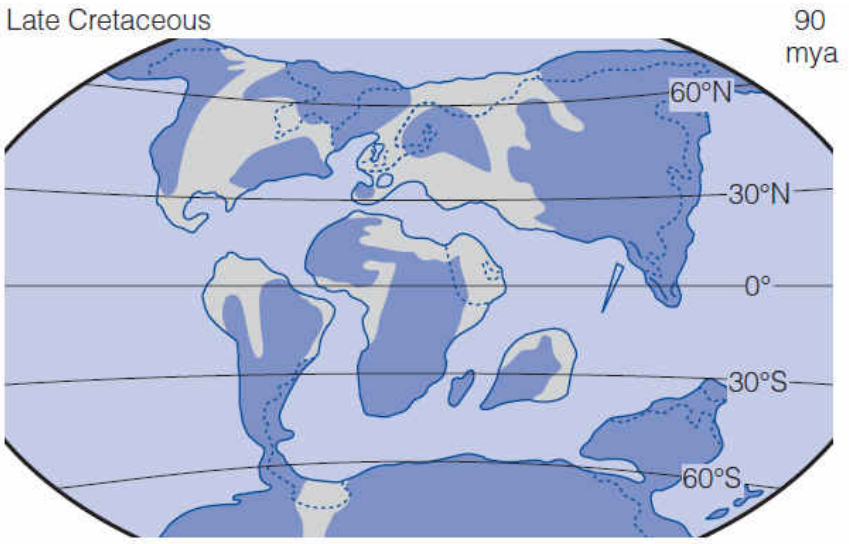
Plate Tectonics



World geography at Middle Cretaceous: Tripel-Winkel projection;
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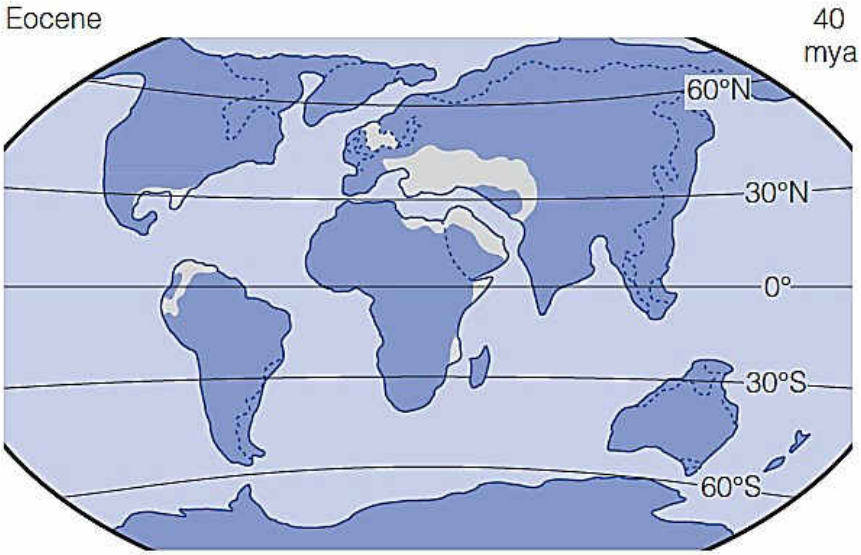
Plate Tectonics



World geography at Late Cretaceous: Tripel-Winkel projection;
outlines of epicontinental seas (light shading) after Smith et al. Dotted lines indicate modern coastlines. Continental positions after Cambridge Palaeomap Services.

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Plate Tectonics



World geography at Eocene: Tripel-Winkel projection; outlines of epicontinental seas (light shading) after Smith et al. Dotted lines indicate modern coastlines. Continental positions after Cambridge Palaeomap Services

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Plate Tectonics

Changing Earth

- **Continental movements, the expansion or contraction of shallow seas and the rise or erosion of mountain chains.**
- **The resulting changes in the relationships between their floras and**

END

Plate Tectonics

Islands and Plate Tectonics

Plate Tectonics

Islands

- **The nature of islands and the biotas that they contain are also affected by the way in which the direct or indirect effects of plate tectonics created them.**
- **These islands may be of three different types**

Plate Tectonics

Continental Islands

- **The first type of island was originally a part of a nearby continent, but it became separated from it by rising sea levels or by tectonic processes that split them away**

Plate Tectonics

Volcanic Island Arc

- **The most obvious of these are the Kurile and Aleutian island arcs that lie along the edge of the Pacific.**
- **Here, old ocean crust is being forced into the depths of the crust, and the resulting**

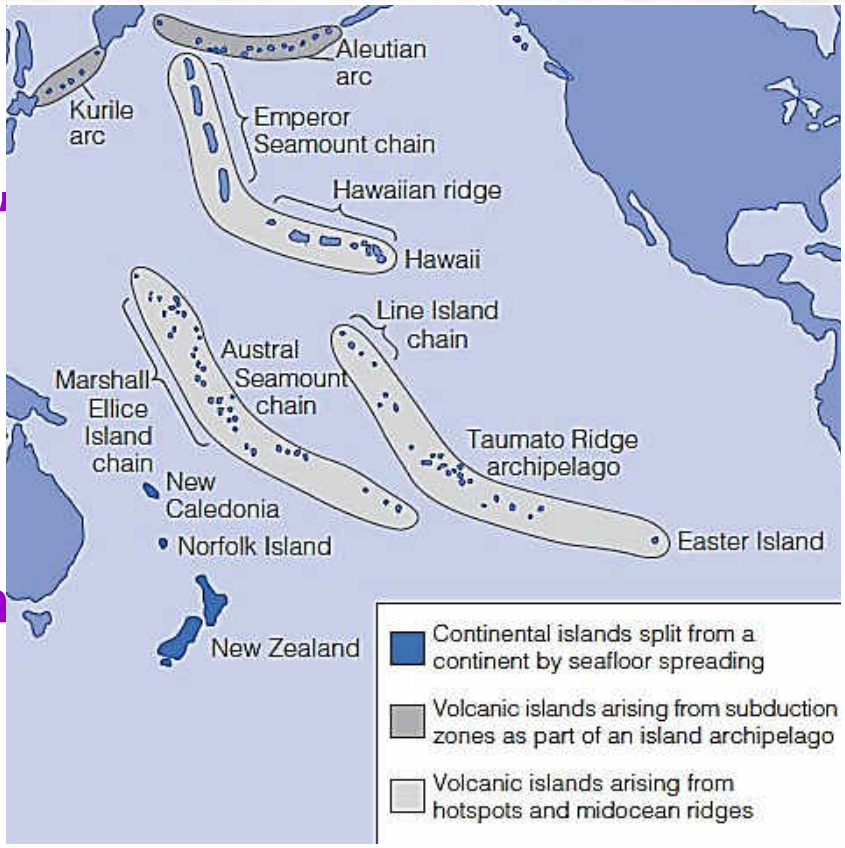
Plate Tectonics

Volcanic Island Hotspots

- **Other islands form as a result of the activity of what geologists call hotspots**
- **These are scattered, but fixed, locations over 700 km deep within the Earth, from which plumes of hot material rise to form**

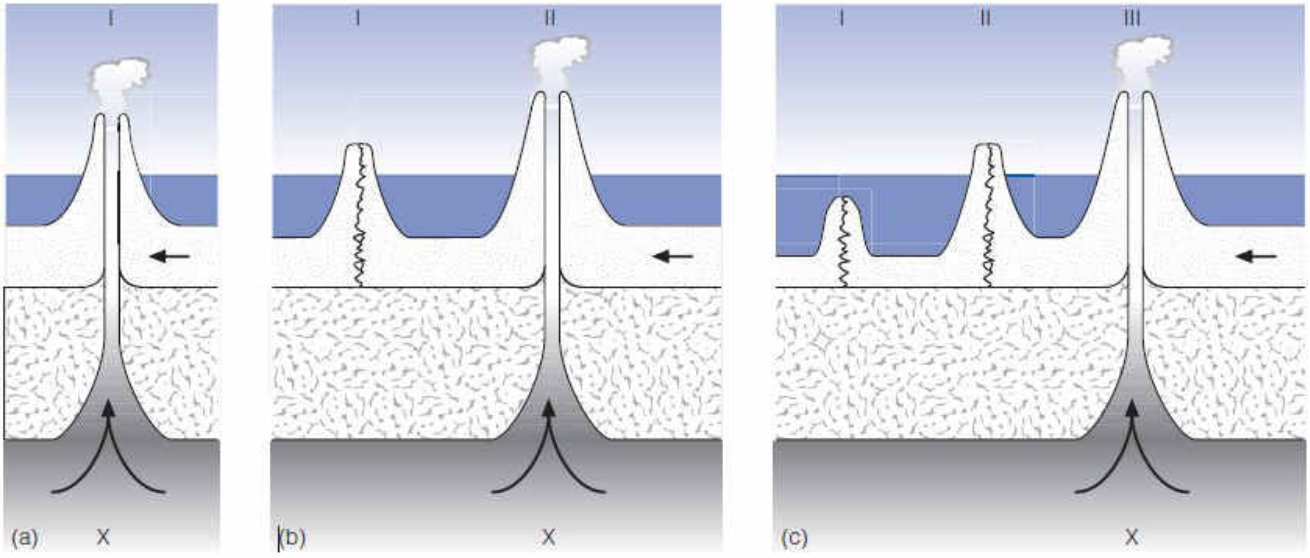
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Map of the Pacific Ocean, showing examples of the three types of island. Adapted from Mielke



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The formation of a chain of islands as the result of the activity of a hotspot

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Plate Tectonics

Plateau

- **A hotspot may also cause the appearance of a larger area or plateau that, if exposed and colonized by animals and plants, could play a role in their dispersal between continents.**

Plate Tectonics

Terranes

- **Volcanic islands remains reach the edge of a trench**
- **They collide with the adjacent continent**
- **Individual patches known as terranes – regions within which the rocks are quite different from**

END

Evolution, the Source of Novelty

Sympatry
versus
Allopatry

Evolution, the Source of Novelty

Sympatry

- **An initially interbreeding population that splits into two or more distinct species sharing a common range exemplifies sympatric speciation.**
- **Darwin's finches and their beak sizes**

Evolution, the Source of Novelty

Allopatric speciation

- **Also referred to as geographic speciation, is a mode of speciation that occurs when biological populations of the same species become isolated from each other.**

Evolution, the Source of Novelty

Defining the Species

- **There is a great variety of definitions of the species which focus on a variety of different aspects of the organisms, so let's first of all consider what type of data are normally the**

Evolution, the Source of Novelty

Biological Species Concept

- **Focuses on its reproductive isolation:**
- **‘The species is a group of natural populations whose members can all breed together to produce fertile offspring’**

Evolution, the Source of Novelty

Ecological Species Concept

- **Arises from the organism’s need to find its own place in the natural world.**
- **In the face of competition from other organisms, it must develop a set of characteristics that give it an**

Evolution, the Source of Novelty

Scientific Definition

- **Reflects the nature and detail of the information available at the time.**
- **Definitions of the species have changed over time**
- **More knowledge about the genetic, ecological**

END

Patterns in the Past

Early Land Life on the Moving Continents

Patterns in the Past

Patterns

- **How the very different geographies, climates, faunas and floras of our planet gradually changed, over the last 400 million years, into those that**

Patterns in the Past

Patterns

- **The movements of the continents and of the timing of the different events of continental fragmentation/union is fairly understood**
- **The distribution of fossil organisms correlates very**

Patterns in the Past

Early Devonian (380mya)

- **Separate floras and/or fish faunas can be distinguished in the northerly placed Siberian continent, the equatorially placed Euramerican continent, Kazakhstan, northern Africa**

Patterns in the Past

Early Devonian (380mya)

- **The fossil record suggests that all the early amphibian and reptile groups evolved in the continent called Euramerica**

Patterns in the Past

One World – for a While

- **The coalescence of the different continental fragments to form Pangaea led to climatic changes. In general, the world became steadily warmer and drier during the Triassic.**

Patterns in the Past

Jurassic & Early Cretaceous

- **Floras become more similar, approaching the modern pattern in which there are gradual latitudinal changes governed by climate, the patterns of dominance of different groups**

Patterns in the Past

Early & Middle Triassic

- **The bulk of the Permian faunas had been made up of synapsid or ‘mammal-like’ reptiles and other older types of reptile, but these disappeared during the Early and Middle**

Patterns in the Past

Subdivision of Pangaea

- **Some fundamental biogeographical consequences, for evolution could now take place independently in each new continent to produce new, unique groups, thus leading to**

END

The Biogeographical Regions Today

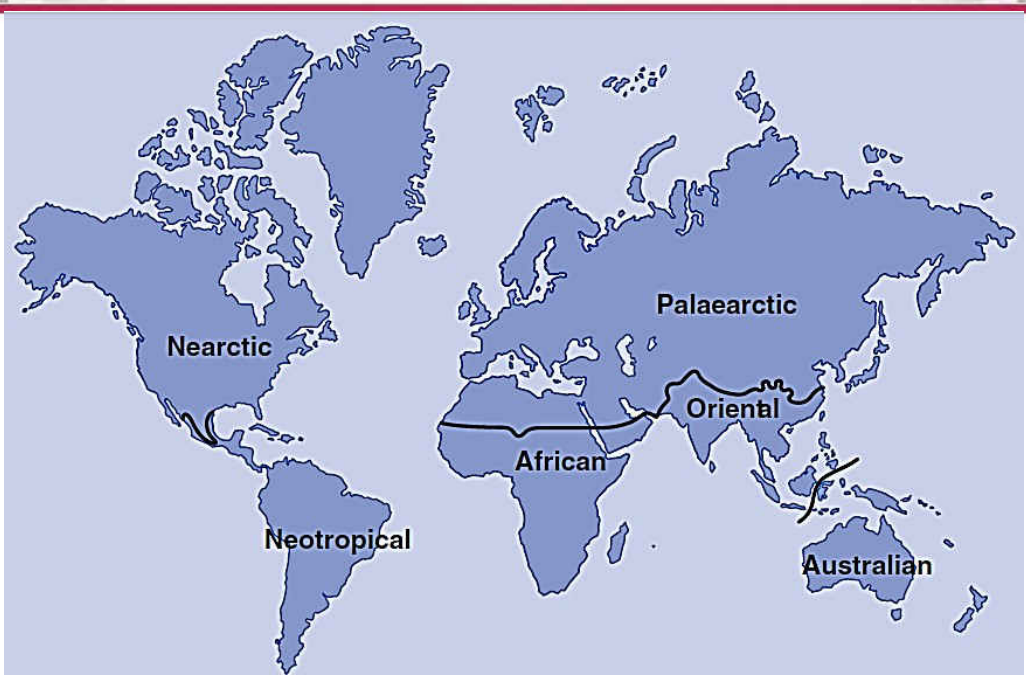
Biogeographical Regions

The Biogeographical Regions Today

Geographical Region

- **Candolle (1820) & Engler (1879) used the patterns of distribution of flowering plants**
- **Sclater (1858) working on birds, & Wallace in 1860–1876, working on mammals, defined the system of**

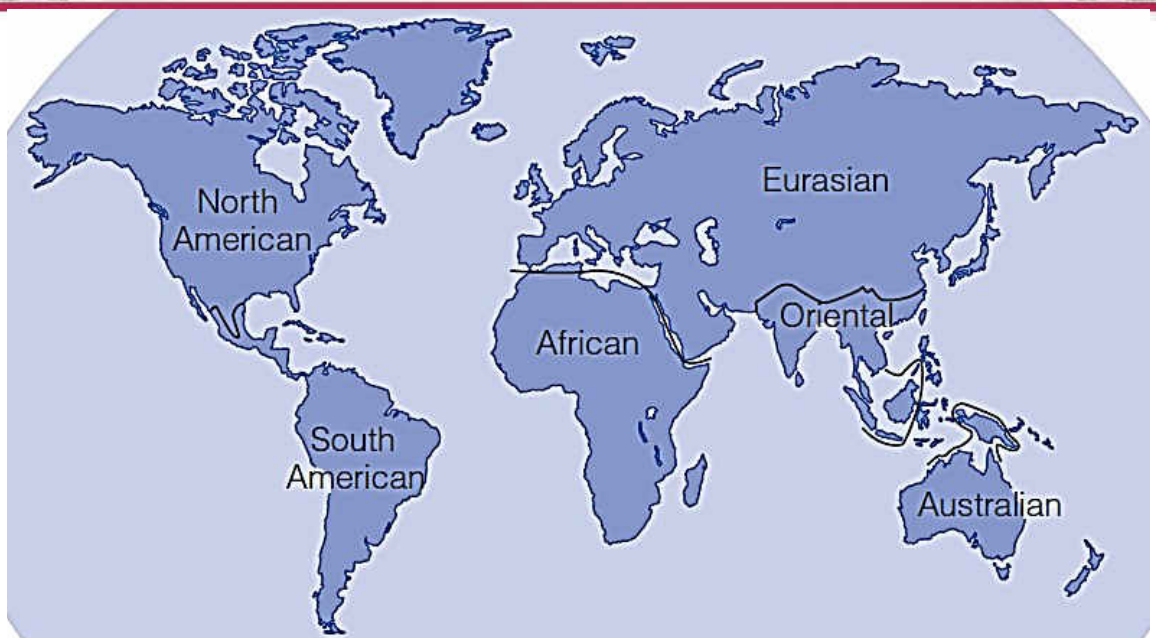
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Zoogeographical regions, according to *Sclater & Wallace*.

