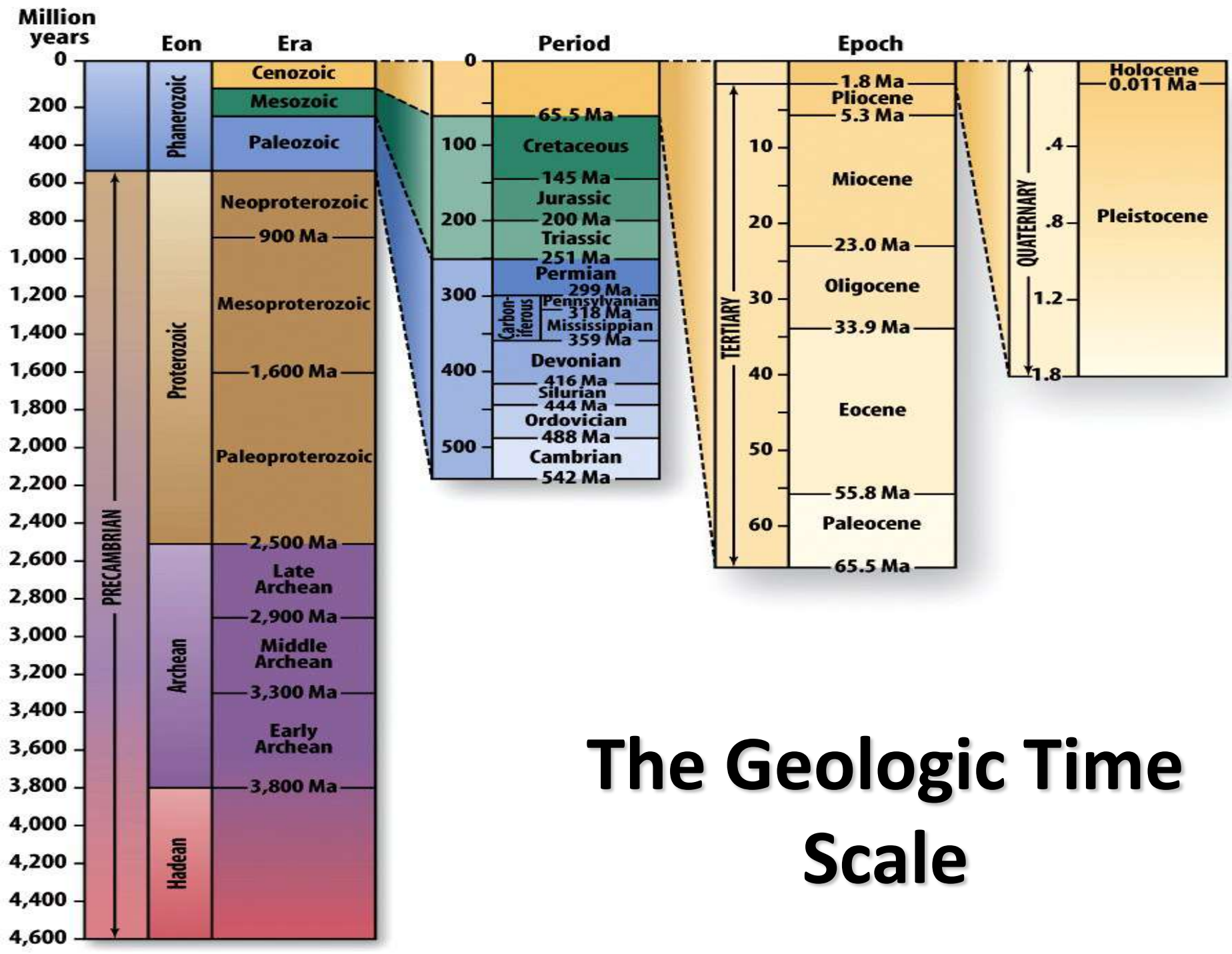
A brief history of the Earth!



