

Cambrian Explosion, Macroevolution, Extinction

Recap

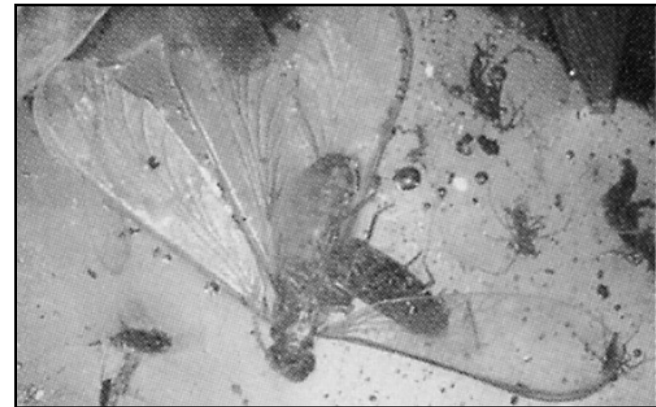
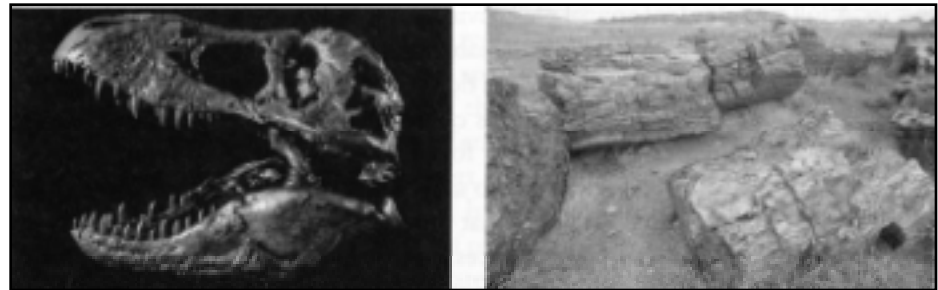
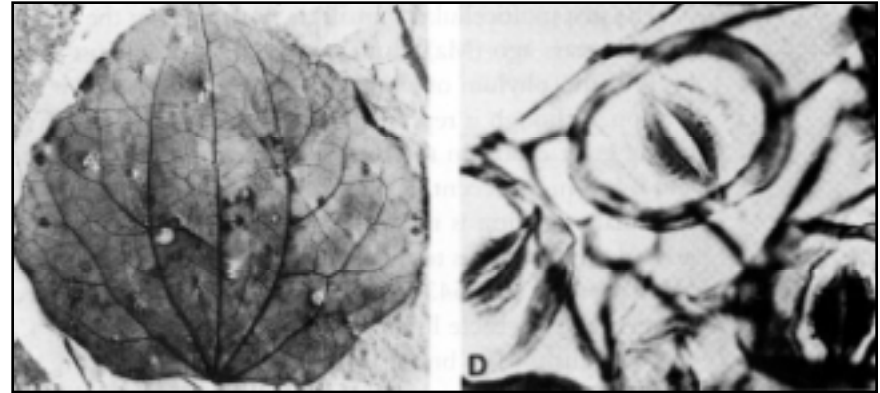
- Cellular life existed probably 3.465 bya
 - Resembled cyanobacteria
 - Likely used DNA
- Life continued as single cell organisms only for about 3.2 billion years
- Multicellular life?

Phanerozoic - visible life

- Multicellular organisms
- Appear as fossils about 565 mya
- next 40 million years
 - Nearly all major phyla appear
 - Called Cambrian explosion
- Paleontology is the study of ancient life through fossils

Types of Fossils

- Impressions
- Permineralized
- Casts
- Amber



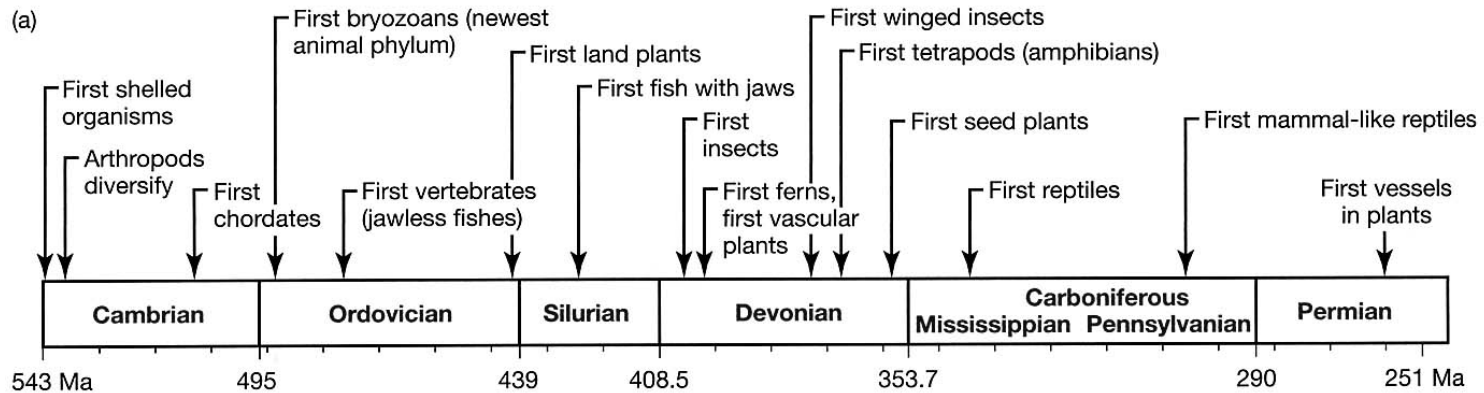
Fossil record

- Fossils created depending on specimen
 - Durability
 - Burial
 - Lack of decay (usually anoxic environment)
- Fossilization rare
 - More likely with marine or lowland delta situations
- Still fossils provide good windows to the past

Geological time

- Based on layers of fossil assemblages
- Dated by radioisotopes
- Time divided into:
 - Eons
 - Eras
 - Periods
 - » Epochs
- Cambrian to present called the phanerozoic Eon
- Phanerozoic has three eras
 - Paleozoic, Mesozoic, Cenozoic