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Biogeographical regions of a group that does not disperse readily – the mammals.

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Mammal Biogeography

- **We can trace the histories of continent-based mammal faunas through time,**
- **Relate their histories to movements of the continents,**
- **How the dispersal of a fauna or group from one continent to**

The Biogeographical Regions Today

	Africa	Oriental	Eurasia	North America	South America	Australia
Rodents	×	×	×	×	×	×
Insectivores, carnivores, lagomorphs	×	×	×	×	×	
Perissodactyls, artiodactyls, elephants	×	×	×	×	×	
Primates	×	×	×		×	
Pangolins	×	×				
Conies, elephant-shrews, aardvarks	×					
Edentates					×	
Marsupials					×	×
Monotremes						×
Total number of orders today*	12	9	7	8	9	3
Total number of terrestrial families today*	44	31	29	23	32	11

Distribution of terrestrial mammals during the Late Cenozoic (Miocene–Pliocene)

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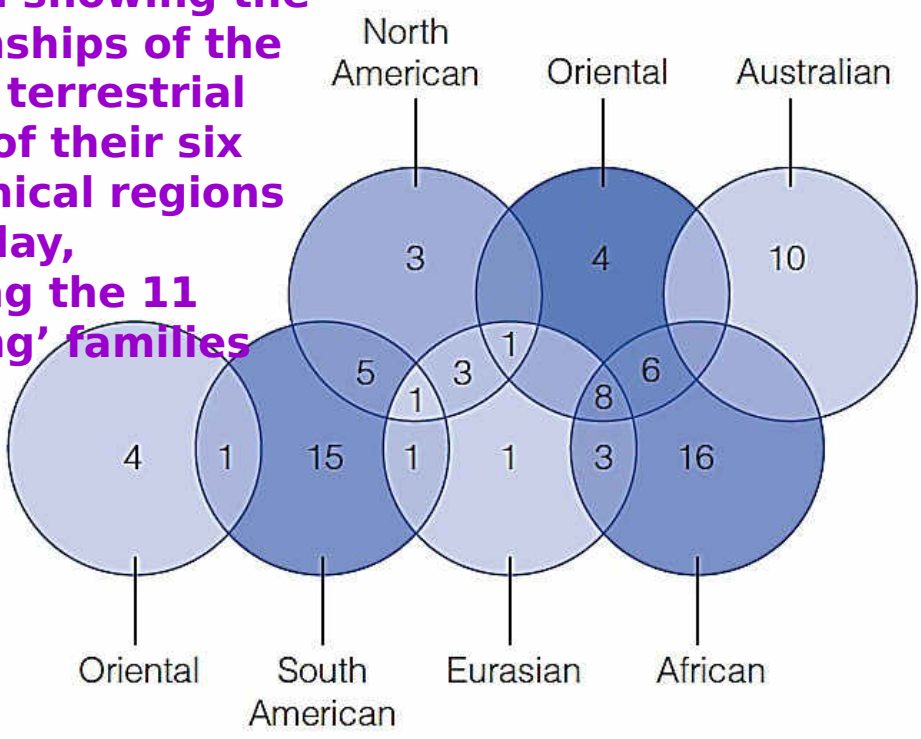
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Mammal Biogeography

- **Possibilities for mammals to disperse between the different continents varied in the past due to changes in the positions of the continents, in the climate or owing to the rise or withdrawal of shallow seas that from time to**

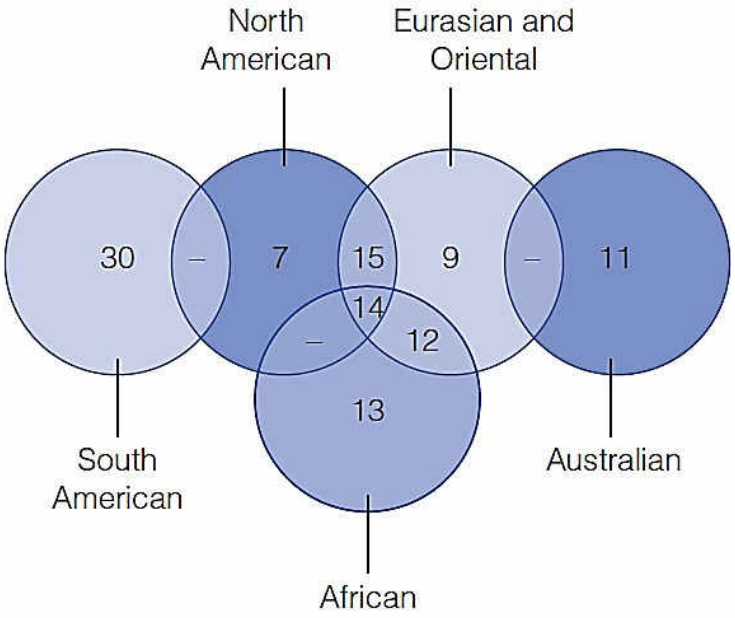
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Venn diagram showing the interrelationships of the families of terrestrial mammals of their six zoogeographical regions today, excluding the 11 'wandering' families



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Venn diagram showing the interrelationships of the families of terrestrial mammals of the continents at the end of the Miocene, excluding the 11 'wandering' families.

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Mammal Biogeography

- **Eisenberg has made an interesting analysis of the extent to which the different ecological niches have been filled in the different mammalian biogeographic**

END

The Biogeographical Regions Today

History of Today's Biogeographical Regions

The Biogeographical Regions Today

Continents

- **Southern continents: complex, as these are all the result of the break-up and dispersal of Gondwana,**
- **Northern continents: mainly the result of the appearance and disappearance of land or sea barriers within North America and**

The Biogeographical Regions Today

Continents

- **This seaway gradually extended clockwise around Africa, to form in turn the southern South Atlantic about 135 mya, and the northern South Atlantic about 105 mya.**
- **India–Madagascar parted from Antarctica about 132 mya, while the**

The Biogeographical Regions Today

Continents

- **India moved rapidly northward; its northeastern corner collided with an island arc about 57 mya, before finally colliding with Tibet in southern Asia about 35 mya, near the**

The Biogeographical Regions Today

Continents

- **Further west, the comparatively small northern movement of South America led to its connection with Northern America about 3 mya, which led to a complex interchange**

The Biogeographical Regions Today

Continents

- **Further east, New Zealand separated from Australia 84 mya, followed by the small continental fragment we call New Caledonia 80–65 mya.**

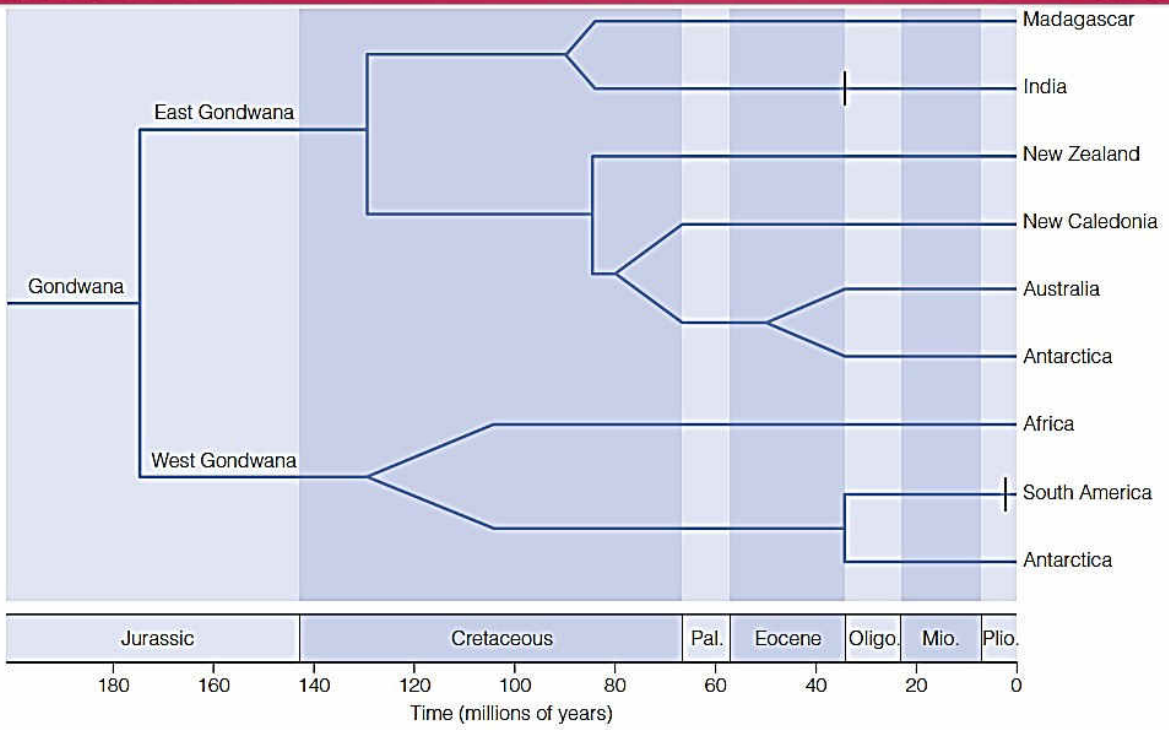
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Continents

- **Australia itself gradually separated from Antarctica 52–35 mya and moved far northward to its present position near South-East Asia, allowing a complex interchange between the**

END-1

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The progressive fragmentation of Gondwana

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The Old World Tropic: Africa

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Continents

- **Two continents, India and Africa originally part of Gondwana**
- **Africa became united with the northern continents during the Mid-Miocene, 16–10 mya**
- **it was probably from Africa that tropical flowering plants dispersed to the tropics of**

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Old World tropical biota

- **It is not yet possible to trace in full the separate contributions of Africa, India and South-East Asia to the final Old World tropical biota**
- **The fossil record of mammals is**

The Biogeographical Regions Today

Africa

- **Contains the best known & most distinctive of Old World tropical mammal fauna.**
- **Molecular studies of the interrelationships of the different orders of placentals suggest that the common ancestor of a group of African placentals entered**

The Biogeographical Regions Today

Africa

- **This group is made up of the elephants, hyracoids (conies), aquatic sirenians (sea cows), elephant shrews, aardvarks, Cape golden moles, insectivorous tenrecs and extinct embrithopods;**
- **they have been placed together in**

The Biogeographical Regions Today

Africa

- **Much of the continent was covered by rainforests of the tropical ever wet and subtropical summer wet biomes for much of the early Cenozoic, until the Late Miocene.**
- **About 19 mya in the Miocene, a firm land connection with**

The Biogeographical Regions Today

Africa

- **The seaway was finally broken near the beginning of the Late Miocene, 12 mya, by rising mountains in Arabia, Turkey and the Middle East.**
- **It was at this time that the early horse Hipparion, which had evolved in North America, appeared in both Eurasia and Africa**

The Biogeographical Regions Today

Africa

- **The elephant originated in Africa in the Eocene, migrated into Eurasia in the Early Miocene and migrated back later in the Miocene**
- **The ancestors of the mammoths and modern Asian elephant probably evolved in Africa 4 to 5 mya and**

The Biogeographical Regions Today

Madagascar

- **Area of 587 000 km2,**
- **Madagascar is second only to New Guinea in size.**
- **Madagascar reached its present position relative to Africa by 121 mya; it separated from India about 88 mya**
- **Became an island, while India**

The Biogeographical Regions Today

The Old World Tropic: India

The Biogeographical Regions Today

India

- **After its separation from Madagascar, India was isolated from direct contact with other land masses during its long journey northward to collide with southern Asia that probably**

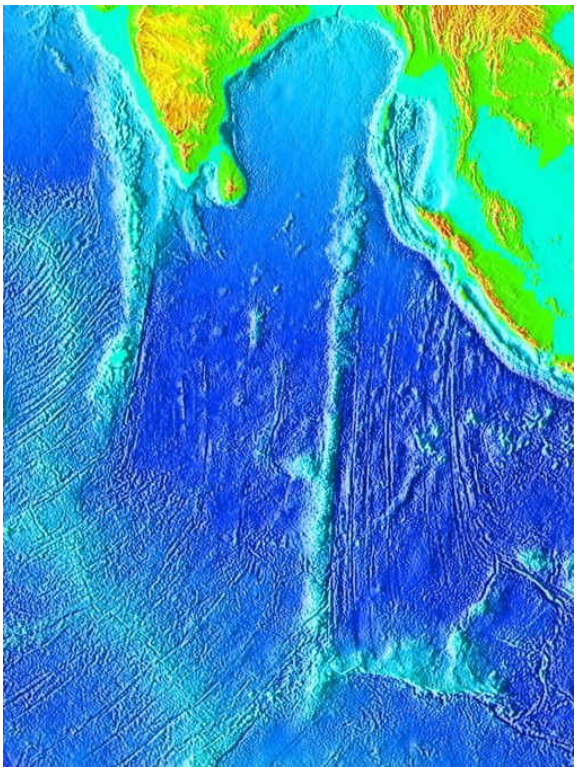
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India

- **Ali and Aitchison believe that oceanic islands and now-submerged oceanic plateau could have provided stepping stones for organisms to disperse between it and other parts of East Gondwana in the**

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There were once islands on the 5000 km long Ninety east Ridge, so-named because it approximately parallels that longitude today. Now eroded away, in the Paleocene to Late Oligocene



https://upload.wikimedia.org/wikipedia/commons/b/b9/NinetyEastRidge.jpg

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India

- The mammal fauna of India in the Cretaceous and Paleocene is unknown, but it must have been quickly colonized by the placental mammals of Asia after its collision with that continent.