The Geologic Time Scale

Age of the Earth

Hadean Eon

Hadean Eon (4.57-3.85 Gyrs)

Hell on Earth:

4.527 Gyrs – formation of Moon

4.5 Gyrs - magma ocean, differentiation of core, mantle and crust

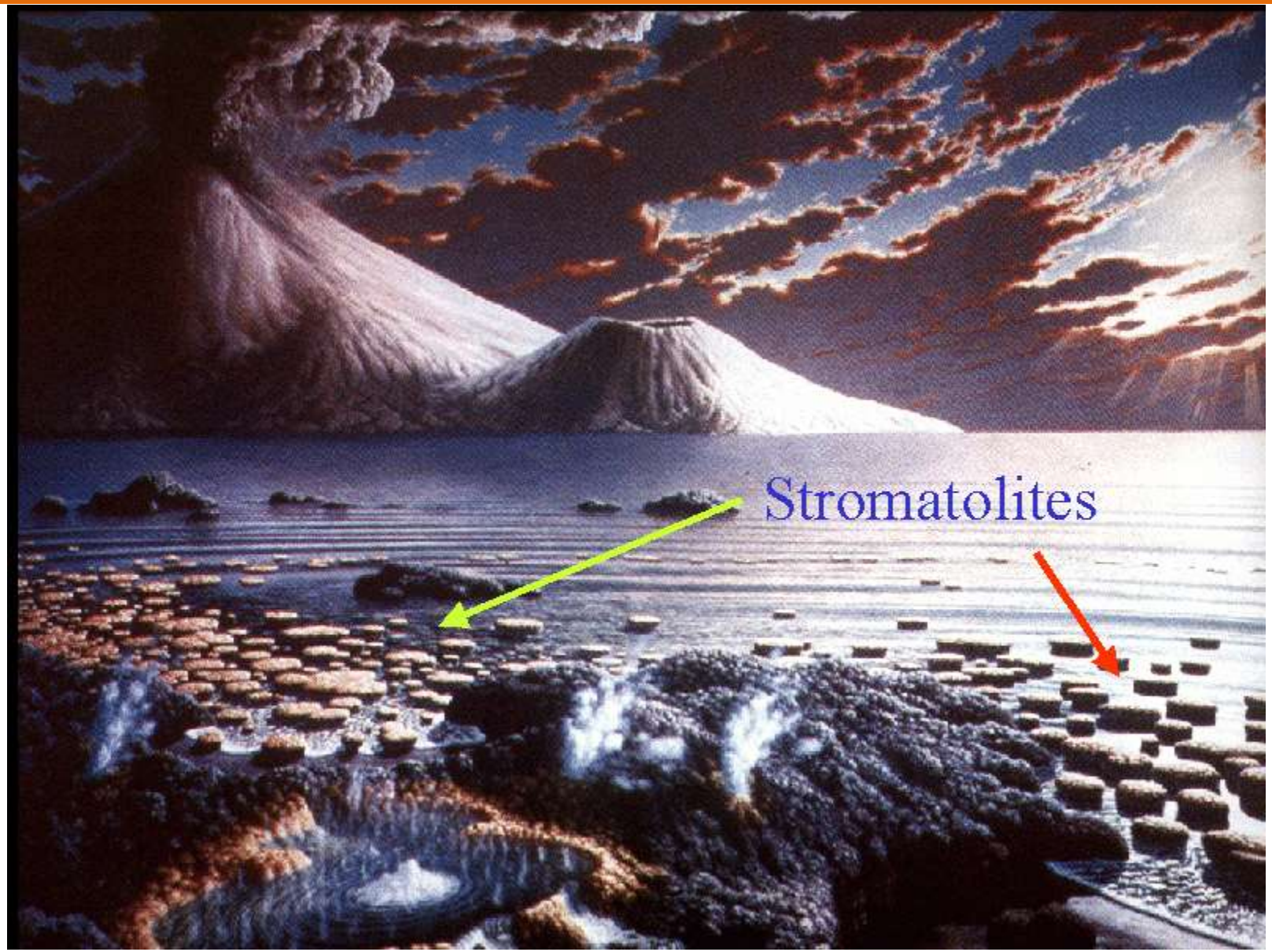
4.4 Gyrs – earliest dated zircons

4.03 Gyrs – earliest dated whole rock

4 – 3.9 Gyrs - Heavy bombardment of meteors and comets would have pulverized or re-melted any solid rock crust, destroyed any early oceans or atmosphere