Paleozoic



Algae abundant	Echinoderms (starfish) and other marine invertebrates diversify		First upland plant communities (evergreen forests), explosive radiation of fish, emergence of amphibians	Insects diversify, coal-forming swamps abundant, sharks abundant, radiation of amphibians	Coal-forming swamps diminish; Antarctic forested
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Climate warm	Climate continues to warm	Climate warm	Climate cooler	Climate warm; little seasonal variation	Glaciation on southern continents
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Oceans cover much of North America	Mountain building begins in eastern North America		Ural and Carpathian Mountains rise		Mountain building ends in eastern North America (Appalachians)
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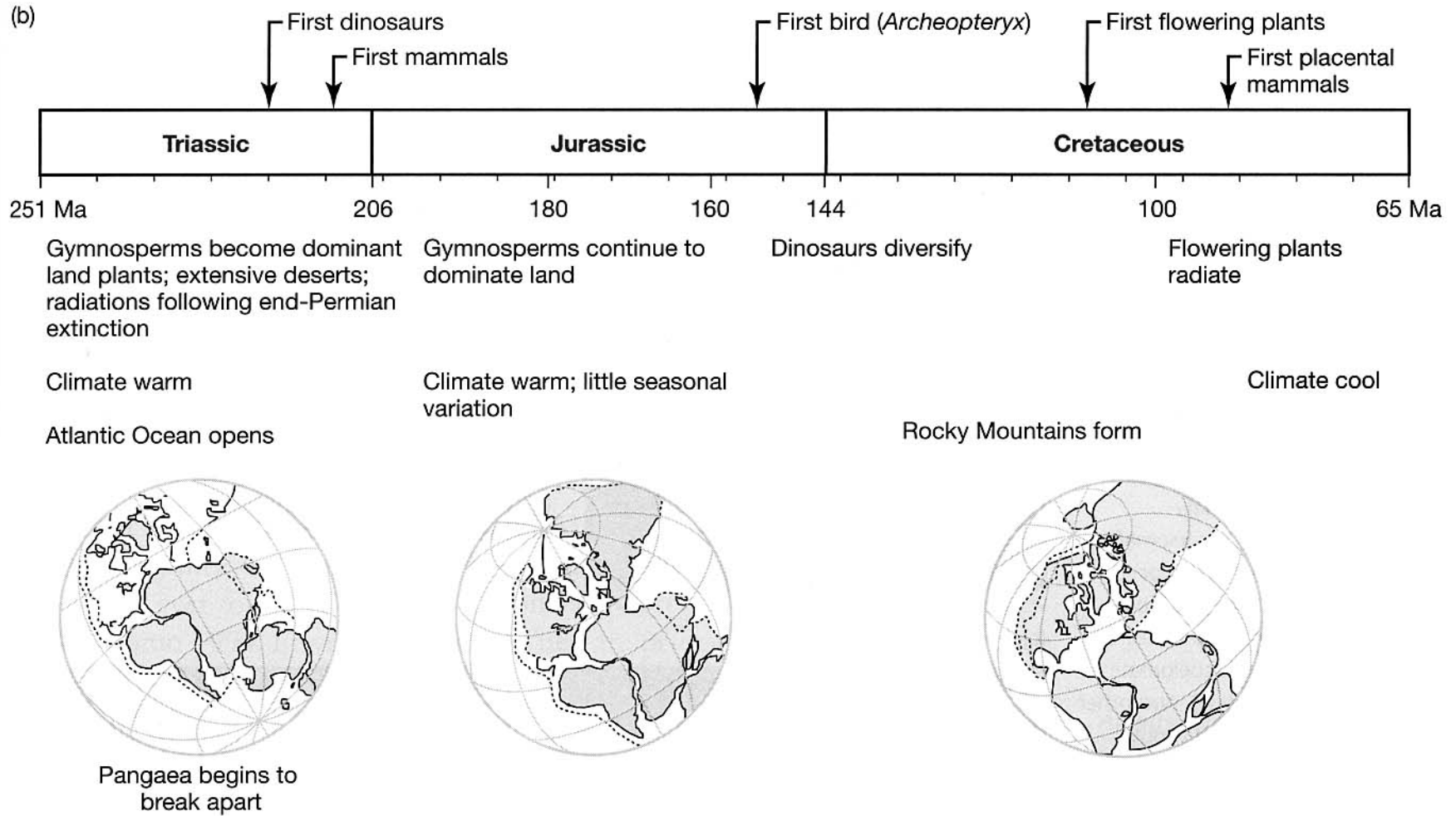


Supercontinent of Laurasia to the north and Gondwana to the south

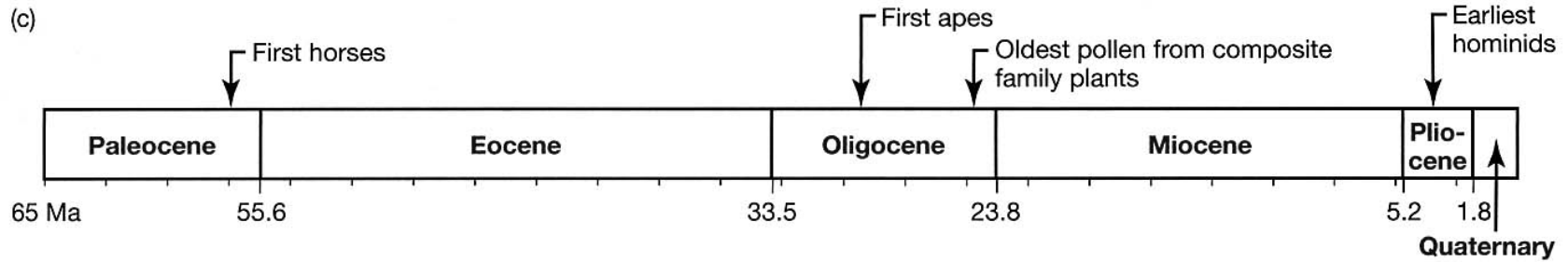


Supercontinent Pangaea intact

Mesozoic



Cenozoic



Radiation of mammalian orders

Radiation of angiosperms and pollinating insects

Radiation of grazing mammals

Ice begins to form at poles

Strong drying trend in Africa and other continents; grasslands form

Beginning of Antarctic ice cap

Worldwide glaciation

Collision of India with Eurasia begins

Alps and Himalayas begin to rise

Opening of the Red Sea

Uplift of the Sierra Nevada



Continents close to present positions

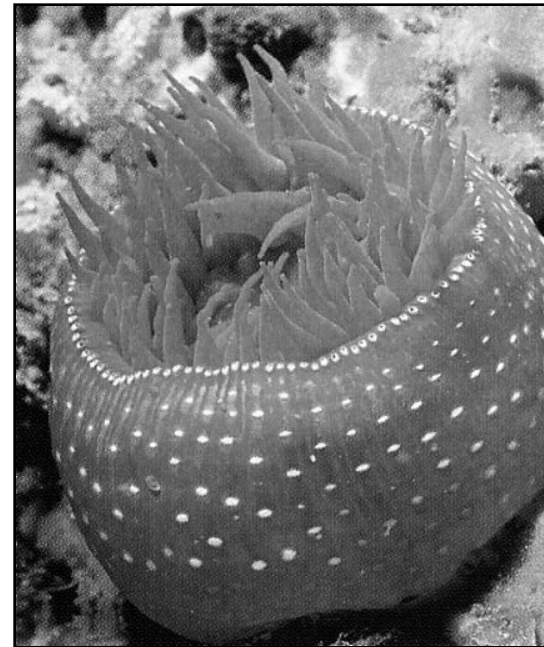
North and South America joined by land bridge

Cambrian Explosion details

- 40 my period nearly all major animal phyla appear
- Phyla assigned based on embryonic development and distinct adult body plans
- Several major divisions
 - Diplo versus triploblasts
 - Types of coelom (gut)
 - Protostome v deuterostome gastrulation

Diploblasts and triploblasts

- Diploblasts have two embryonic tissue types
 - Endoderm and ectoderm
 - Radially symmetrical
 - E.g. sponges, cnidarians, ctenophores
- Triploblasts have three (mesoderm layer added)
 - Bilateral symmetry