The Biogeographical Regions Today

India

- **About 3 mya, an increase in aridity, related to the uplift of the Himalayan Mountains to new heights, led to the northern parts of the Indian subcontinent becoming much drier and also**

The Biogeographical Regions Today

India

- **Led to an increase in the numbers of grazing mammals such as horses, antelope and camels, and of elephants.**

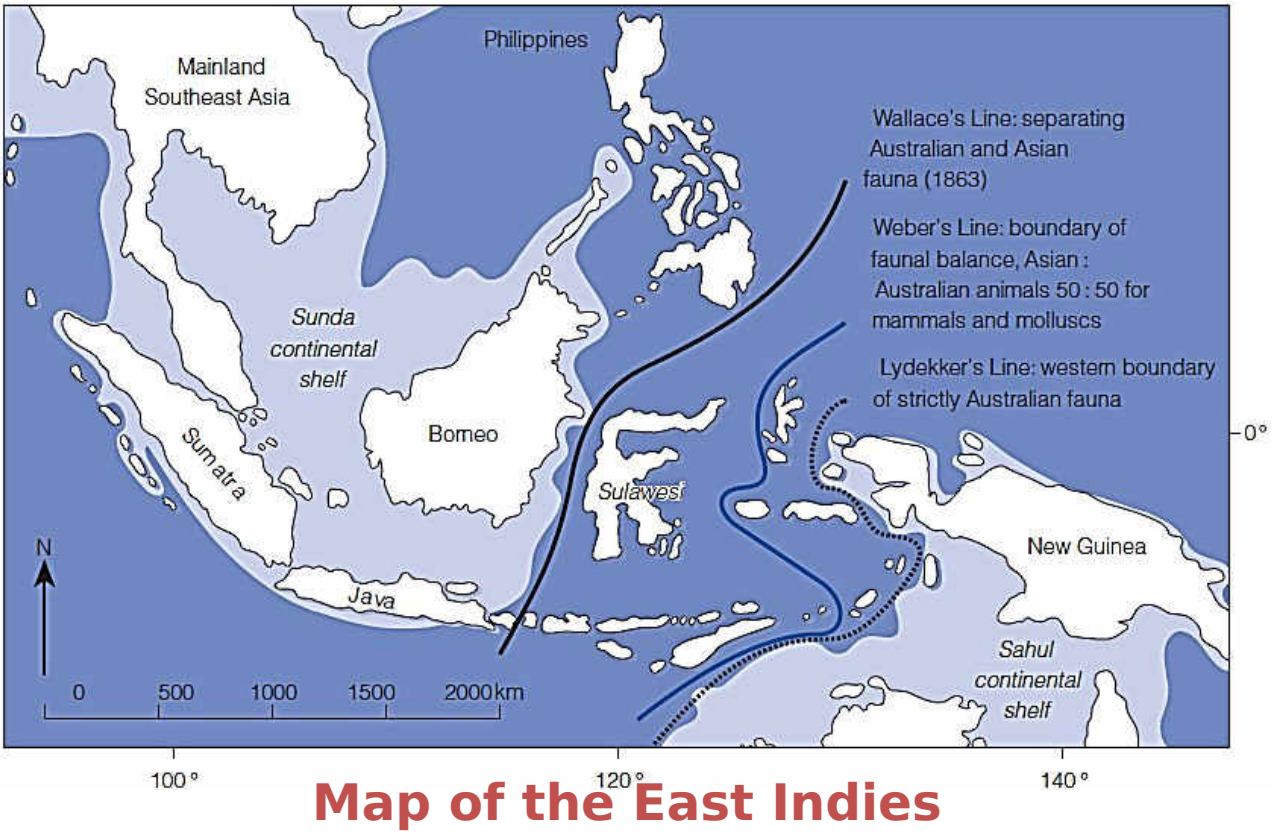
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East Indies

- **A complex pattern of islands lies on the continental shelves of South-East Asia (the Sunda shelf) and that of New Guinea–Australia (the Sahul shelf), and these have been colonized**

END-1

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Map of the East Indies

Cox, C. Barry, Peter D. Moore, and Richard Ladle. *Biogeography: an ecological and evolutionary approach*. John Wiley & Sons, 2016

The Biogeographical Regions Today

Australia

The Biogeographical Regions Today

Australia

- **The history, characteristics and biogeographical affinities of the biota of Australia are the most unusual and interesting**
- **Their explanation requires a rewarding understanding of the interplay between continental**

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Australia

- **By the Middle and Late Cretaceous, Gondwana had lost both India and Africa and retained only a narrow connection with South America, so that Antarctica–Australia was the most substantial remnant of the old supercontinent.**
- **Its fauna included marsupial**

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Australia

- **In the early Cenozoic, when its marsupials were undergoing their great radiation, whose diversity paralleled that of the absent placentals. It was also the time and environment in which the songbirds**

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Australia

- **The Oscines then dispersed to Asia in the Eocene, where their descendants started the worldwide radiation that today comprises nearly half of all living species of bird.**
- **Australia only started to move**

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Australia

- **By the Early Oligocene, around 35 mya, it had separated sufficiently far from Antarctica for the deep-water Antarctic Circumpolar Current of cooler water and associated westerly winds to become established.**

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Australia

- **Australia's northward movement brought it into the 30°S high-pressure zone of low rainfall.**
- **Australia became increasingly arid from the Late Oligocene and into the Miocene.**
- **Australia's annual rainfall is also extremely variable due the El Niño**

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Australia

- **The mammals of Australia had to adapt to these climatic changes.**
- **This fauna is made up of marsupials alone (plus the few egg-laying monotremes), and they have radiated into a great variety of forms, occupying the niches that placentals have**

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Australia

- **The marsupial equivalents of rats, mice, squirrels, jerboas, moles, badgers, anteaters, rabbits, cats, wolves and bears all look very like their placental counterparts – only the kangaroo looks quite unlike its**

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Australia

- **Molecular results**
- **Arboreal possum families radiated in the Eocene in Nothofagus forests**
- **The early marsupial herbivores: kangaroos and wallabies appeared after the Eremean grassland**

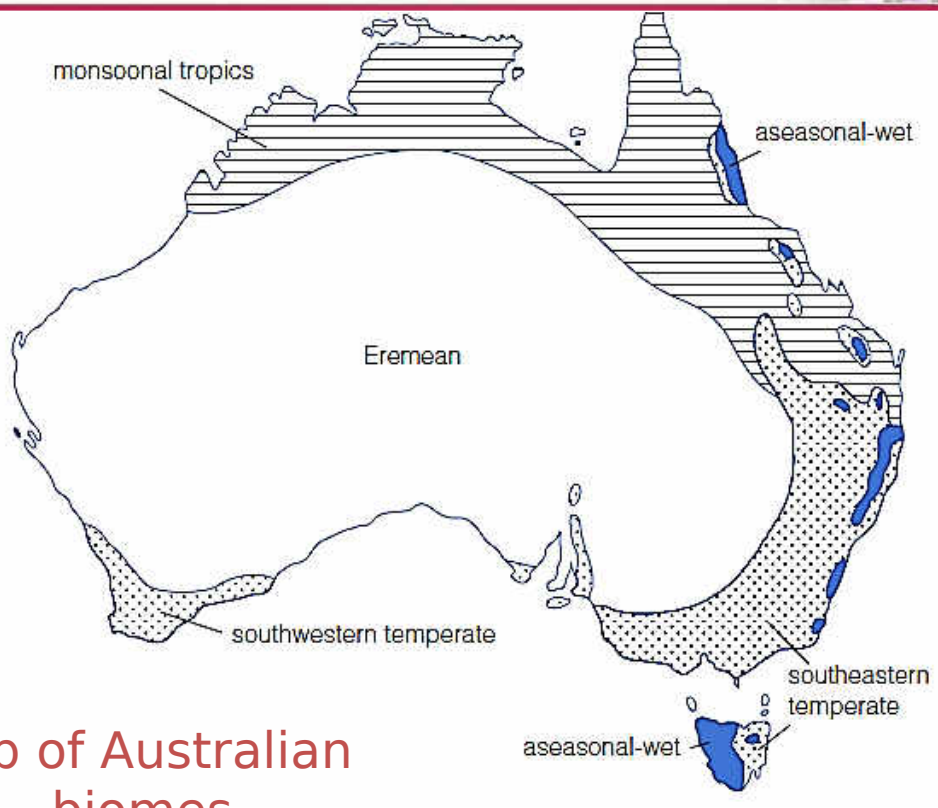
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Australia

- **Apart from humans and the aerial bats, only the rats spread naturally as far as Australia,**
- **50 species now form 50% of the diversity of the Australian land mammal fauna.**
- **Human beings probably arrived 60 000 to 40 000 years ago and**

END-1

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Map of Australian biomes

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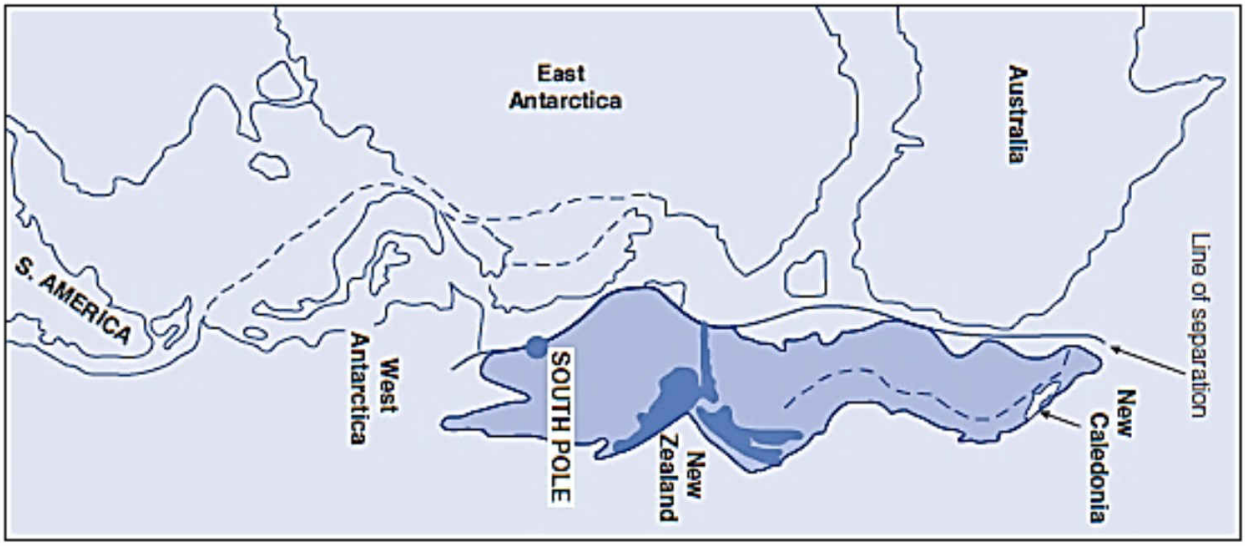
New Caledonia

The Biogeographical Regions Today

New Caledonia

- **Geological studies show that New Caledonia is the smallest (about 1600 km2) surviving fragment of Gondwana**
- **Rifted away from Australia in the Late Cretaceous 80–65 mya and reaching its present position 1500 km east of it 50 mya.**

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The original position of Zealandia (shaded) close to the South Pole, before it broke away from Gondwana. From McDowell

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New Caledonia

- **In view of the large amount of research that shows the frequency of long-distance dispersal in such scenarios, most biogeographers today believe that this was the mechanism of arrival of the ancestors of the**

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New Caledonia

- **Geological studies show that the island was submerged for long periods in the Paleocene–Eocene, so that the island was not available for colonization until about 37 mya.**
- **The New Caledonian species must therefore have diverged**

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New Caledonia

- **Panbiogeographers reject long-distance dispersal.**
- **They theorize that the Cretaceous ancestors of the present biota were widespread across the Pacific islands, including on supposedly formerly exposed large plateaux such as the Ontong Java**

The Biogeographical Regions Today

New Caledonia

- **Biogeographers have investigated the history of the angiosperm family Sapotaceae.**
- **Resulted from nine colonizations of the island between 33 and 4.2 mya, dates that are about 40 million years**

The Biogeographical Regions Today

New Caledonia

- **New Guinea and Australia were the most important sources of the arrivals, those from Pacific islands arriving only more recently, 27–24 mya. These results are clearly totally incompatible with the**

END

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New Zealand

The Biogeographical Regions Today

New Zealand

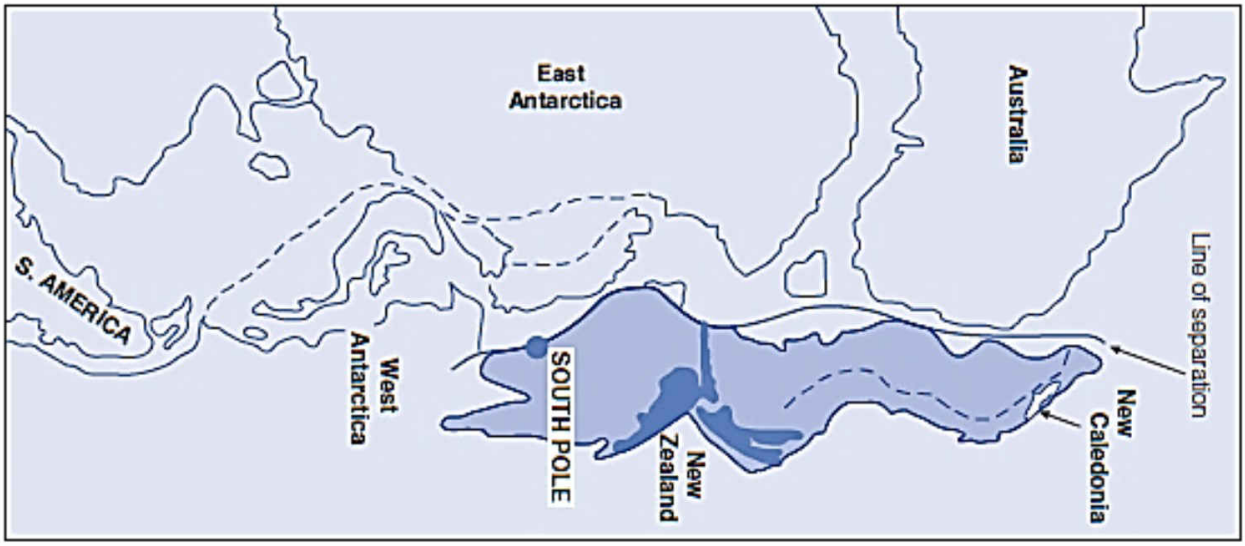
- **New Zealand is unique. Its total area, 270 000 km2, makes it far larger than any other Pacific oceanic island**
- **It is therefore not so vulnerable to the fluctuations of population and diversity that characterize them**

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New Zealand

- **When it first separated from Gondwana in the Late Cretaceous, about 82 mya, it was part of a minicontinent known as Zealandia almost half the size of Australia**
- **Stretching as far as New Caledonia to the northwest and**

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The original position of Zealandia (shaded) close to the South Pole, before it broke away from Gondwana. From McDowell

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New Zealand

- **This small landmass drifted northeastward to its present position, separated from Australia by the Tasman Sea, 1400 km wide.**
- **Most of it sank below sea level 30–25 mya, during the Oligocene, and it is possible that**

The Biogeographical Regions Today

New Zealand

- **Molecular studies that provide the dates of divergence of the New Zealand lineages from their closest external relatives have shown that many of New Zealand's organisms (especially the plants) reached there in**

The Biogeographical Regions Today

New Zealand

- **Molecular studies that provide the dates of divergence of the New Zealand lineages from their closest external relatives have shown that many of New Zealand's organisms (especially the plants) reached there in**