3.9 – 3.85 Gyrs – After bombardment land masses and oceans developed very quickly (sedimentary rocks dated to 3850 Myrs)

Archean Eon (3.85 – 2.5 Gyrs)



Archean Eon (3.85 – 2.5 Gyrs)

A time of great change:

- Oceans continued to form which removed H_2O and CO_2 (by dissolution) leaving N_2 as main gas in atmosphere
- Amount of continental crust rapidly increased from 0 to 80% of today's area
- Plate tectonics began probably towards end of Archean
- Weathering of new crust created ocean salinity
- First life evolved and had colonized shallow and deep oceans by end of Archean
  - Very simple, prokaryotic (no nucleus), photosynthetic organisms which released O_2 to environment, including atmosphere
  - Organisms limited to fermentation rather than respiration to release energy - less efficient so cells were small and simple
  - Built structures known as stromatolites

What do we need to make life?

- And where would we get it?

Origin of life on Earth: What we know

- Life probably developed on Earth ~3.5 billion years ago
- Evidence?
- Earliest organism probably even simpler than bacteria
- 3 things needed for this organism to develop:
  - Chemosynthesis = synthesis of small organic molecules e.g. amino acids
  - Biosynthesis = combination of small organic molecules into larger, more complex molecules e.g. proteins
  - Development of chemical processes needed for replication e.g. DNA and RNA

Origin of life on Earth: Possible mechanisms

Not known how or where life originated.

Origin of life on Earth: Possible mechanisms

Not known how or where life originated.

1. ‘Primordial soup’

   - products of chemosynthesis collected in surface waters and combine to form larger molecules due to lightening or meteor/comet impacts

vw.cbs.dtu.dk/staff/dave/roanoke/bio101ch19a.htm

Origin of life on Earth: Possible mechanisms

Not known how or where life originated.

2. Black smokers (deep-sea hydrothermal vents)

   - organic molecules formed on surfaces of mineral grains, became concentrated and more complex reactions began to occur

Origin of life on Earth: Possible mechanisms

Not known how or where life originated.

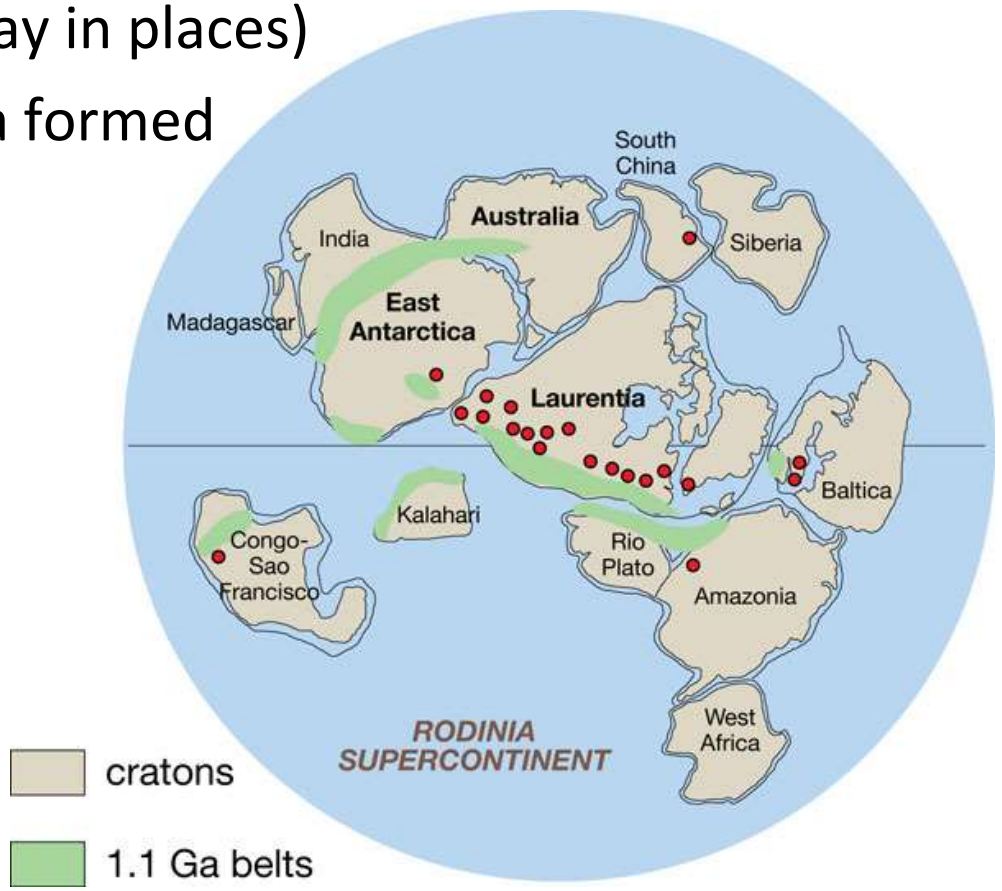
3. Organic molecules from space (panspermia!)