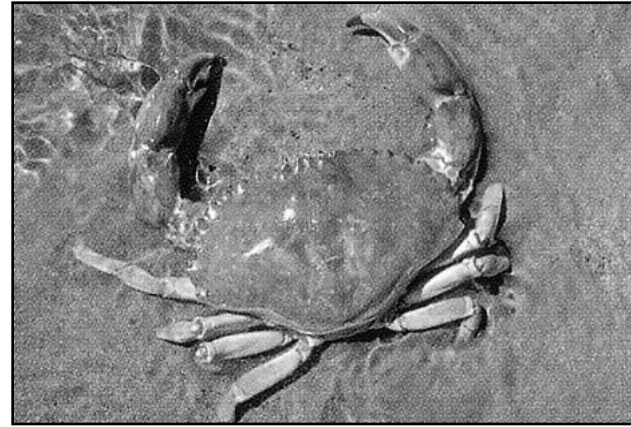
Triploblast coelom types

- Acoelomates
 - No gut, like flatworms
- Coelomates
 - Have coelom = true gut
 - Derived from mesoderm
- Pseudocoelomates
 - Have body cavity, but not from mesoderm
 - Secondarily derived



Triploblast coelomates

- Protostomes
 - Mouth first gastrulation
- Deuterostomes
 - Mouth after anus

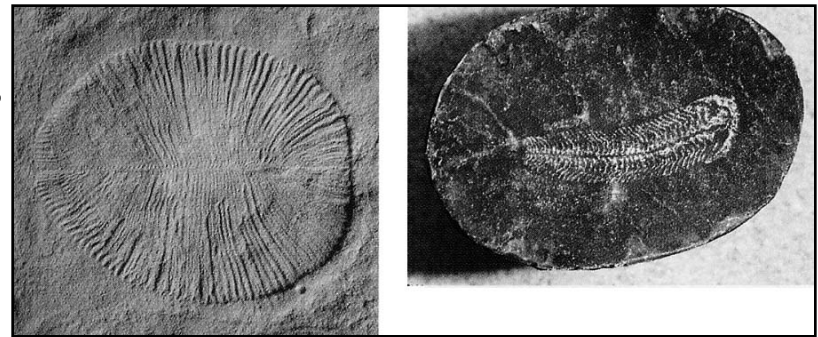


Faunal Cambrian diversification

Two well preserved faunas 40 my apart

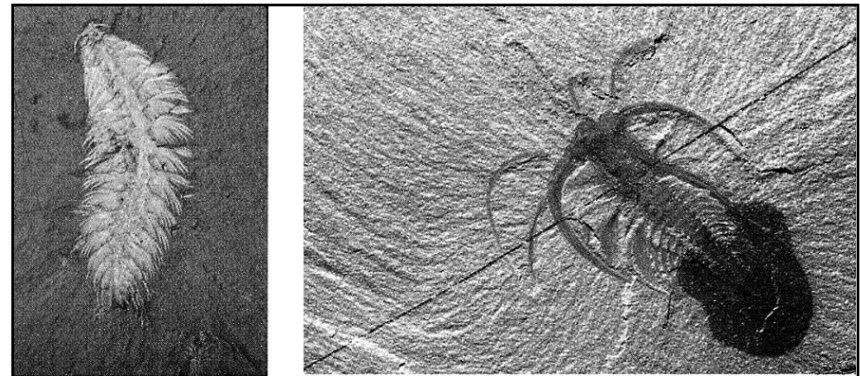
- Ediacaran, first found in Australia

- Dated to 565 mya
- Soft bodied impression fossils
 - Sponges, jellyfish, comb jellies



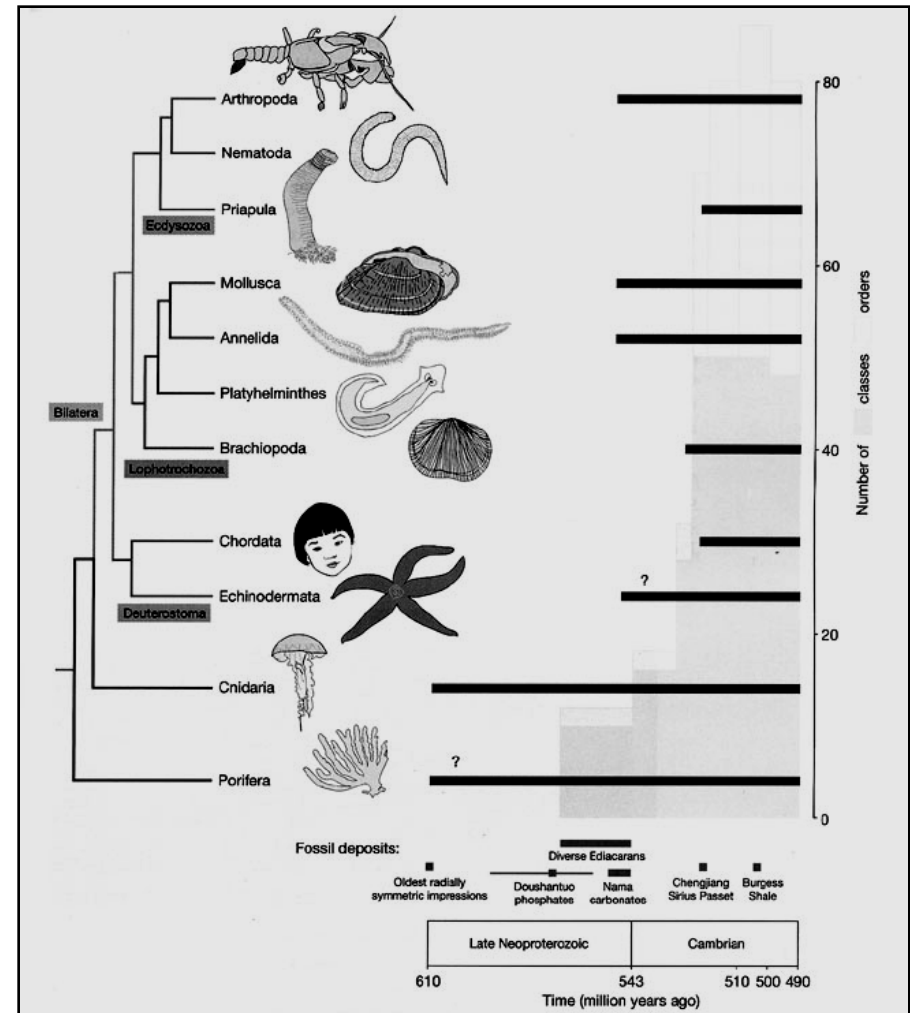
- Burgess Shale (British Columbia) Chengjiang (China)

- Dated to 520-515 mya
- Impression fossils



Dating Cambrian Explosion

- Molecular data
- Early divergence
 - E.g. 1 bya
 - Not 565 mya
- Suggests older fossils may be found.



Why Cambrian explosion?