The Biogeographical Regions Today

- **A group of mainly New Zealand scientists has recently reported the results of an analysis of the mitochondrial genome of the endemic New Zealand frog *Leiopelma***
- **The divergence times between the two species are well over 65 mya, far earlier**

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- The ancient and diverse fauna, unlikely to have been able to arrive by overseas dispersal.
- This includes earthworms, the velvet worm Peripatus, arachnids, the unusual endemic lizard Sphenodon (from Miocene) and the flightless

The Biogeographical Regions Today

- The New Zealand flora is highly endemic at the species level (86% of its less than 2500 species are endemic), but with no endemic families, perhaps because as yet there has not been sufficient time for their

END

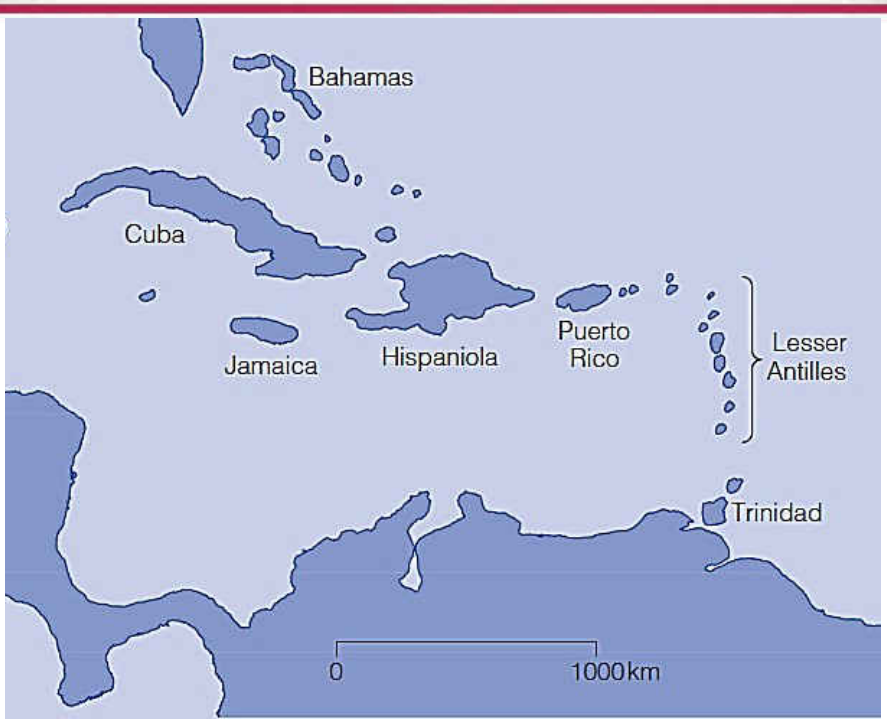
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The West Indies

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- **Though superficially similar in their geographical position, poised between two continents the islands of the Caribbean do not present the same fascinating problems as the islands of Wallacea because they do not lie between continents with**

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The West Indies

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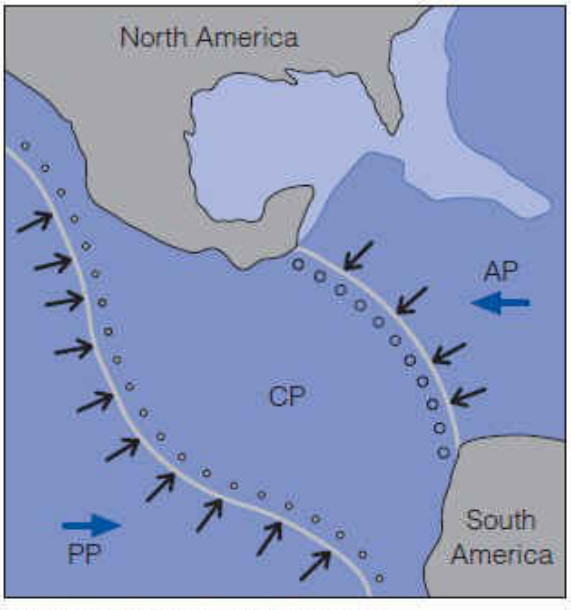
- **Instead, they have posed a different, interesting problem:**
- **Are their faunas and floras primarily the result of vicariance, due to evolution on islands that arose by the break-up of a larger 'proto-Antillean' landmass, or are they the result of**

The Biogeographical Regions Today

- **What is now the Caribbean region began as merely a gap between North America and South America and therefore also between the Atlantic plate to the east and the Pacific plate to the west**

The Biogeographical Regions Today

The formation of the West Indies.



(a) Late Cretaceous 150 mya

Dark grey tint indicates dry land; light blue tint indicates shallow water; dark blue tint indicates deep water. Filled arrows indicate plate motion: AP, Atlantic Plate; CP, Caribbean Plate; PP, Pacific Plate. Smaller arrows indicate where ocean crust is being consumed, leading to the appearance of volcanic islands.

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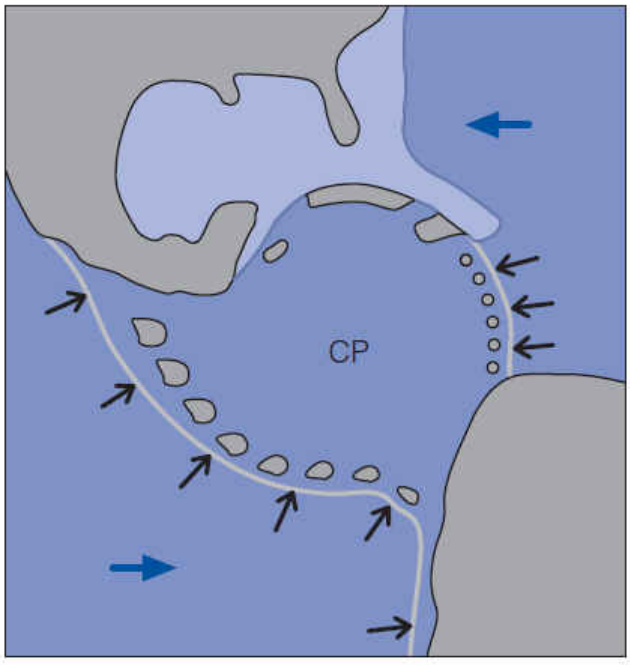
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- **In the Early Cenozoic, a northward component of movement as South America approached North America, resulting in the appearance of the Greater Antilles (the larger islands of Cuba, Jamaica, Hispaniola and Puerto Rico)**

The Biogeographical Regions Today

The formation of the West Indies.

Dark grey tint indicates dry land; light blue tint indicates shallow water; dark blue tint indicates deep water. Filled arrows indicate plate motion: AP, Atlantic Plate; CP, Caribbean Plate; PP, Pacific Plate. Smaller arrows indicate where ocean crust is being consumed, leading to the appearance of volcanic islands.



(b) Eocene 50 mya

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- The ecological diversity of the islands is largely based on the radiation of a comparatively small number of higher taxa, some of which contain a very large number of species.

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- This suggests that a small number of immigrants, finding themselves in environments lacking their normal competitors, were able to diversify opportunisticall

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- 1300 native species of freshwater or terrestrial vertebrate in the islands, of which 75% are endemic
- contain 672 species of amphibian and reptile, which belong to about 75 different evolutionary

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- Of these 75 different evolutionary lineages, 49 are related to South American taxa, and only four to North American taxa (the origins of the remaining 22 lineages are Africa, Central America or uncertain).

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- The West Indies islands thus provide a fascinating picture in which geological, faunal and molecular studies seem to be converging on a convincing story of

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- It is also an interesting contrast to the East Indies or Wallacea, where the history of the neighbouring continents has been quite different.

END

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South America

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South America

- **The history of the biota of South America has been dominated by the effects of the great earth-engine of plate tectonics.**
- **Westward drift of the continent, mountain building and consequent climatic changes**
- **changes in its relationship with North America.**

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South America

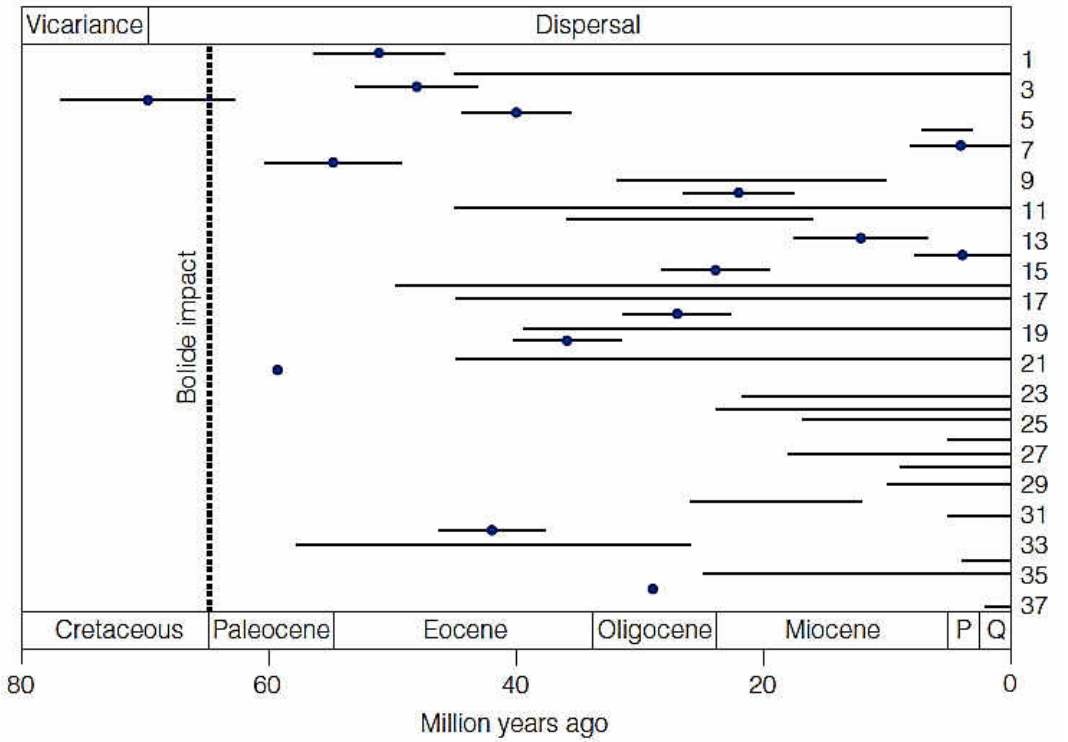
- **There had been islands in that region ever since the Americas started to move westward in the Early Cretaceous.**
- **This may have been the route by which some North American dinosaurs dispersed southward in the Mid-Cretaceous,**

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South America

- **But this connection has always been tenuous, sometimes permitting passage and sometimes becoming broken.**
- **This led to cycles of immigration, isolation and evolution, and**

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Times of origin of 37 independent lineages of endemic West Indian amphibians and reptiles From *Hedges*

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- **The mammal fauna of South America today is characterized by a few marsupials (opossums) and a diversity of edentate placental mammals known as the Xenarthra (sloths, armadillos and South American anteaters) that are hardly known**

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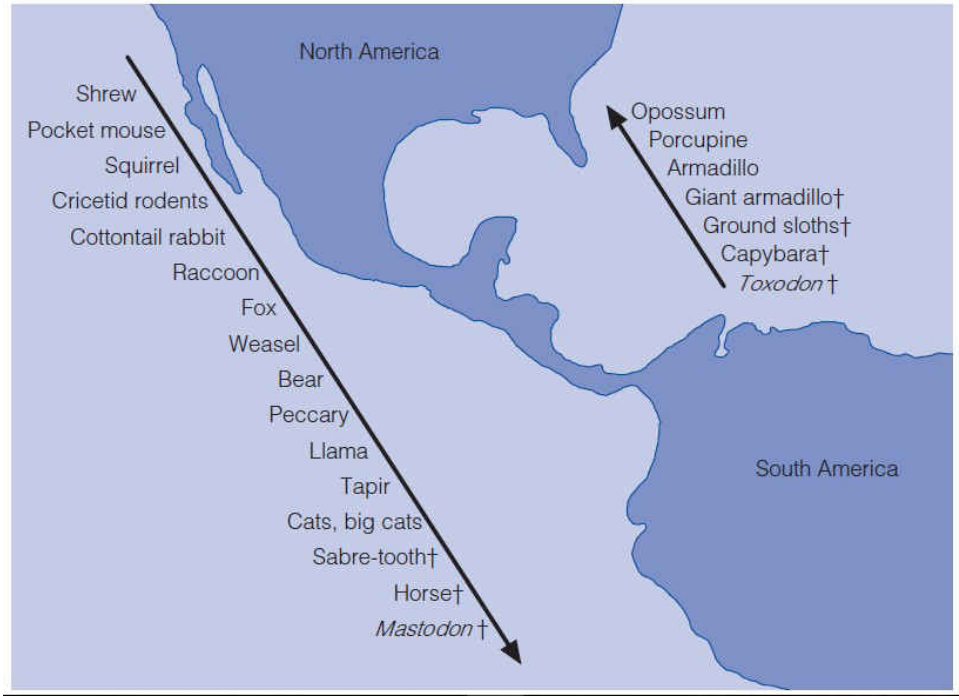
- In the Late Cretaceous, South America had a mammal fauna of strange marsupials and of ungulate placentals quite unlike anything known elsewhere in the world.

The Biogeographical Regions Today

- Alfred Wallace, noted that the range boundaries of Amazonian birds seemed to coincide with the pattern of the rivers.
- It is fascinating that recent research shows that closely related taxa of some birds are to be found on either side of rivers

END-2

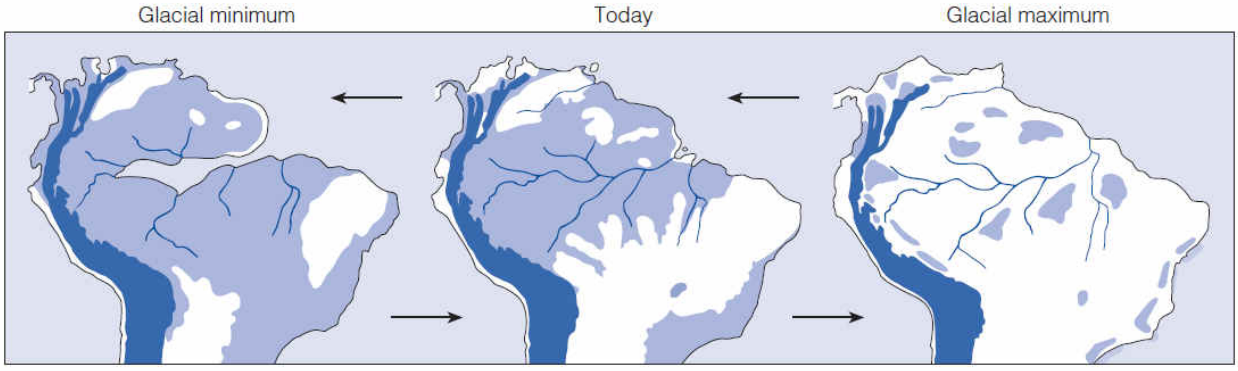
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The migrants of the Great American Interchange. A cross after the name indicates that it later became extinct in its new continent.

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Maps of northern South America showing the suggested extent of the lowland rainforests (light blue) during the different phases of the glacial cycle. Dark blue areas represent land above 1000 m, and white represents grassland. The coastlines have been adjusted to reflect the changes in sea levels, but the pattern of the Amazon Basin drainage is left unaltered in all three maps, to facilitate comparison. Adapted from Lynch.