   - many organic molecules found in space but where does energy come from and how would the molecules survive the conditions of space

Proterozoic (2.5 Gyrs – 542 Myrs)

Transition to the modern world:

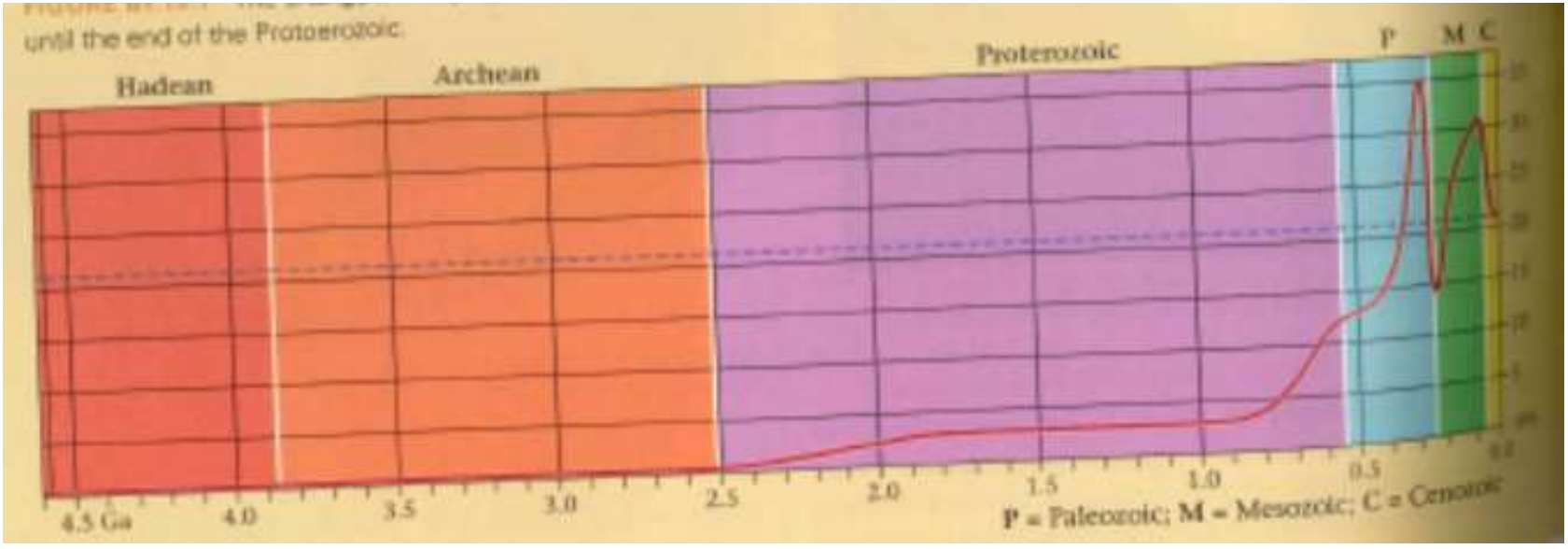
- Continental crust continued to form but at a slower rate
- Collisions resulted in formation of large stable continents (cratons) that still exist today in places)
- At 1000 – 750 Myrs Rodinia formed