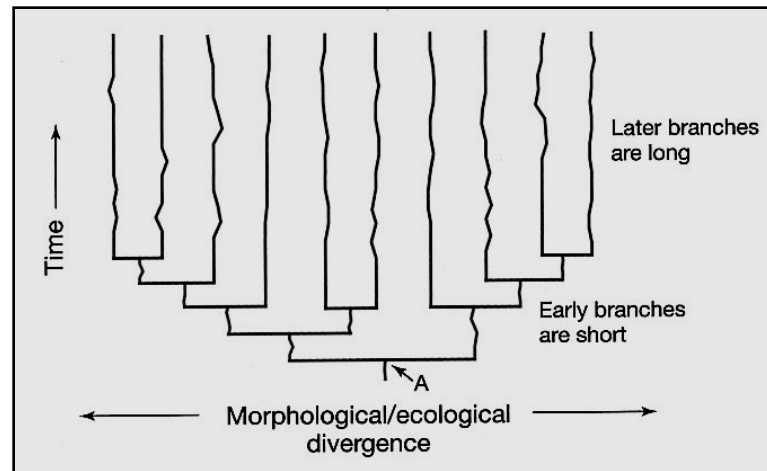
- Ecological niches
 - Ediacaran fauna sessile or planktonic filter feeders
 - Cambrian developed grazers, predators, burrowers, swimming
- New modes of active locomotion made possible by rising oxygen in sea water
- Predation and locomotion favor hard body parts
 - Shells
 - Mineralized skeletons

Macroevolution

- Microevolution
 - Within population evolutionary change
 - Adaptation, selection, drift etc.
- Macroevolution
 - Large scale changes in history of life
 - Adaptive radiation
 - Gradual change versus stasis
 - Extinction

Adaptive radiation

- Single ancestral species diversifies into a wide range of descendent species
 - Accompanied by ecological niche diversification
- E.g. Galapagos finches, Hawaiian *Drosophila*



Triggers for adaptive radiation

- Ecological opportunity
 - Islands with “empty” niches; few competitors
- Morphological innovation
 - E.g. arthropod jointed limbs
 - Allowed exploitation of land

Rate of major evolutionary change: stasis versus gradualism

- Stasis: things stay the same
 - Or in “equilibrium” condition
- Punctuated equilibrium
 - Idea that most evolutionary change occurs rapidly
 - Associated with speciation events
 - Long periods of no change between
- Gradualism
 - Idea that most evolutionary change is continuous

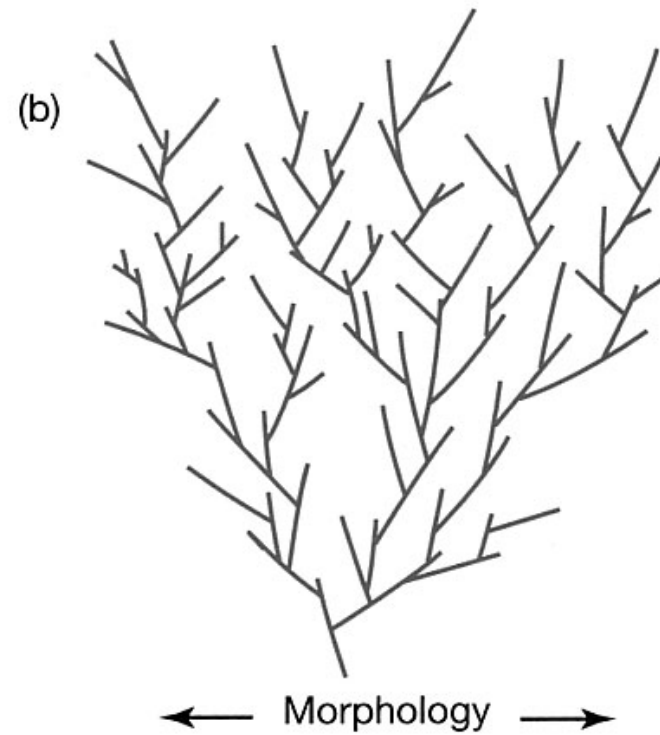
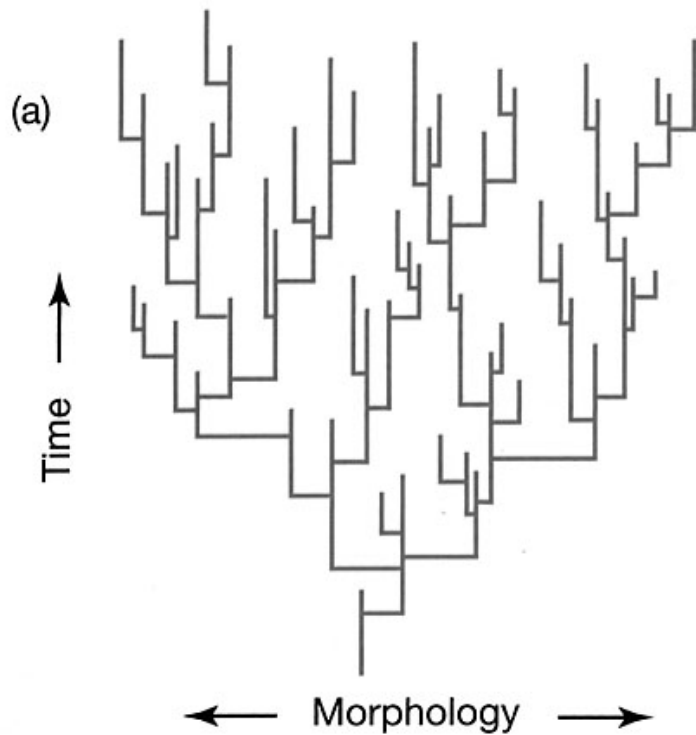
Darwin was a gradualist

- Expected evolutionary change to be slow and continuous
 - Predicts many many intermediate forms
 - Many of course have been found in major groups
 - But many fossil morphological species
 - Appear suddenly in fossil record
 - Fewer transitional forms than you might expect
- Darwin attributed stasis to incomplete fossil record

Eldridge and Gould

- 1972 published idea of “punctuated equilibrium”
- Accepts stasis as real
 - There are long periods of time during which a species changes little morphologically
 - Sudden changes “punctuate” the stasis

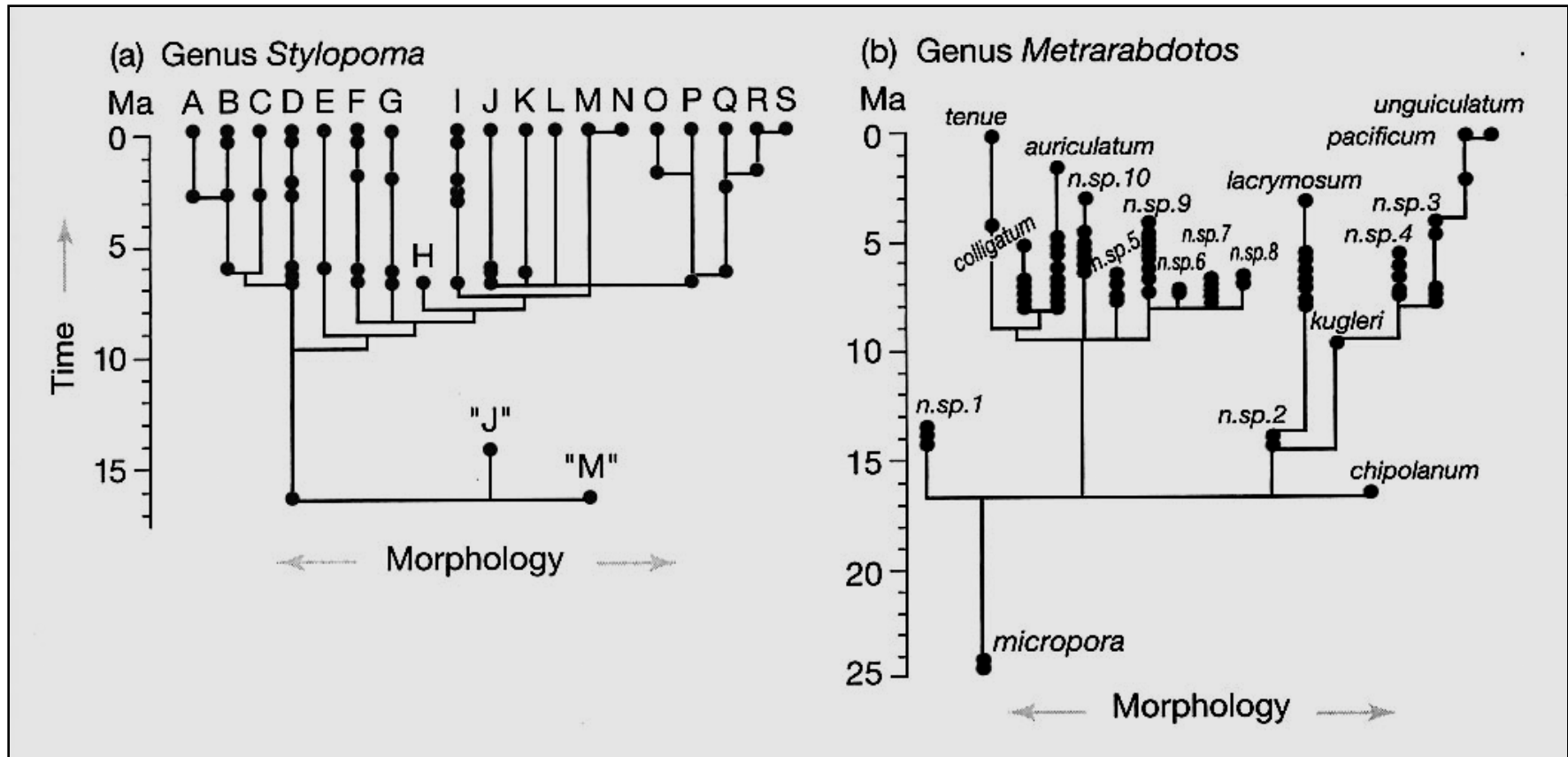
Punctuated equilibrium v. gradual change