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The Northern Hemisphere: Holarctic Mammals

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Northern Hemisphere

- **In contrast to the Southern Hemisphere, that of the Northern Hemisphere has been comparatively uniform**
- **Although shallow epicontinental seas and the developing North Atlantic have from time to time subdivided the**

The Biogeographical Regions Today

Northern Hemisphere

- **the biogeographical results of plate tectonic movements in the Northern Hemisphere were far less complex and dramatic than those in the Southern Hemisphere.**
- **In addition, their faunas and floras have in the recent**

The Biogeographical Regions Today

Northern Hemisphere

- **There are the two great regions of temperate and cold-adapted biota.**
- **Although the two continents are usually distinguished as being separate ‘North American’ and ‘Eurasian’ zoogeographical regions, they are sometimes**

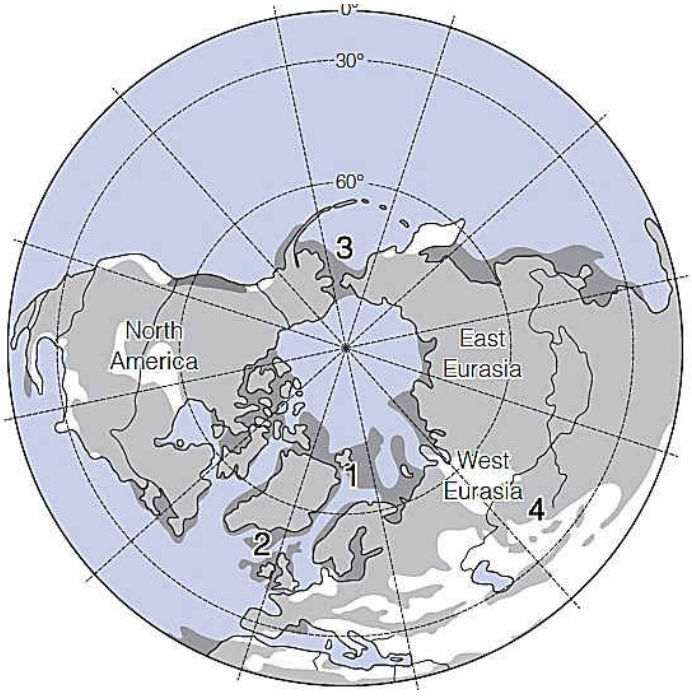
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Northern Hemisphere

- **The controls on the dispersal of animals and plants in these northern continents have therefore been changes in sea level or climate, and the effects of these in four different crucial areas have recently been described by the Greek**

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Simplified palaeogeographical reconstruction of the high northern latitudes during the Paleocene, to show the key dispersal locations in the Paleocene and earliest Eocene. (1) de Geer route; (2) Thulean route; (3) Beringia; (4) Turgai Sea. From



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Northern Hemisphere

- **the de Geer route (1) connected**
- **northeastern Greenland to Scandinavia in the**
- **Latest Cretaceous–Early Paleocene (71–63 mya);**
- **the Thulean route (2) connected northern North**
- **America to Europe via a ridge of land that is now**
- **submerged; and**

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Northern Hemisphere

- **the route of land across the Bering Sea between Siberia and Alaska (3) was dry during parts of the Paleocene.**
- **The Turgai Seaway (4) ran from north to south near the Ural Mountains.**

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- Much of Europe was, until about 30 mya, covered by a shallow epicontinental sea, so that the area was an archipelago of islands of varying size, rather like the East Indies today.
- Because of their position in fairly high northern latitudes, some of

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- The biogeographical importance of the climate of the Bering region can be seen in its influence on faunal exchange between North America and Eurasia.
- In the Early Oligocene, few mammals crossed.
- In the Oligocene, a number of Asian mammals

END

Ice and Change

The Ice Ages

Ice and Change

Ice Ages

- **Ice Ages are relatively rare events in the Earth's 4.6 billion years of history.**
- **Although the polar regions receive less energy from the sun than the equatorial regions, they have been supplied with warmth by a free circulation of ocean currents**

Ice and Change

Ice Ages

- **Only occasionally do land masses pass over the poles, or form obstructions to the movement of waters into the high latitudes, which can result in the formation of polar ice caps.**
- **The approximate timing of glacial episodes during Earth's history.**

Ice and Change

Huronian Glaciation

- **2.4 to 2.1 billion years ago**
- **Putative cause: Volcanic activity**

Ice and Change

Cryogenian Ice Ages

- **850 to 630 million years ago**
- **Putative Cause: Loss of CO2 from the atmosphere due to recently evolved multicellular organisms**

Ice and Change

Andeab-Saharan Ice Age

- **460 to 430 million years ago**
- **Putative Cause: Triggered by volcanic activity that deposited new silicate rocks, which draw CO2 out of the air as they**

Ice and Change

Karoo Ice Age

- **360 to 260 million years ago**
- **Putative Cause: Falling CO2 as a result of the expansion of land plants. As plants spread over the planet, they absorbed CO2 from the atmosphere and released oxygen**

Ice and Change

Antarctica freezes

- **14 million years ago**
- **Putative Cause:**
- **Falling CO2 caused by the rise and subsequent erosion of the Himalayas.**
- **The weathering sucked CO2 out of the atmosphere and**

Ice and Change

Recent Glaciations

- **Quaternary glaciations (2.58 million to 12000 years ago)**
- **Older Dryas (14700 to 13400 years ago)**
- **Younger Dryas (12800 to 11500 years ago)**
- **Putative cause: Fall in atmospheric CO2**

Ice and Change

Recent Glaciations

- **Timing of the glacials and interglacials driven by periodic changes in Earth's orbit and amplified by changes in greenhouse gas levels**

END

Ice and Change

Causes of Glaciation

Ice and Change

Antarctica

- **During the most recent Ice Age, the movement of Antarctica into its position over the South Pole led to the development of a Southern Polar Ice Cap 42 mya.**
- **Falling global temperature then led to then development of the Greenland Ice**

Ice and Change

Rearrangements

- **Rearrangements of the Northern Hemisphere land masses have subsequently resulted in the isolation of the Arctic Ocean so that it received relatively little influence from warm-water currents, leading to its becoming frozen some 3 to**

Ice and Change

Albedo

- **The presence of two massive polar ice caps increased the albedo, or reflectivity, of the Earth, for whereas the Earth as a whole reflects about 40% of the energy that falls on it, the ice caps reflect about 80%.**

Ice and Change

Milankovich

- **Why the recent Ice Age has not been a period of uniform cold, but has consisted of a sequence of alternating warm and cold episodes.**
- **A proposal to explain this pattern was put forward in the 1930s by the Yugoslav**

Ice and Change

- **Milankovich constructed a model based on the fact that the Earth's orbit around the sun is elliptical and that the shape of the ellipse changes in space in a regular fashion, from more circular to strongly elliptical.**
- **It takes about 96 000 years to complete a cycle**

Ice and Change

- **When the orbit is fairly circular there will be a more regular input of energy to the Earth through the year, whereas when it is strongly elliptical the contrast between winter and summer energy supply**

Ice and Change

Tilt of the Earth's Axis

- **A second source of variation is produced by the tilt of the Earth's axis relative to the sun, which again affects the impact of seasonal changes, with a cycle duration of about 42000 years**

Ice and Change

Wobble of the Earth's axis

- **The third consideration is a wobble of the Earth's axis around its basic tilt angle, which shows a cycle of about 21 000 years.**

Ice and Change

Milankovich Cycles

- **All of these cycles affect the strength of solar intensity that is received by the Earth, and the pattern of climatic change should, according to Milankovich, be a predictable consequence of summing the effects of these**

Ice and Change

Volcanic Eruptions

- **Produce large quantities of dust, which are thrown high into the atmosphere.**
- **Reducing the amount of solar energy arriving at the Earth's surface, and dust particles also serve as nuclei on which condensation of water droplets**

Ice and Change

Volcanic Eruptions

- **Both of these consequences would favour glacial development.**
- **Attempts to correlate volcanic ash content with evidence of climatic changes in ocean sediments, however, have not met with**

END

The Human Intrusion

The Emergence of Humans

The Human Intrusion

The Pleistocene

- **The Pleistocene was a time of climatic instability, which had considerable impact on the distribution patterns of organisms over the face of the Earth.**
- **It was a time of extinctions, but also one of diversification for**

The Human Intrusion

Rate of Evolution

- **There has been much debate concerning whether speciation became faster or slower during the Quaternary Ice Age, and the general conclusion is that extinction rates within the Pleistocene exceeded**

The Human Intrusion

Mammals

- **For mammals, it was a time of extensive evolution, and most living species of mammal evolved during Quaternary times, driven by climatically unstable Quaternary environments**
- **One of the**

The Human Intrusion

Effect of Humans

- **Human has had an even greater impact on the biogeography of the Earth than even the Ice Ages.**
- **It has therefore been suggested that this period of time should be known as the**

The Human Intrusion

The Emergence of Humans

- **The fossil history of humans is still very incomplete, but each year brings new material to light, helping to fill in the gaps and providing a more detailed picture of how**

The Human Intrusion

The Emergence of Humans

- **The primates of the New World and the Old World became separated from each other some 40 (mya), and it is the Old World branch that is**

The Human Intrusion

The Emergence of Humans

- **Closely related to the great apes, which include the orangutan *Pongo*, and especially to the gorilla *Gorilla* and the chimpanzees *Pan***

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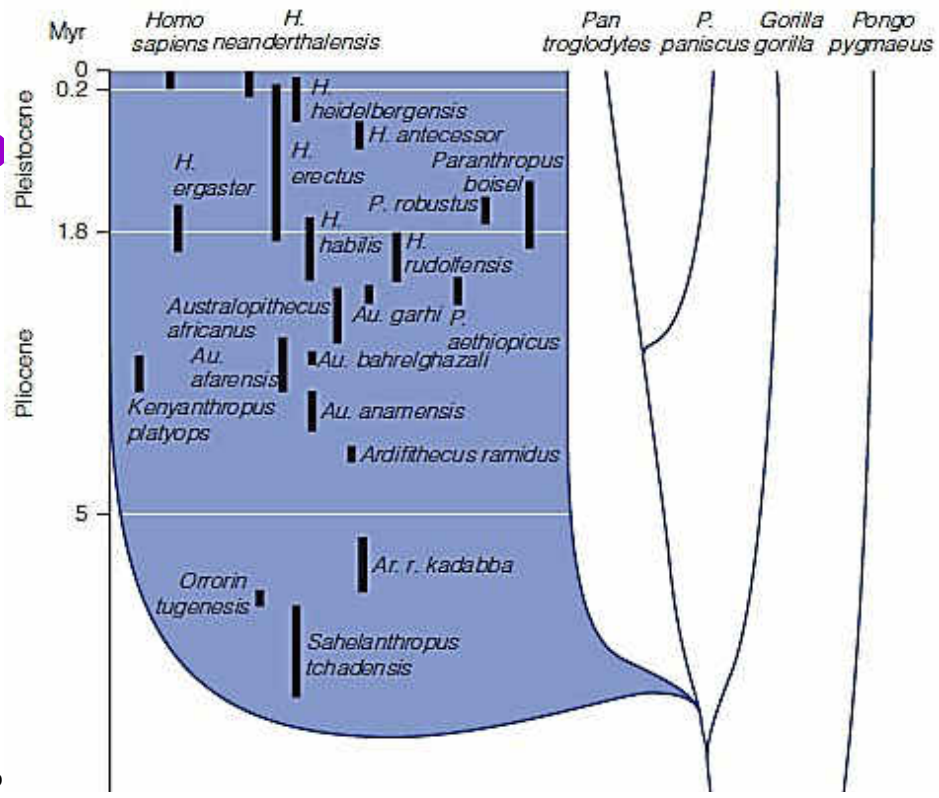
The Emergence of Humans

- **The separation of the human ancestral branch (the hominins) from the great apes (the two groups are known jointly as hominids) taken place about 7 mya.**
- **Almost 99% of human genetic**

The Human Intrusion

The relationships between the hominins and the great apes.

From Carroll. From McDowell



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The Human Intrusion

The Emergence of Humans

- **The hominin line became more bipedal and developed a larger brain and greater manual dexterity.**
- **While chimpanzees remained in the lower canopy of the forest, the ancestors of humans took to**

END

The Human Intrusion

Biogeography of The Early Hominids

The Human Intrusion

Miocene (5 mya)

- **Biogeography of the early hominids, which lived during the Miocene (5 mya)**
- **We can study the fossil record of other, larger and more common mammal groups, such as the *hyaenids* and the proboscideans associated with *hominids***

The Human Intrusion

Miocene (5 mya)

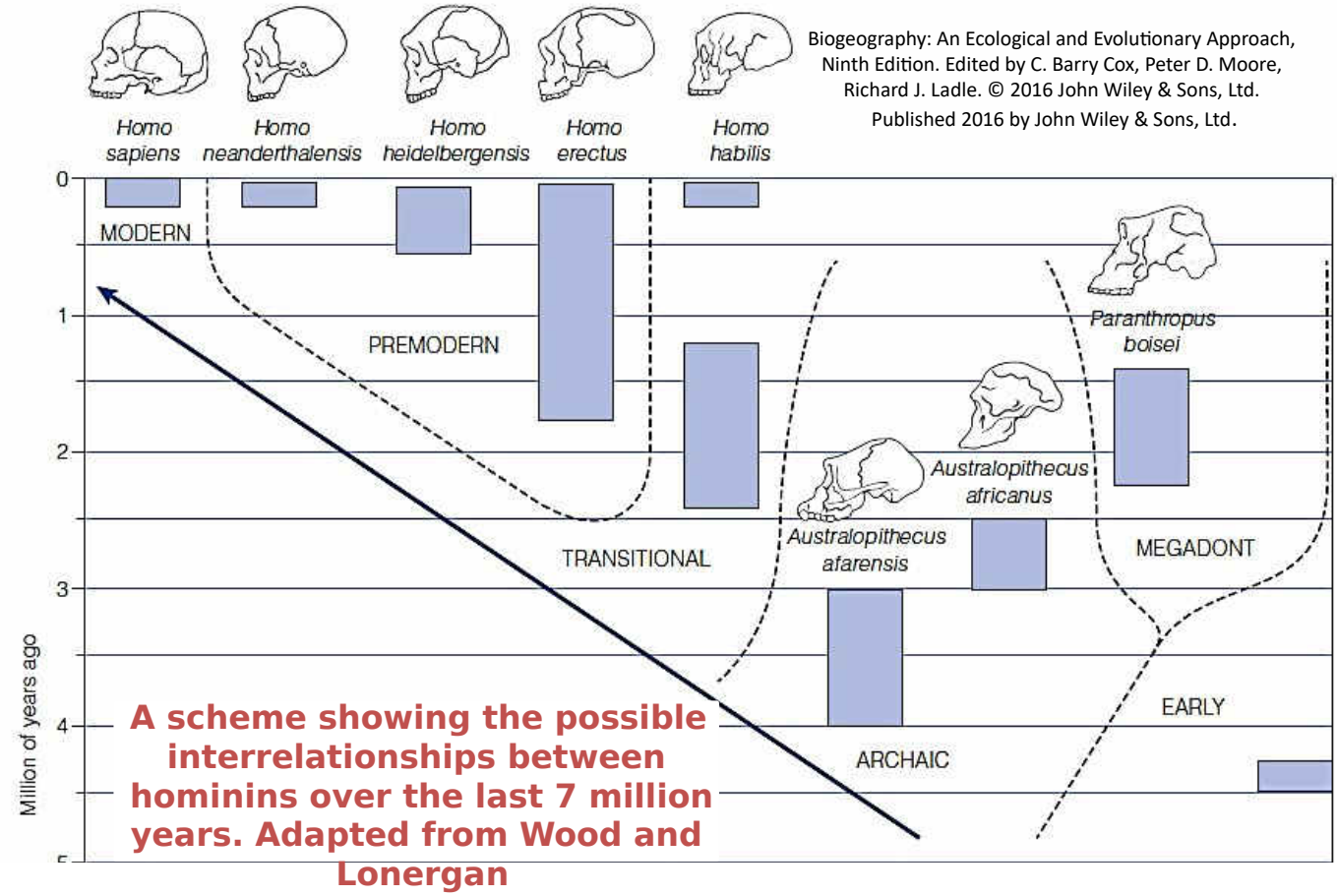
- **These share a common set of patterns involving speciation in Africa in the Early Miocene and expansion into Europe, Asia and North America during the Middle Miocene, followed by a movement back into Africa.**