Proterozoic (2.5 Gyrs – 542 Myrs)

Transition to the modern world:

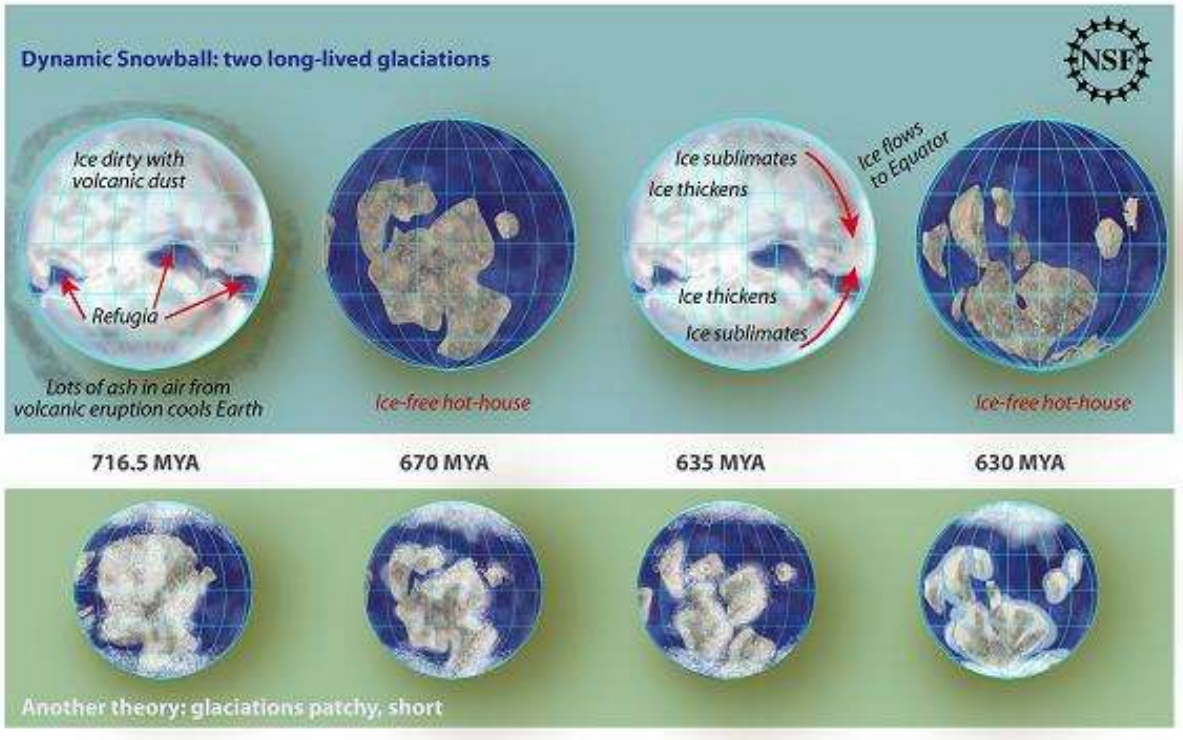
- Life continued to evolve and become more complex from prokaryotic to eukaryotic (2.7-2.1 Gyrs)
- Why? Because of atmospheric oxygen increases which allowed respiration and large, more complex cells
- Similar pattern occurred again at 750 Myrs – perhaps multicellular creatures