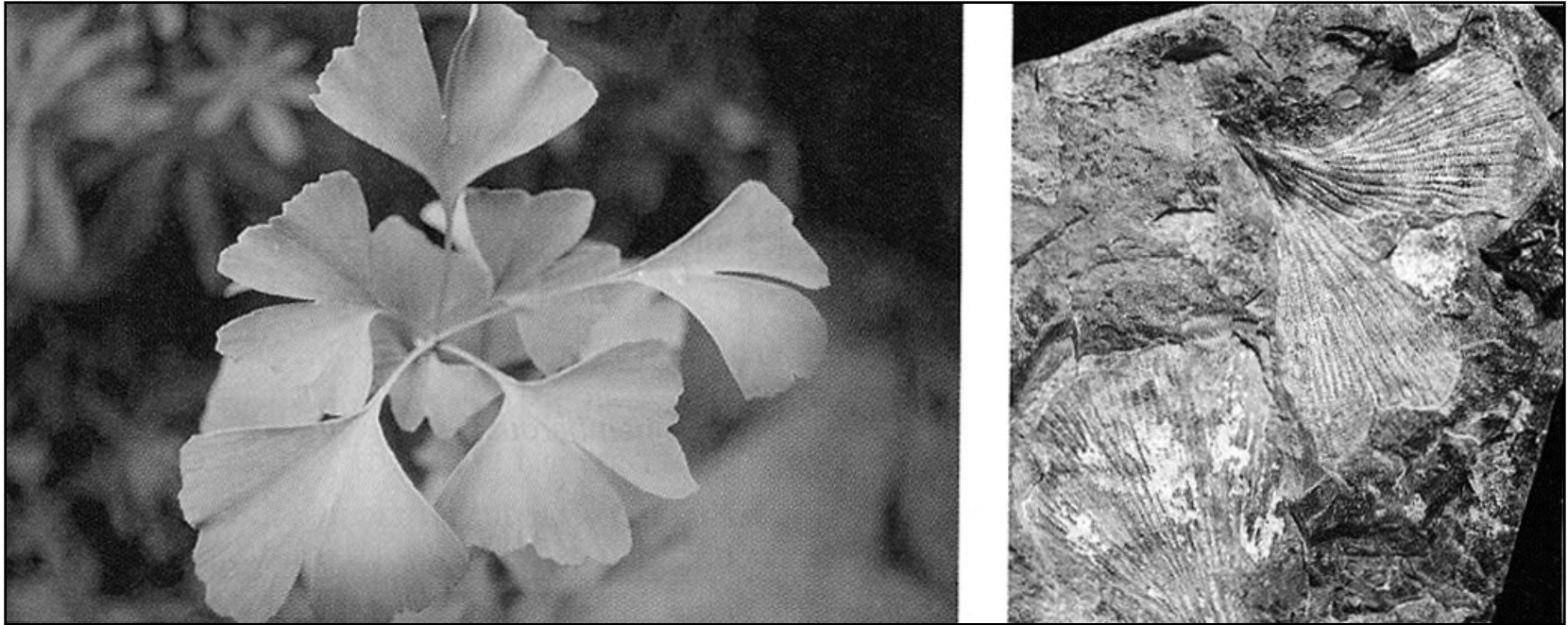
Timescales

- Paleontologist might say
 - Speciation was “instantaneous” in fossil record
 - An “instant” in geologic time could easily be 100,000 years in ecological time
 - Tens or hundreds of thousands of generations
- Evidence of stasis
 - Requires group with known phylogeny
 - Sampling at close time scales

Bryozoan stasis



“Living fossils” show stasis



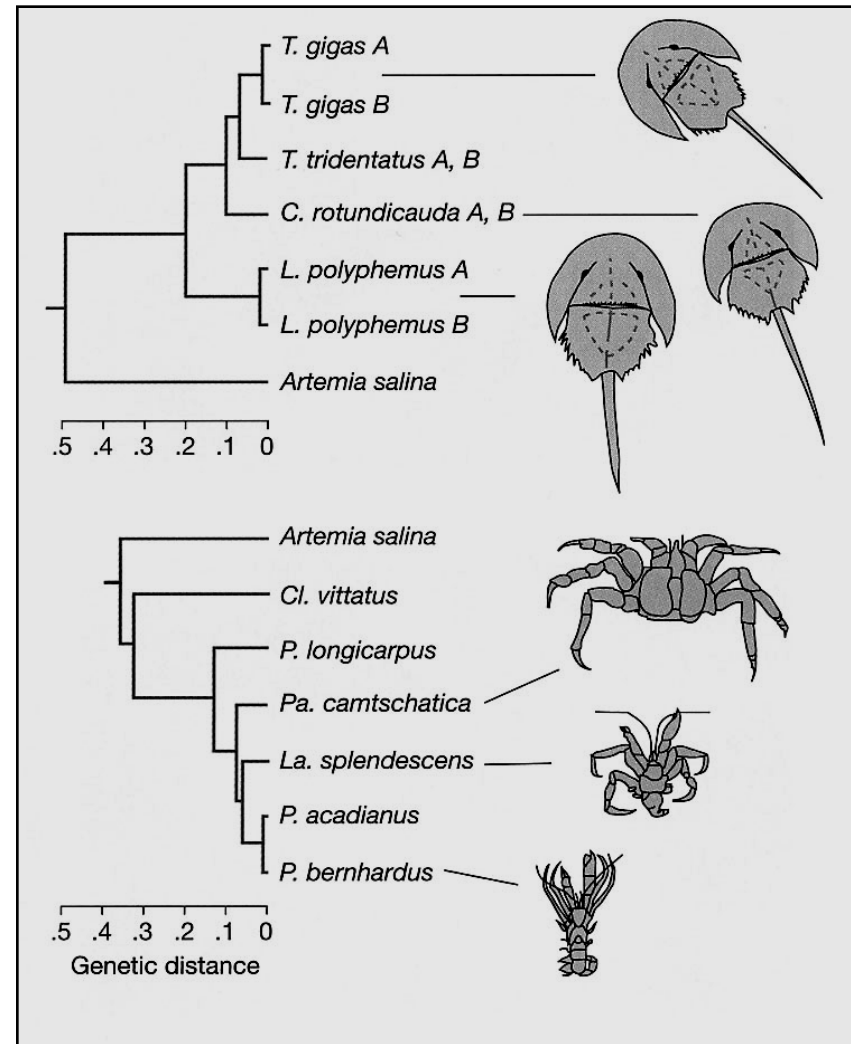
Modern Ginkgo plant and 40 my fossil.