The Human Intrusion

Miocene (5 mya)

- **It is very likely that hominids (which include the ancestors of apes and humans) followed similar changing patterns of distribution in the Miocene.**

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A scheme showing the possible interrelationships between hominins over the last 7 million years. Adapted from Wood and Lonergan

The Human Intrusion

Early Hominins

- **In 2002, Michel Brunet and his fellow researchers discovered six fossil bones (a cranium and some lower jaws) that had hominin similarities**
- **They were assigned to a new genus on the human line of evolution and**

The Human Intrusion

Archaic Hominins

- **The earliest finds were in Tanzania and Ethiopia and dated from around 4 mya.**
- **Among the fossils of this age is the partial skeleton known as *'Lucy,'* which has supplied a great deal of anatomical information about early**

The Human Intrusion

Megadont Hominins

- **A short-lived side-line of hominin evolution lived in East Africa 2.3–1.4 mya.**
- **Characterized by heavy, strong jaws and large molar teeth with a thick coating of enamel, this hominin was originally named *Zinjanthropus* but**

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Transitional Hominins

- ***Homo habilis*, a species that lived nearly 2 mya.**
- **It is different from the australopithecines in having an upright posture and larger brain.**
- **Structure of its arms and hands suggests it was still quite adept at climbing, and its ankle has**

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Pre-modern Homo

- **A new hominin, *Homo ergaster,* appeared around 1.9 mya, closely followed *Homo erectus***
- ***Homo erectus* left Africa about 1.7 mya, and had spread into eastern Asia by 100,000 years later**
- ***Homo heidelbergensis,***

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Pre-modern Homo

- **Appearance of *Homo neanderthalensis* about 200,000 years ago with evidence of *Homo sapiens* appearing later, in 160,000-year-old deposits from Ethiopia**
- ***H. neanderthalensis* and *H. sapiens* co-existed in Europe and Asia Minor**

END

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Modern Homo

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The Spread

- **Even before the last glaciation had begun, H. sapiens was spreading into the Middle East and also further south into the African continent.**
- **By the middle of the glaciation, our ancestors had reached the Asian interior and north of the**

The Human Intrusion

The Spread

- **By the middle of glaciation they spread across the Tibetan Plateau into South-East Asia.**
- **Australia became populated by about 50,000 ya, and humans had reached northern Europe and eastern Asia by the time the glaciation was at**

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The Spread

- **Only the Americas remained empty of our species**
- **The sea levels were lower, perhaps by around 100 m.**
- **A land bridge formed across the Bering Straits, linking Siberia to Alaska.**
- **This is the most likely route by**

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Map showing the probable routes taken during the spread of *Homo sapiens* out of Africa over the past 100,000 years.

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The Spread

- **A human skeleton dated to 13,000–12,000 ya, found in Mexico, that shows a mixture of Asian and Native American features**
- **Traces of human occupation about 15,500 ya north of Austin in Texas, at Monte Verde in southern Chile about 14**

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The Spread

- **Human bones dated to about 13000 ya found in the Channel Islands off California also suggest that some, at least, of the early Americans may have arrived by boat**
- **Evidence of a maritime culture, similar to that on**

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The Spread

- **A completely different line of enquiry on this problem comes from the study of the geography of human languages, which suggests that the colonization of the New World must have taken place before the major advance of the last**

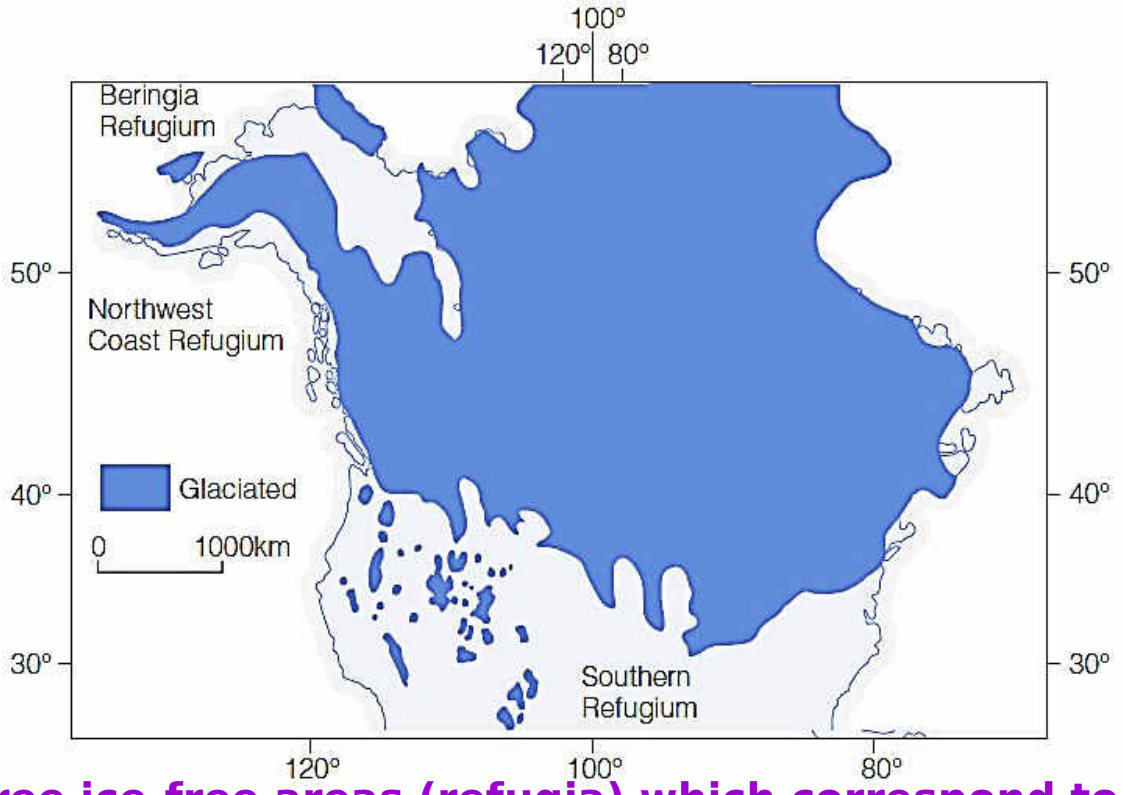
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The Spread

- **R.A. Rogers revealed three distinct groups of Native American languages centred on the three ice-free refugial areas of North America during the height of the last glaciation**
- **The current view of most researchers is that there was a single**

END-1

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Three ice-free areas (refugia) which correspond to the language groups of Native Americans.

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Modern Humans and the Megafaunal Extinctions

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Extinctions

- **The spread of the human species during the last glaciation was accompanied by the extinction of many species of large mammals, known as the megafauna – first in Australia, then in Eurasia and finally in North America**

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Who did that?

- **It was long assumed that these extinctions were the result of the climatic changes, but the American anthropologist *Paul Martin* suggested that humans may have been the culprits**

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Who did that?

- **He pointed out that most of the animals that became extinct were large herbivorous mammals or flightless birds, weighing over 50 kg body weight**
- **In other words, precisely the fauna humans might have**

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Who did that?

- **The record of extinctions has been studied in the greatest detail in North America.**
- ***Martin* suggests that 35 genera of large mammal (55 species) became extinct in North America at the end of the last (Wisconsin)**

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Who did that?

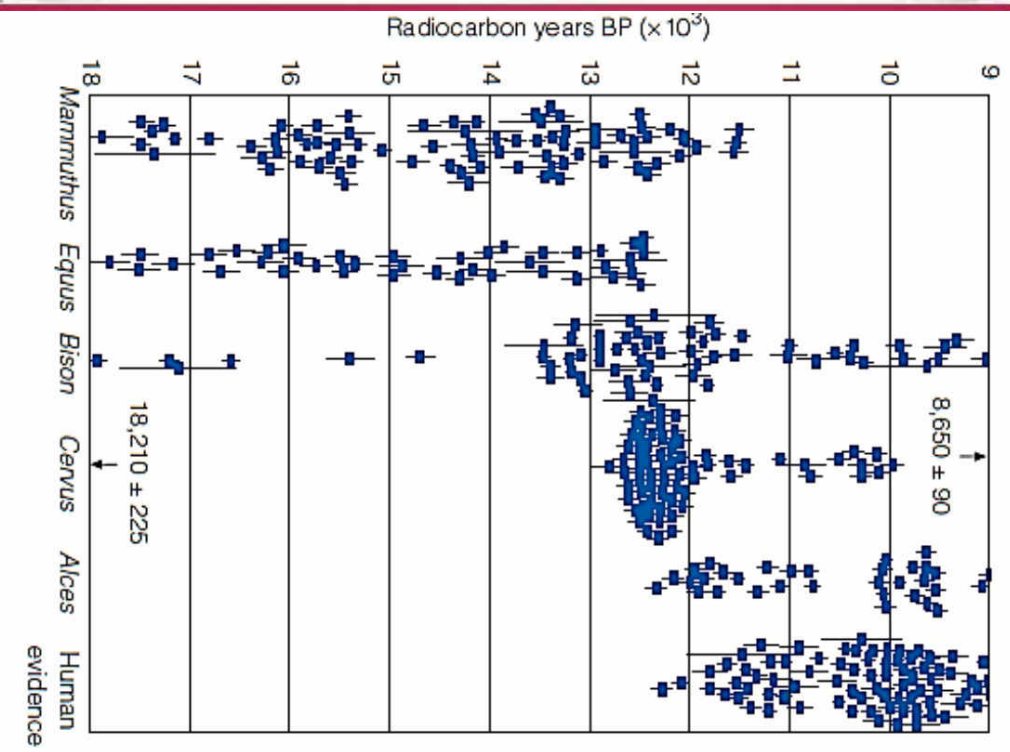
- **The debate continues, and the extinction of so many different species of mammals may not have been caused by one single factor.**
- **Studies show that the time of extinction can be correlated with the arrival,**

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Who did that?

- **Dale Guthrie of the University of Alaska has obtained radiocarbon dates for the Late Pleistocene and Early Holocene remains of many large mammal fossils from Alaska and the Yukon Territory**

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Radiocarbon dates of fossil mammal bones from North America showing the loss of mammoth and horse around the time of the Pleistocene–Holocene transition.

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Who did that?

- **The case for human involvement in the megafaunal extinction process is complicated by the fact that it took place at a time of rapid climatic and environmental change.**

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Who did that?

- **It has been proposed that some form of planetary impact took place at around 12,900 years ago that could have affected the climate and the megafauna**
- **Discovery of tiny diamonds in sediments reminiscent of the**

END

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Plant Domestication and Agriculture

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Success of Homo Sapiens

- **Can be explained including high brain capacity, maunal dexterity, toolmaking and social organization.**
- **Their adaptability was another feature that enabled the suvival of our species through times of fluctuating**

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Alternative Sources of food

- **When prey animals became scarce, human readily turned to alternative sources of food.**
- **By about 164,000 ya, human groups in south africa resorted to marine habitats for their main food supply, harvesting shellfish and**

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Middle East Experimentation

- **By the end of the last cold period, people in the middle east were experimenting with the technique to enhance their food supplies.**
- **In the fertile region of Levant grew a number of annual grasses with**

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Middle East Experimentation ?

- **The people occupying these regions at the time were hunters and gatherers of the Upper Palaeolithics, feeding on a rich variety of animals, including gazelles, birds, rodent, fish and mollusks.**

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Wild Barley, Wheat Other Grass

- **Some settlements have been discovered in Isreal dating from about 23, 000 years ago, and their hearths contain residues of charred dough made from the seeds of wild barley, wheat and other grass**

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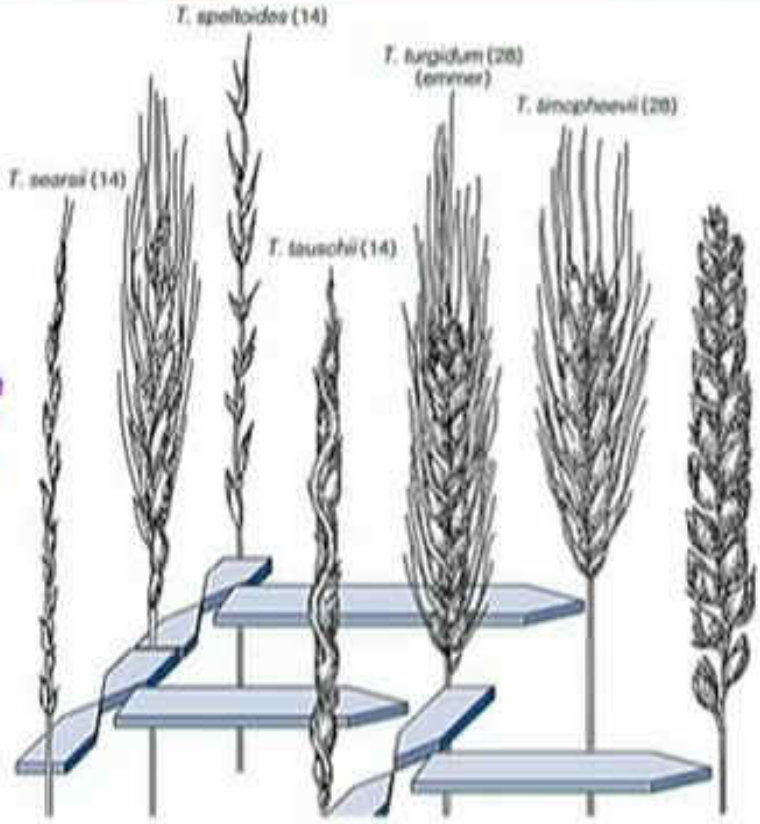
Wild Barley, Wheat Other Grasse

- **It was then a simple step to retain some of the seeds from one season to the next, and to select those strains that were richest in edible grains.**