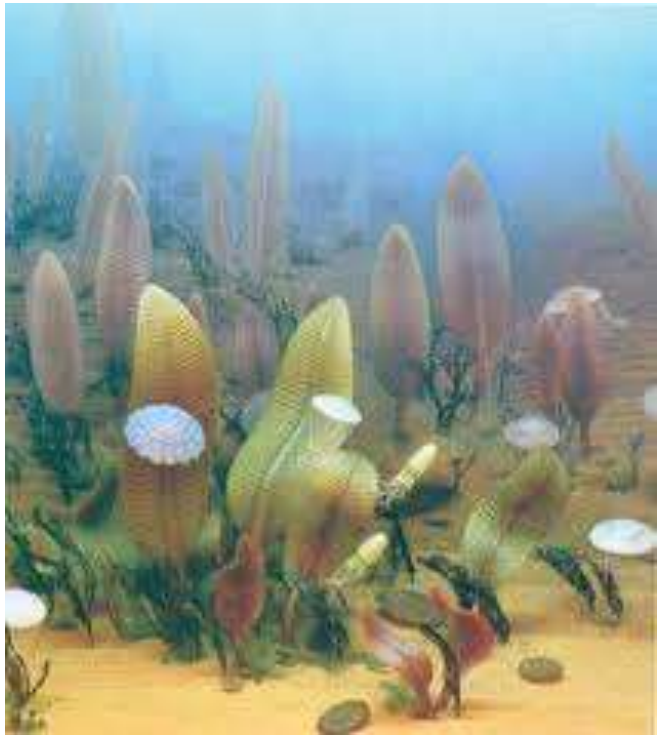


Proterozoic (2.5 Gyrs – 542 Myrs)

Transition to the modern world:

- Very radical climate changes at the end of the Proterozoic – Snowball Earth
- Subsequently extremely rapid evolution (known as Ediacaran fauna)

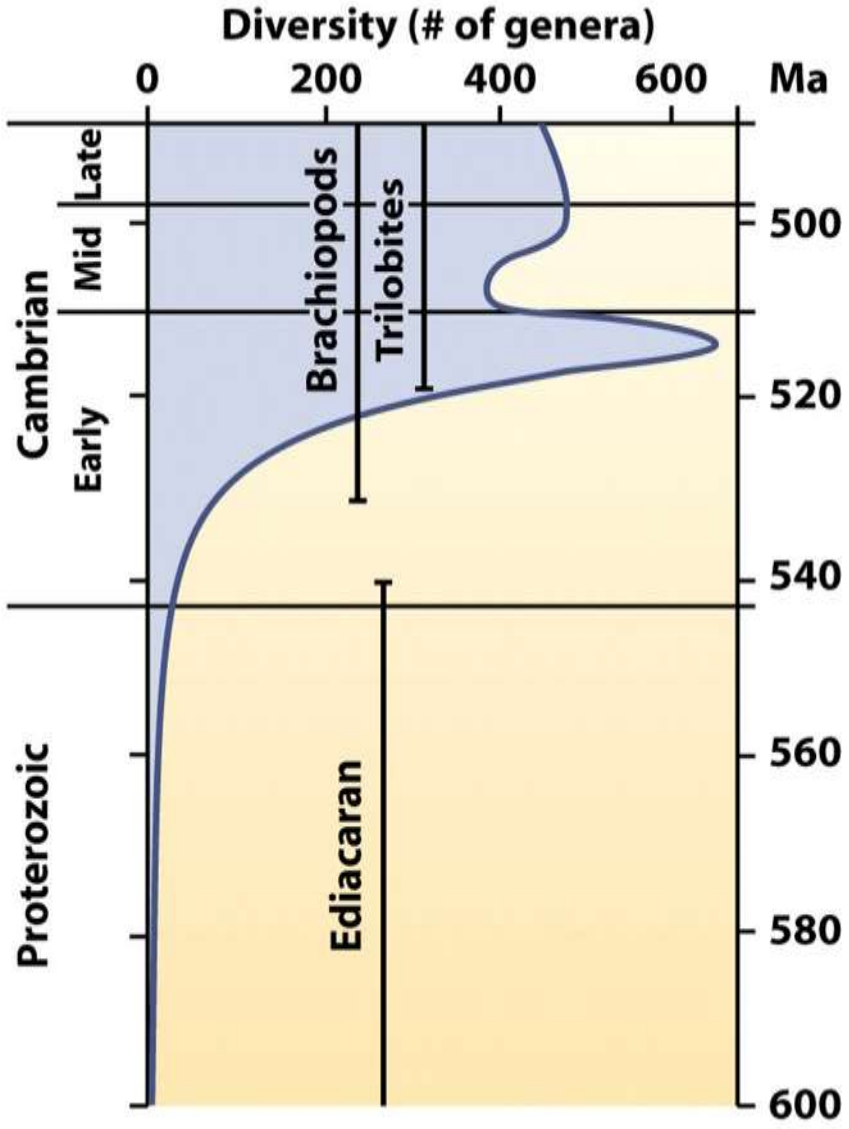




Phanerozoic (542 Myrs – today)