Consensus

- Both gradualism and punctuated equilibrium occur
 - Likelihood even depends on types of organisms
 - Small marine forms gradual
 - Foraminifera, radiolarians
 - Larger organisms more often punctuated
 - Arthropods, bivalves, corals etc.

Why stasis?

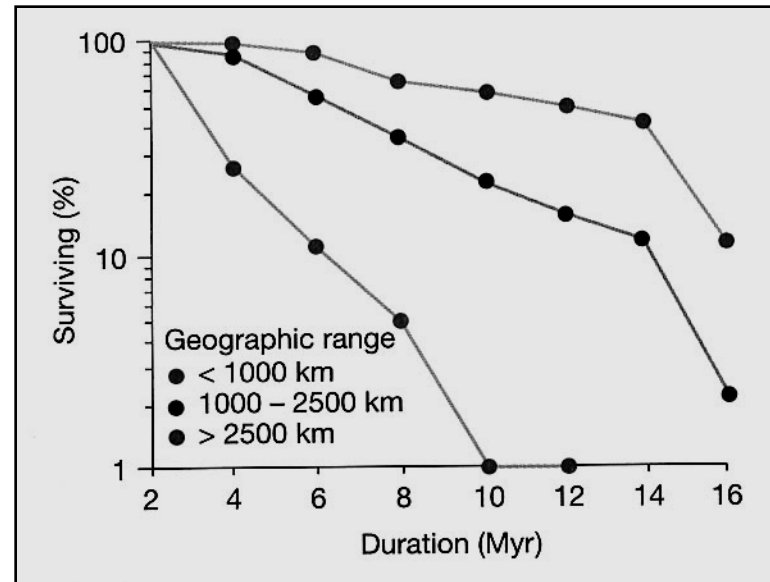
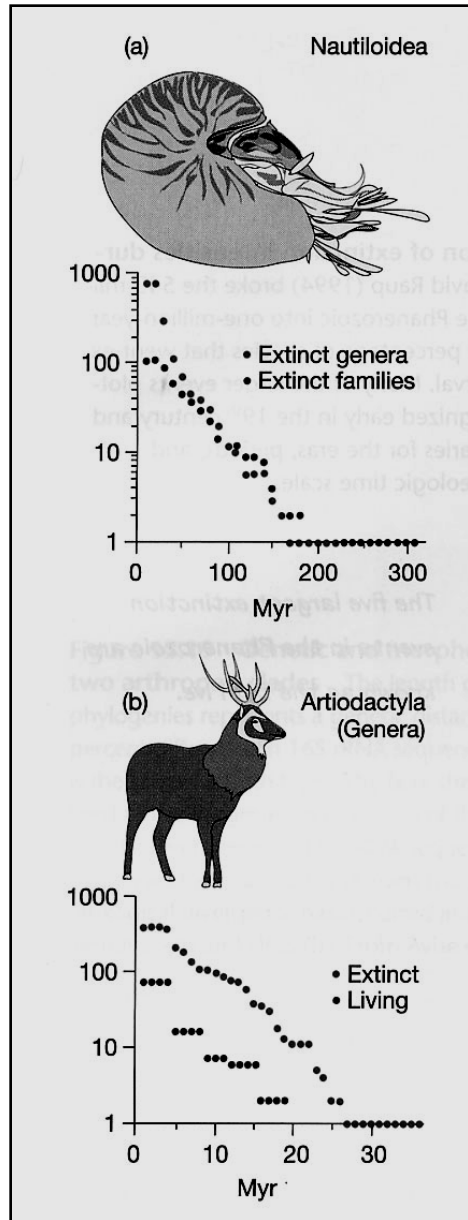
- If stasis is real, and it seems to be, then why?
 - Ecological stability for morphotypes
 - Continued adaptation in coevolutionary races
- Horseshoe crabs show morphological stasis
 - But still have lots of evolutionary change



Extinction

- Species and higher taxa die out
 - Normal fate of species
 - Background extinction
 - Species longevity
 - Mass extinctions

Normal species extinctions



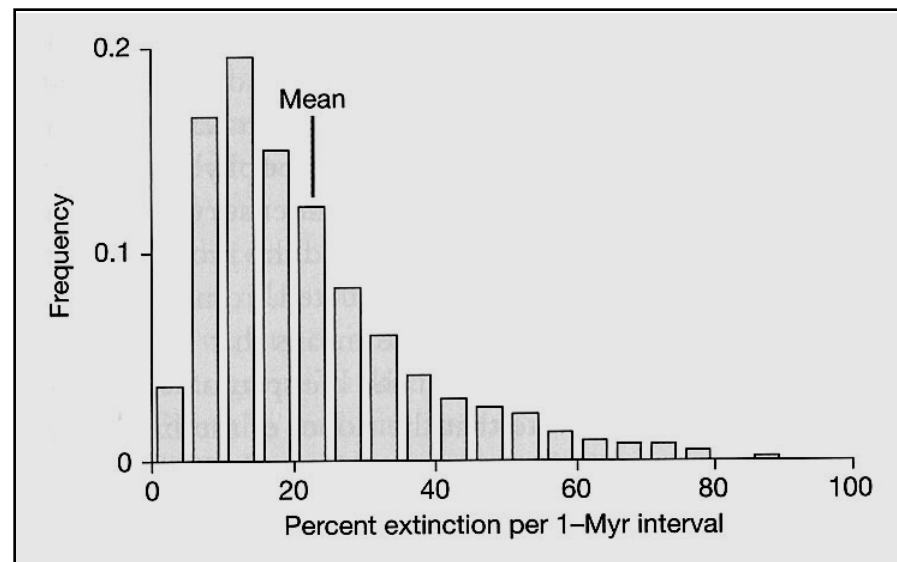
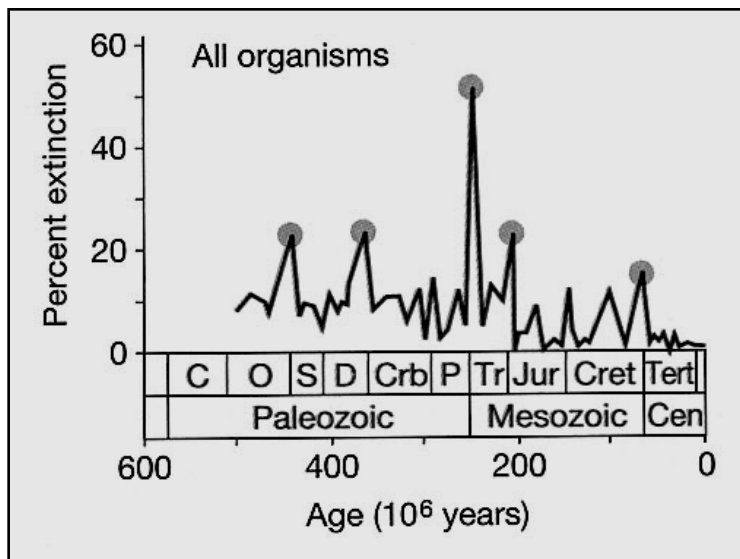
Linear curves mean extinction rates constant within clades