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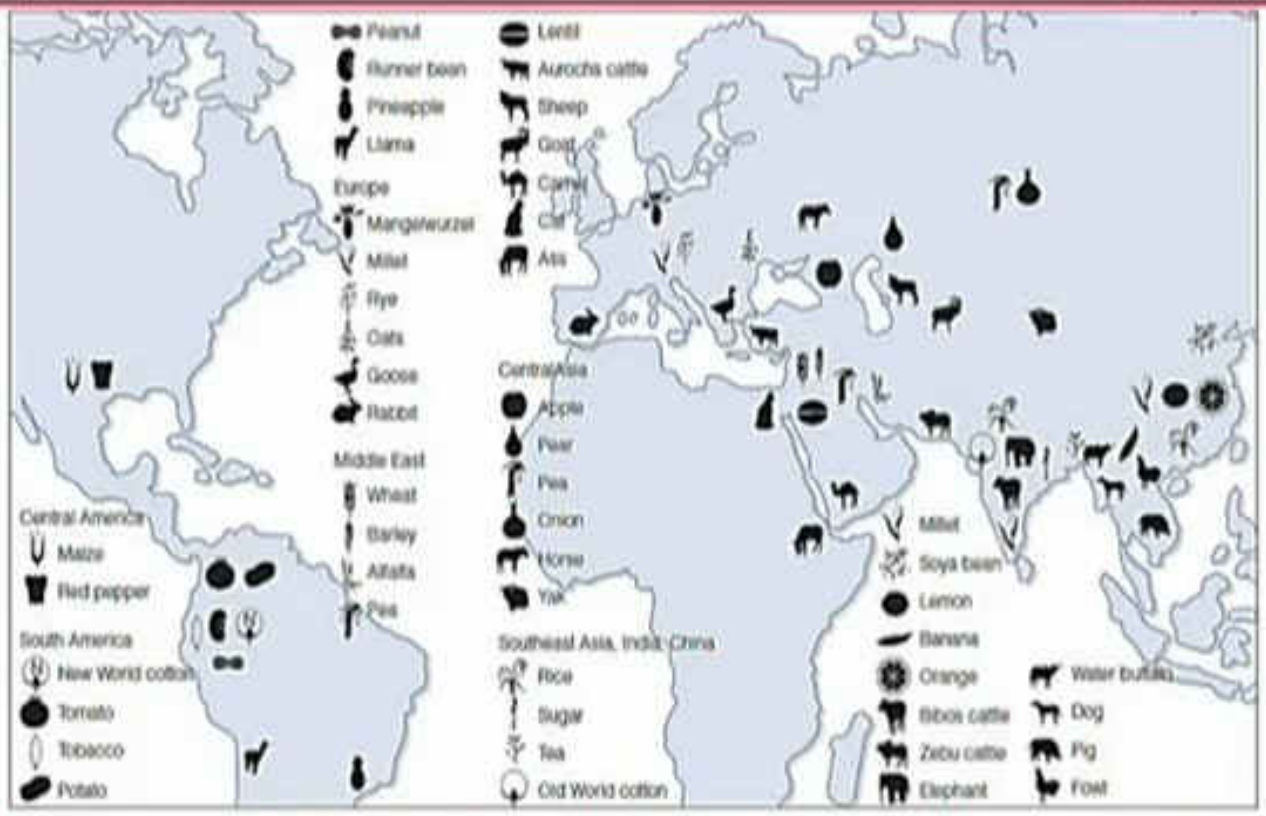
The Evolution of Modern Bread Wheat.

This reconstruction is tentative, but it represents the probable course of crossings among the wild wheat species that led to the early domesticated forms of the genus Triticum, and the subsequent crossings of domesticated wheats with wild species and chromosome doubling that led to bread wheat. Figures in parentheses after names represent chromosome numbers



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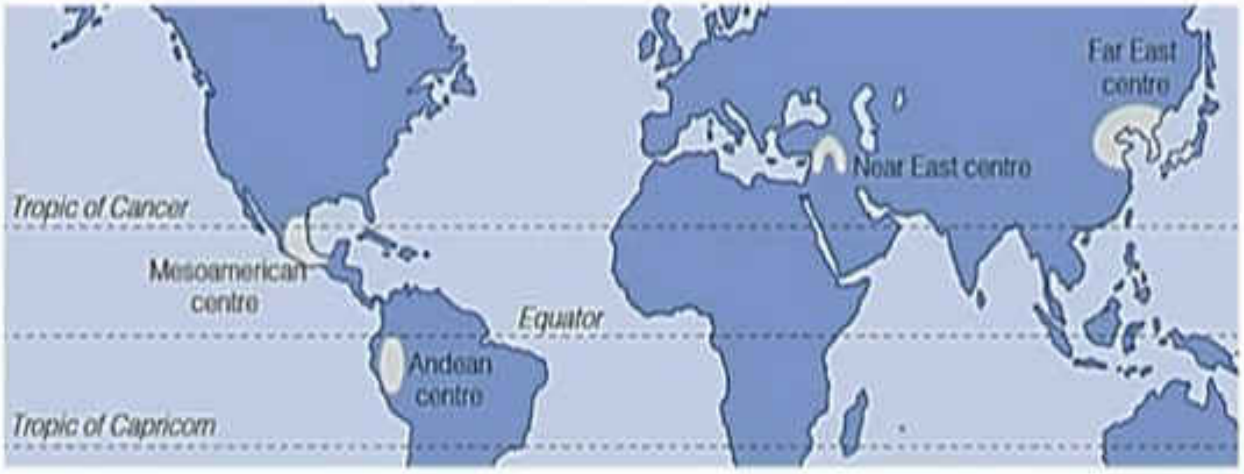
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Areas Where Different Animals and Plants were Probably First Domesticated

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The Four Main Centers in Which Agricultural Systems Developed Independently of one another

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Animal Domestication

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Wolf and Jackal

- The domestication of some animals may have preceded that of plants.
- There is some evidence, for instance, that early cultures had domesticated the wolf or, in some North African communities, the

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Wolf bones

- **Bones of dog/wolf associated with human settlements (found as far back as 400, 000 years).**
- **Joint burials of dogs with humans, which provide a reasonable indication of domestication, are known that**

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Wolf DNA

- **Molecular studies may give the best clue**
- ***Carles Vila,* from the University of California, Los Angeles, ans his colleagues have analysed mitochondrial DNA samples from 162 wolves and 140 dogs,**

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Dogs' Origin

- Their studies support the idea that the dog evolved from the wolf, but the differences between the two groups suggest that the evolutionary separation took place about 100,000 years ago, but later work suggests it could be as little as 30,000 years ago.

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Sheep's Origin

- The first traces of domesticated sheep come from Palestine around 8000 radiocarbon years ago.
- These may have originated from one of the three European and Asiatic sheep, or may have resulted from interbreeding

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Cattle's Origin

- **The domestic cattle of Europe (which were subsequently introduced into North America) have DNA that is very distinct from that of fossils aurochs bones and is more closely related to *Bos taturus* of the Middle East.**

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Cattle's Origin

- **The cattle of Africa and India, on the other hand, seem to have arisen from different stocks, suggesting that cattle's domestication took place in several different locations and was based on different bovid**

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Evolving together

- Humans modified the genetic constitution by selecting for certain qualities, such as placid behavior, as well as for high meat or milk production.
- Close association of people with animals also led to genetics modifications in the human species, as in the cases of milk digestion

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Cattles Origin

- It is likely that the milking of cattle was being practiced in the Near East about 9000 years ago.
- Milk evolved in the mammals as a mean of increasing the growth rate of the very young.
- Its major constituent is the carbohydrates lactose.

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Diversification of *Homo sapiens*

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Human Diversification

- As humans spread around the world and developed their own cultures and food resources, they diversified in the response to the new environmental pressure. Some of the modifications they developed resulted from

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Human Diversity

- **Some of the diversity found among human races is less easy to explain, as in the case of the blood groups.**
- **Rh, is found in 30% of all Caucasians: rare in the peoples of the Far East and among Native Americans.**
- **A and B: absent**

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Human Diversity

- **One of the most visually obvious sources of diversity among humans is the color of their skin.**
- **There is a great range of the skin colors and shades within the human species, and there is an evident geographical**

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Human Diversity

- People of the equatorial regions have darker skins than those of the high latitudes.
- Protection from the intense light, especially the harmful ultraviolet radiation (UVR).
- UVR can causes skin cancer and is also responsible for the destruction of certain B vitamins, such as folic acid, in the skin.

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Human Diversity

- A positive advantage for lighter skin color in the peoples of higher latitudes is, like everyone, they need vitamins D, which is the manufactured in the skin from biochemical precursors when exposed to UVR.
- This vitamin is required for calcium metabolism and bone growth.

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Human Diversity

- One good example is the blood condition called sickle cell anemia that, as its name suggests, causes anemia and other malfunctions of the blood system.
- In West Africa the gene for sickle-cell anemia occurs in the over 20 % of the population.

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Human Diversity

- When people were forcibly transported from West Africa to North America as salves, the gene fro sickle- cell anemia became distinctly less advantages, and its incidence among North Americans of African descent has now dropped to below 5 %.

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Human Diversity

- In the Central America, where malaria remains a greater risk, the gene is still found in 20 % of the people of West African origin.

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Environmental Impact of Early Human Cultures

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Environmental Modification

- **As essential consequence of domestication and subsequent human spread.**
- **In the postglacial climate the conditions in the temperate regions became cooler and wetter, the agriculture concept continued to**

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Environmental Modification

- **The incentive to modify the environment to make it more suitable fro enhanced productivity of the domestic animals and plants became a major driving force for the expanding human populations.**

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Environmental Modification

- **In pre-agricultural times, the Mesolithic people of northern Europe discovered that the opening of the forest and burning to retain open glades provided a higher productivity of the red deer (*Cervus elaphus*)**

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Environmental Modification

- **Hunting and foraging strategies of the Native Americans produced a patchwork of seasonal settlements that involved burning forest.**
- **This led to sharp divisions between habitats, such as prairie**

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Environmental Modification

- **Intensive clearance in the eastern United States and Canada was usually delayed until the arrival of European settlers in the 18th and 19th centuries.**
- **It is often marked in the pollen diagrams by a marked rise in**

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Environmental Modification

- **Environmental change has accelerated in the last few centuries, and the face of the Earth is changing ever faster.**
- **The destruction that temperate forests have experienced during these recent centuries is how being**

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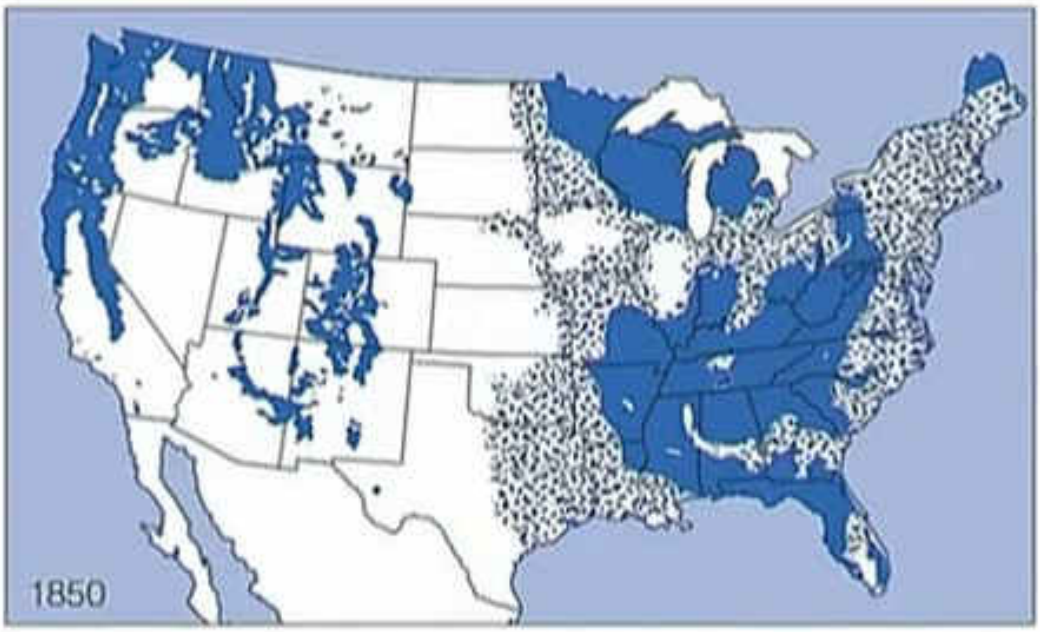


The extent of virgin forest in what is now the United States of America in 1620 of American old-growth forests.

From Linz et al

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The extent of virgin forest in what is now the United States of America in 1850 of American old-growth forests.

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The extent of virgin forest in what is now the United States of America in 1920 of American old-growth forests.
From Linz et al

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Conservation Biogeography

Introduction

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Relevance

- The study of biogeography has deep roots with much of the foundational work completed by the end of the 19th century.
- Nevertheless, the contemporary relevance of biogeographically research has never been greater.

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Anthropocene

- The current scientific consensus is that we are entering a unique period in the history of the Earth, a dramatic transformation of the life on Earth reminiscent of some of the events of the far past that led to mass extinction.

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Conservation

- **Ultimately, the degree to which human action alters the diversity and distribution of life on Earth depends on the willingness and capacity of societies, organizations and individuals to conserve what is left of the natural**

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Conservation Resources

- **However, conservation resources are limited, and it is imperative that we make rational, empirically grounded decisions about where to invest these limited resources (both taxonomically and**

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- **Biogeography has an essential role to play in this endeavor, providing tolls and concept to identify key realistic predications of what may happen to species and ecosystems under different scenarios of the human**

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Welcome to the Anthropocene

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Anthropocene

- **The enormous impacts that humans have had on biological communities, landscapes and even the global climate have led some scientist to dub the current geological epoch the Anthropocene**

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Anthropocene

- **From the Greek Anthropos ‘human being’ and kainos ‘new’**
- **In recognition of the pervasiveness, diversity and enormous magnitude of the various impacts that humans have had on the natural environment**

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Anthropocene

- **Controversial**
- **There is ample justification for a new geological epoch.**
- **Holocene: The official geological epoch stretching from the end of the pleistocene (nearly 12 000 years ago) too the present day.**

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Anthropocene

- **Specifically, in a blink of n eye from a geological perspective, humans have managed to significantly alter atmospheric chemistry, make the worlds ocena far more acid, rearrange and transform river system, accelerate rates**

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Anthropocene

- **Specifically, in a blink of n eye from a geological perspective, humans have managed to significantly alter atmospheric chemistry, make the worlds ocena far more acid, rearrange and transform river system, accelerate rates**

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Anthropocene

- **Appropriate a huge proportion of global net primary productivity, break down biogeochemical barriers causing the homogenization of biotas and create an enormous variety of noval ecosystems and**

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Anthropocene

- **Many of these effects (e.g. Extinctions and biological invasion) are irreversible, while others, such as the increase in the atmospheric concentration of green house gases, may be beyond the limited capacity**

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Anthropocene

- **Some scientists have suggested that the start of the Anthropocene should depend on when humans impacts became regionally significant.**
- **In this context, New Zealand was the last major area with an intact biota to enter 750 years**

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Anthropocene

- **Other scientists suggest that the start of the industrial revolution in the late 18th centaury is a more appropriate start date for the new epoch.**
- **There is also support for placing the start of the Anthropocene at**

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Anthropocene

- **The Anthropocene is the most notable for the accelerating loss of biodiversity and the remarkable re-sorting and restructuring of the communities due to human-assisted migration.**
- **The loss of**

Conservation Biogeography

Anthropocene

- **The Anthropocene is the most notable for the accelerating loss of biodiversity and the remarkable re-sorting and restructuring of the communities due to human-assisted migration.**
- **The loss of**

Conservation Biogeography

Anthropocene

- **Perhaps the loss (extinction) of species that has been most studied and, importantly, has probably played the biggest role in alerting societies to the often catastrophic impacts of human actions on the natural worlds.**

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Effect of Anthropocene

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Climate Migrants

- There is undeniable evidence that biodiversity is decreasing.
- However, in addition to extinctions, biological communities are also changing their composition as new species arrive.
- Some of these

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Climate Migrants

- Winners in the climate change lottery are likely to be in the minority given the extraordinary levels of fragmentation that compromise natural dispersal.
- In many habitats, especially islands, the majority of the new arrivals have

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Invasive Species

- Human- assisted dispersal of non-native species (sometimes referred to as alien species or invasive species) differs from natural dispersal events in the number and frequency of events.
- Natural dispersal events, especially

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Climate Migrants

- **Winners in the climate change lottery are likely to be in the minority given the extraordinary levels of fragmentation that compromise natural dispersal.**
- **In many habitats, especially islands, the majority of the new arrivals have**

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Characteristics	Prehistoric invasions	Human-assisted invasions
Long-distance dispersal events	Very rare	Common
Species transported per event	Few	Few to many
Propagule size	Typically small	Small to large
Mechanisms of dispersal	Few	Many
Temporal and spatial dynamics	Few, episodic short-distance events	Many, continuous long-distance events
Biotic homogenization	Weak and local	Strong and global
Potential for interacting with other stressors	Low	Very high

A comparison of prehistoric versus human-assisted biological invasions. Adapted from Ricciardi

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Biotic Homogenization

- Since the same nonnative species have been introduced into multiple sites, the net effect is for these ecologically diverse regions to become more similar (known as biotic homogenization).