~530 Myrs

- "Cambrian explosion"
- Major increase in organism diversity
- Introduction of internal and external skeletons
- Why did this 'explosion' occur?
  - Sexual reproduction?
  - Continued buildup of O_2 allowed formation of carbonate skeletons?



Phanerozoic (542 Myrs – today)

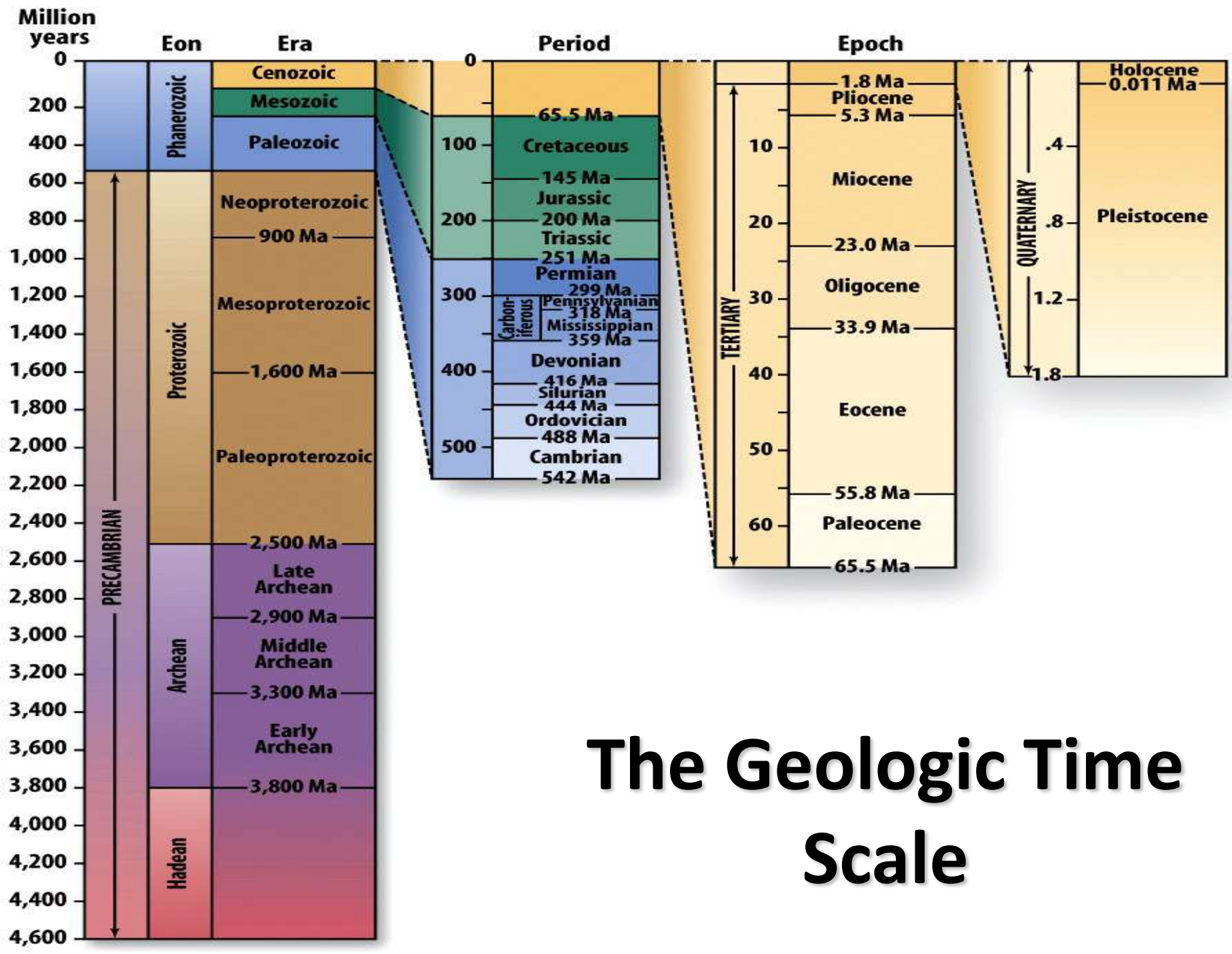
~500 million years ago

- Life left oceans to develop on land
- For life to exist on land need:

Phanerozoic (542 Myrs – today)

~500 million years ago

- Life left oceans to develop on land
- For life to exist on land need:
  - Structural support
  - Ability to transfer water within the organism and keep from dehydrating
  - Ability to exchange gases with air instead of water
  - Moist environment for reproductive system
  - Protection from UV radiation



The Geologic Time Scale

Summary - Life on land: Plants

- Evolved from green algae
- Earliest plants were seedless, reproduced using spores e.g. ferns
- Gymnosperms – evolved seeds which allowed plants to spread to more diverse habitats e.g. conifers
- Angiosperms – developed flowers to attract pollinators, increasing their reproductive success