Geographically widespread taxa less likely to die off

“typical” species lifespan ca. 1 my

Mass extinctions

- 5 times in Phanerozoic % extinction peaks
 - Mass extinctions 60% of species died



Importance of mass extinctions

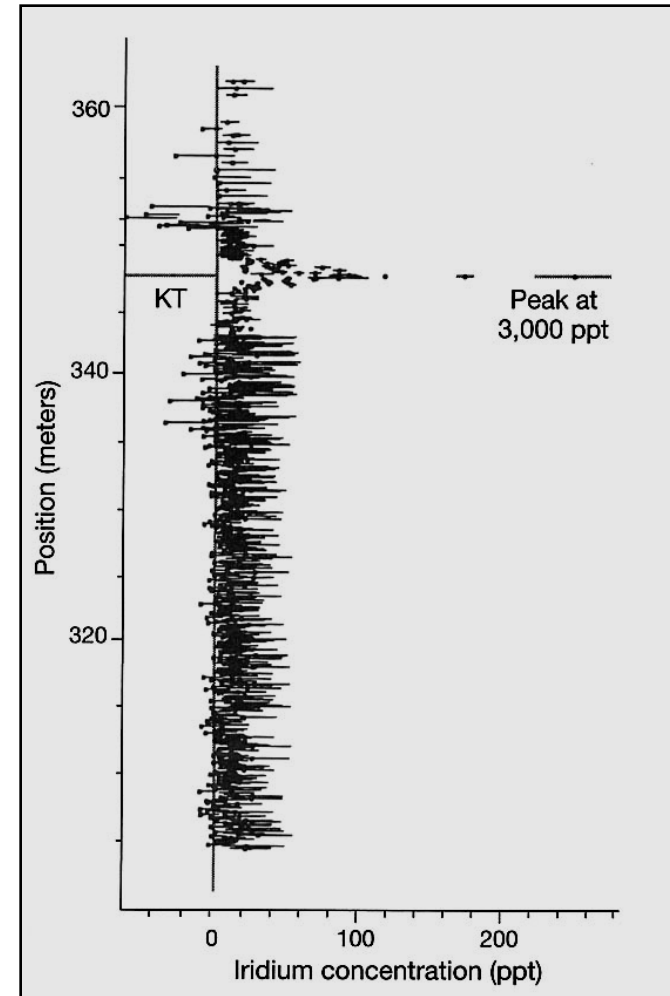
- Major groups may die off
 - Opens competitive vacuum
 - Lots of open niche space
 - E.g., dinosaur extinction allowed mammals to diversify (adaptive radiation)

So how did those dinosaurs die?

- What are mechanisms of mass extinctions?
 - Environmental change
 - Oxygen production by photosynthesis surely poisoned the environment for previously dominant anaerobic bacteria
 - Meteor impacts
 - Cretaceous-Tertiary boundary
 - Called K-T boundary, 65 mya

Asteroid impact evidence

- Iridium layer
 - Iridium naturally rare on earth, abundant in asteroids, peaks at K-T boundary
- Based on amount of iridium, asteroid estimated to be 10 km wide

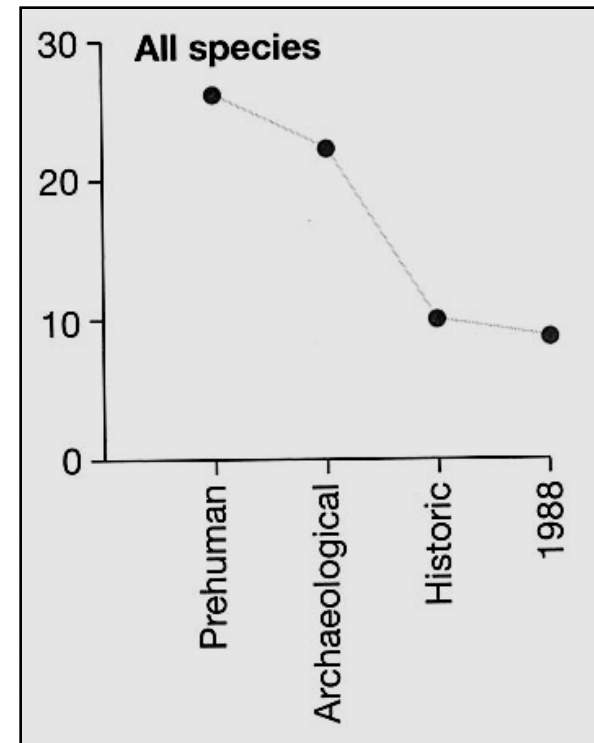


Human induced extinctions

- Many think a 6th mass extinction event underway
 - Caused by humans

Evidence: polynesian bird fauna

- Estimated 2000 bird species (20%) went extinct as humans colonized pacific islands
 - E.g. 60 spp. On Hawaii
 - 1500 years of human habitation
 - 44 species on New Zealand
 - Data for 'Eua (Tonga) ->
- Causes
 - Hunting
 - Introduction of rats, dogs, pigs