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Biotic Homogenization

- Biotic homogenization can be thought of as the process by which former biotas lose their biological distinctiveness at any level of biological organization, including genetic and functional characteristics.

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Reconfiguration of communitie

- **The enormous influx of non-native species into a wide variety of ecosystems has led to a dramatic and unique re-sorting and reconfiguration of many communities, especially those near major human**

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- **However, the ecological consequences of such wide-scale biotic invasions are diverse and, often, counterintuitive.**
- **For example, while human density is associated with a decrease in species richness at small spatial scale, at lager spatial scales it is associated with**

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- These results indicates that at the local level, humans are driving species extinct through the effects of habitat loss, fragmentation and overexploitation, but over larger areas relatively few species are being lost while many new (non-native) species are being added.

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What is behind the Biodiversity Crisis?

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Biodiversity Decreases

- **When habitat is damaged, fragmented, restricted or completely destroyed**
- **When exotic species replace native species**
- **When the biophysical conditions change more rapidly**
- **When natural resources are**

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Biodiversity Decreases

- **Once a population has been driven to very low numbers, stochastic factors such as demographic shifts, genetic degradation and chance environment events such as diseases out breaks or usual weather events can wipe out the last few individualism causing extinctions.**

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Biodiversity Decreases

- **The single factor responsible for the greatest reduction of biodiversity during the Anthropocene is undoubtedly habitat loss.**
- **In Europe, large-scale habitat loss has been going on for millennia Britain's once vast forests had been largely reduced to**

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Biodiversity Decreases

- **The loss of Britain's forest must have been catastrophic for populations of woodland species such as bears, wolves and beavers, which all eventually succumbed to the pressures if small population size and overexploitation in the Middle ages.**

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North America

- **Until the beginning of the eighteenth centaury, deforestation was relatively small scale and mainly a consequence of clearance for subsistence farming by both indigenous peoples and the growing population of European immigrants and their descendants.**

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Tropical forests

- **Tropical forests originally covered bewteen 14 and 18 million km2, but by the late 1980s only about half that area remained.**
- **A high-resolution satellite study from 2013 indicated that 2.3 million km2 of forest was lost between 2000 and 2012.**

Conservation Biogeography

Human exploitation

- **Overhunting and over-harvesting may be the second most important cause of species extinctions.**
- **In the central and west Africa found that 177 wild species from 25 orders are hunted for meat, with 31 species classified as threatened by IUCN.**

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Pesticides and Toxins

- **The threat of pesticides and other toxicants is perhaps less visible than it once was.**
- **However, there is an increasing recognition that less toxic, but more widely used, compounds may be having considerable impact on ecosystems.**

Conservation Biogeography

Change Climate

- Climate is crucial factor for an organisms ecology, physiology and behavior, so the implications of changing climate are inherently complex to predict.
- This is an enormous challenge to biogeographers wishing to predict how individual organisms and

Conservation Biogeography

Climate Change

Tackling Climate changes

The implications of climate change are inherently complex to predict.

This an enormous challenge to biogeographers wishing to predict how individual organisms and ecosystems will respond. So far most of the focus has been on answering two key questions.

Questions

How will the current geographical range be affected under different climate change scenarios?

How many species and which one will be unable to adjust their geographical range in alignment with changing climate and therefore become threatened with extinction?

Conservation Biogeography

- **Approches**
- Two general approaches have emerged to answer these questions are:
- Mechanistic Models
- Species Distribution Models

Conservation Biogeography

- **Mechanistic Models**
- Quantify the relationships between key physiological and behavioral processes and the external environment.
- All other things being equal, mechanistic models are more powerful since they tell you about the underlying processes driving pattern. They are more likely to work correctly when extrapolating beyond the observed conditions.

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- **Species Distribution Models**
- A more flexible and widely used method for forecasting climate-induced range changes is a family of models known as species distribution models (SDMs).
- These relate the presence of a species to some aspect of the environment, typically a number of standard climate variables.
- A basic species distribution model has three components:
- Observed land use
- Observed species distribution
- Observed climate

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- This was the approach takin 2004 by the British biologist Chris Thomas and colleagues
- Thomas study, published in journal Nature, used and SDM approach to model the potential effects of global warming on the distribution ranges of 1103 species strategically land animals and plants.
- SDMs have been strongly criticized because of the wide number of assumptions and uncertainty implicit in such complicated models.

Conservation Biogeography

Crisis Management: Responding to Biodiversity Loss

- Conservation Movement
- The modern conservation movement emerged in the late 19th century in response to fundamental changes in world-views concerning the relationship between humans and the natural world.
- The early conservation movement was concentrated in the large Urban areas of Europe and North America and was motivated by two main values:
- To preserve natural areas for the intellectual and aesthetic contemplation of nature
- The acceptance that human dominion over nature goes hand in hand with a moral responsibility to preserve species from extinction

Conservation Biogeography

- It the latter half of 20th century conservation, these foundational values began to change and new values were added
- since the late 1980s: The protection of the world's biological diversity (biodiversity).
- Biodiversity was coined to make politicians and bureaucrats aware of looming extinction crises, particularly in the tropics.
- Cemented in International policy through the Convention on Biological Diversity (CBD), formulated at the 1992 Earth summit Rio de Janeiro

Conservation Biogeography

- Emphasized the economic and social benefits that efforts to save genes, species and ecosystems could brings
- The CBD, along with Agenda 21 on sustainable development, provides a comprehensive framework for sovereigns nations to develop a national legislative response to the biodiversity crises.
- Many countries have thus developed national biodiversity strategies (identifying strategic needs) or action plans (identifying technical responses and practical steps) as ways of fulfilling their obligations to the CBD

Conservation Biogeography

- The CBD lays great emphasis on in situ conservation of viable populations (Article B) and calls for the establishment of protected area networks, the rehabilitation of degraded areas and the protection of habitats and species in natural surroundings.
- Governments worldwide have responded to this challenge by adding to existing protected area.
- There are currently more then 100,000 protected areas that cover 14.6% of terrestrial land area and 2.8% of marine environment.

Conservation Biogeography

The Birth of Conservation Biogeography

Conservation Biogeography

- **Anthropocene**
- The dramatic effect of a single species has led to the widespread use of the informal geological term Anthropocene to refer to the current epoch during which human activities had a significant impact on the environment

Conservation Biogeography

- **Conservation Management**
- Scientist have played an essential role in documenting and modeling changes in ecology and biogeography,
- Starting in the late 1800s, conservation movement have evolved in response to threats, with the most prominent organizations.

Conservation Biogeography

- **Organizations**
- World Wildlife Fund (WWF), Conservation International, The Nature Conservancy and The Wildlife Conservation Society, rely heavily on scientific evidence and reasoning to target resources for conserving the aspects of biodiversity, they value most highly.
- **Scientific interest**
- Scientific interest in conservation problems arose much later then the conservation organizations.
- Before the 1970s, conservation practice was informed by heterogenous literature drawn from forestry and agricultural and biological sciences.

Conservation Biogeography

- Conservation biology drew heavily on concepts and theories from ecology, population biology and natural resource management with a strong focus on population or landscape-scale processes.
- The first International Conference 1978
- **Taking off**
- Conservation biology really took off in 1986 with the founding of the Society for conservation Biology (SCB), followed closely by the first edition their influential journal, also titled Conservation Biology in 1987.

Conservation Biogeography

- **Perspective**
- As a scientific discipline, conservation biology is primarily concerned with application biology, taxonomy and genetics to conservation problems (e.g extinction and population decline).
- **Paradigms**
- British ecologist Graham Caughley (1994) divided conservation biology research into two overarching paradigms
- The declining paradigms population
- The small population paradigm

Conservation Biogeography

- Robert Whittakar et al 2005 suggested a new subdiscipline of Conservation Biogeography, which they define as the application of biogeographical principles, theories and analysis to problems concerning the conservation biodiversity.

Conservation Biogeography

Conservation Biogeography in action

Conservation Biogeography in action

- **Goal**
- Central goal of conservation biogeography is to help societies to maximize the use of very limited conservation funds.
- We cannot provide the same level of protection for all remaining areas of the natural world, and to the species that currently exist.

Conservation Biogeography

- **Protected areas**
- The key to achieving the goal of conservation of biodiversity and the most important weapon in the fight against biodiversity are protected areas (PSs).
- The designation and placement of Pas do not simply depend on scientific principles.
- Being influenced by a range of historic culture and legal factors.
- Nevertheless within these constraints, biogeography has an important role in ensuring that conservation maximizes the impact of irreplaceable conservation interventions.

- In a series of classic papers, Dasmann and Udwardy put the idea of Biogeographical representation into practice.
- Building upon earlier maps of biodiversity they created a nested hierarchy of biological regions and thereby provided a framework.
- Dasmann-Udwardy framework follows greats such as Alfred Russel Wallace by dividing the world into biotic realms.
- They then applied a biome classification system within each of these realms, distinguishing smaller biotic provinces.

Ecoregions scheme

- DU Approach was quickly superseded by schemes developed by international conservation non-governmental organizations (NGOs).
- Closely related contemporary framework to the original Dasmann-Udvardy framework WWFs Ecoregions schemes.

Hotspots Schemes

- The recently formed (1987) NGO Conservation International (CI) developed a hotspots scheme which was specifically designed to maximize the number of specie saved given the resources available for conservation.
- An inevitable consequence of almost all prioritization is that there will always be winners and losers.
- New global biogeographical classification system for coastal and shelf areas known as the Marine Ecoregions of the world and MEOW.

Conservation Biogeography

The Future is Digital

Information revolution

- With profound impacts, on culture, science, politics and commerce
- The venerable discipline of biogeography will be in the frontline of these changes as new technologies transform the quantity and quality of biogeographical data.

Base Unit

- The base unit of biogeographical knowledge is a record of species at a precisely defined point in time and space.
- How to collect the data?
- A professional scientist would enter the field collect specimens, bring them back to the laboratory for identification, place the preserved specimens in museum collections and publish data in scholarly reports or scientific articles.
- Taxonomists will always be needed
- However, advances in mobile technology may eventually provide a way to circumvent the taxonomic impediment and generate enormous quantities of data on species occurrences.

- Core component is the development of apps which are able to link the technological forces of cloud and mobile computing, social networking and big data to transform mobile devices into sophisticated biodiversity sensors and powerful computers.

Biogeography Apps

- The iBat app (Indicator Bats Programme) uses a handy ultrasonic bat detector that can be plugged into a standard smartphone, enabaling users to record bat calls and upload the geo-referenced data to an online data base.
- Uses an open access classification tool (BatsID).
- iBatsID deploys ensembles of artificial neural networks to classify time-expending recordings of bat echolocation calls from 34 European bat species.
- Recordings not suited for machine identification are submitted to a Zooniverse Real Science online project.

Zooniverse

- Zooniverse is a collection of online citizen species projects with over half a million registered users.
- Using the remarkable pattern recognition capacities of human brain, citizen volunteers classify, extract and discuss science data from photos of galaxies to ancient documents.

The map of life

- The Map of Life, an ambitious, global bioinformatics project is a public, online quality vetted distribution map for every species on earth.
- The Encyclopedia of life, a project inspired by biogeographer, E.O Wilson, aims to make available via the internet virtually all information about life present on Earth.

Conservation Biogeography

conclusions

Interesting times

- The information revolution, advances in molecular technology and an evolving culture of international collaboration are generating enormous quantities of biogeographical data and a new generation of sophisticated tools to uncover the hidden patterns of nature.

Anthropocene

- All this is taking place during an unparalleled period of environmental change which will result in a resorting readjustment of life on earth, the magnitude of which has not been seen since the last mass extinction.

Affects and solutions

- These changes will have consequences at every scale, from local to global, and will have lasting impacts on the future evolution of life on our small, blue planet.
- Conservation biogeography cannot provide all the solutions to the problems of biodiversity loss.
- Conservation biogeography can provide many of the tools and concepts to make scientifically informed choices about what and where to project and the potential consequences of future environmental change (e.g climate change, habitat loss and invasive species.

- The greatest challenge facing scientists may be turning their concepts and predictions into practice.
- Influencing politicians and convincing skeptical publics are the real challenge.

Integration

- Biodiversity needs to be fully integrated into other sectors of environmental governance.
- This will only occur when high-quality biodiversity data are available to key decision makers in forms that they can actually use.

Role of conservation Biogeographers

- Conservation biogeographers can contribute by providing improved frameworks and concepts that give meaning and structure to biodiversity information and by producing models and visualizations tools that are of genuine practical importance.

zoogeography and Paleontology

Zoogeography and Paleontology of Pakistan

Northern Highlands and Plains

- Some of the wildlife species found on northern mountainous areas and Pothohar Platue include the non-threatened mammal species of Bharal, Euarsian Lynx, Himalyan goral Indian leopard, Marco polo sheep marmat.

The threatened species

- Include Asiatic Black bear, Himalayan brown bear, Indian Wolf, Kashmir gray langur, Kashmir red deer, markhor, rhesus macaque, Siberian ibex, smooth-coated otter, and white bellied musk deer, bird species of cheer pheasant, peregrine Falcone, western tragopan, and reptile species of mugger crocodile.

Indus plains and Deserts of Sindh

- Mammals: the nilgai red fox and wild boar
- Birds: Alexandrine, parakeet, barn owl, black kite, myna, hoopoe, Indian peafowl, red-vented bulbul, rock pigeon, shelduck and shikra.
- Reptiles: Indian cobra, Indian star tortoise, Sindh krait.

The threatened species

- Mammals: the axis deer, blackbuck, hog deer, Indian rhinoceros, Punjab urial and Sindh ibex.
- Birds: white-backed vulture and reptile species of black pond turtle and gharial.
- Extinct
- The Asiatic lion used occur in this region. In 1810, a lion was killed near Kot Diji.

Western Highlands, Plains and Deserts

- Mammals species include the caracal Blanfords fox, dromedary camel, goltered gazalle, Indian crested, porcupine, long-eared hedgehog, markhor, ratel and striped hyena.
- Birds: bearded, vulture, houbara bustard and merlin.
- Reptiles: leopards gecko and saw-scaled viper.
- Amphibian: Baluchistan toad.

Pakistan Museum of Natural History

- The Pakistan Museum of Natural History has extensive collection of articles of zoological importance.

The end

www.vuCtn.com

Good Luck

Regards : Zarva Chaudhary

Admin:

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* Laiba Mahi *