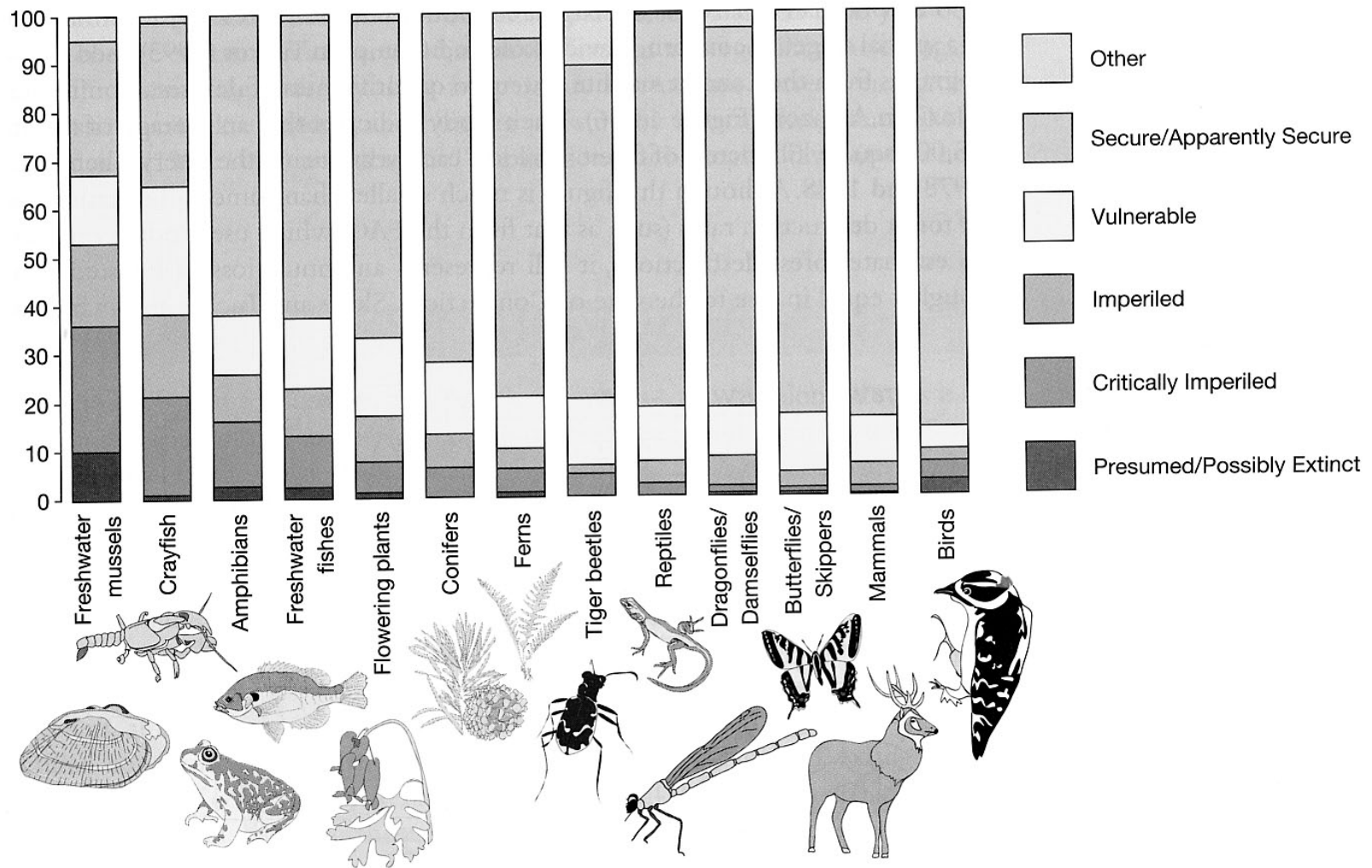
North American Pleistocene megafauna

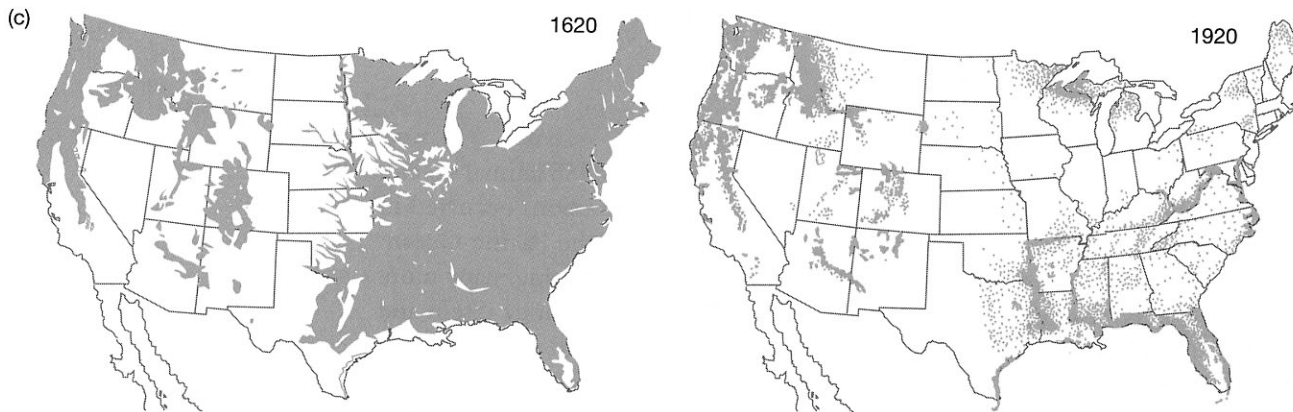
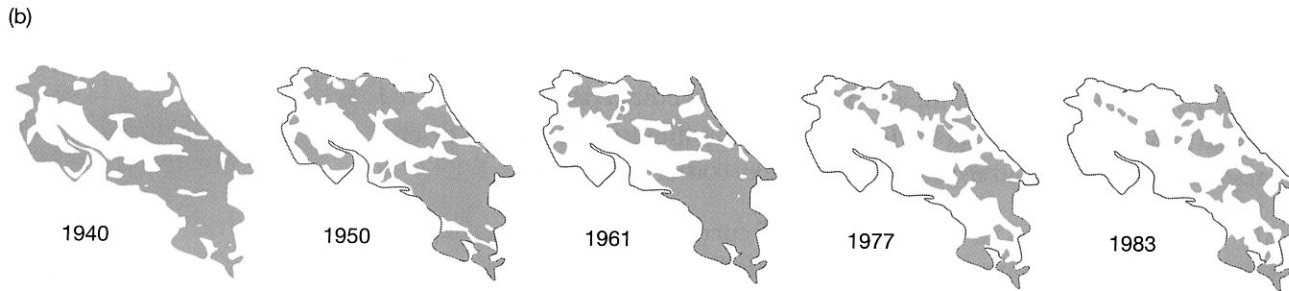
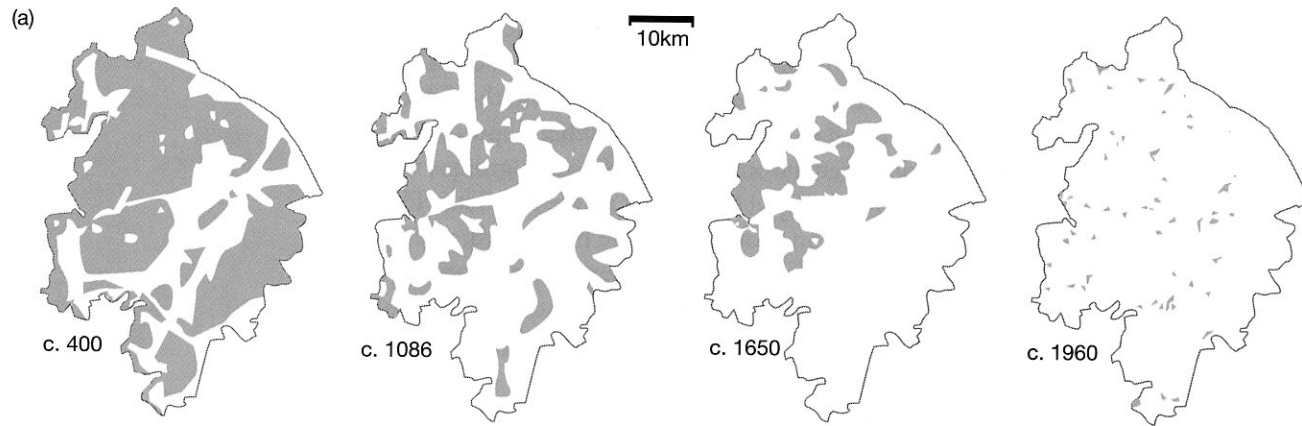
- Woolly mammoths, giant ground sloths, camels, woolly rhino
- Died off at same time as human arrival from Beringia
- Likely due to hunting and climate change

Modern human extinctions

- Since 1600, relatively few identified
 - 486 animal species, 600 plants
- Major current threat habitat loss

North American species status





Habitat loss: forests

Warwickshire,
England

Costa Rica

USA