http://www.lni.wa.gov/Safety/Research/Dermatitis/EdMat/PhytoS

Summary - Life on land: Insects

- Ocean arthropods were first animals to move to land, probably in the form of centipedes and millipedes
- Well suited to the land environment due to their exoskeletons and small size
- Insects are the most diverse and numerous animal group, despite their simple vascular systems

Summary - Life on land: Vertebrates

- First animals with backbones were fish. Later moved onto the land because their fins could act as limbs and existing vascular system
- Evolved into amphibians – limited to moist environments
- Amphibians → reptiles → mammals and birds
- Mammals so successful due to:

Summary - Life on land: Vertebrates

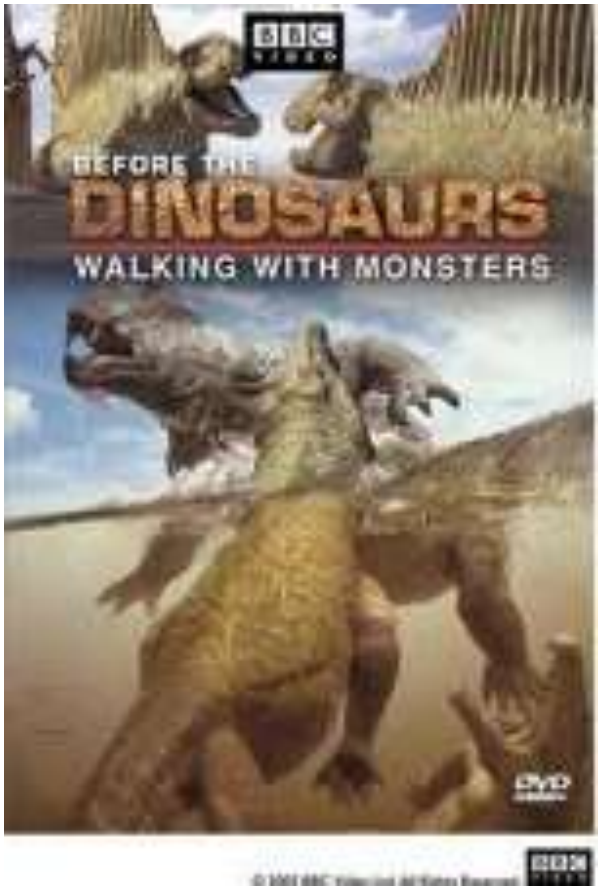
- First animals with backbones were fish. Later moved onto the land because their fins could act as limbs and existing vascular system
- Evolved into amphibians – limited to moist environments
- Amphibians → reptiles → mammals and birds
- Mammals so successful due to:
  - More complex brain
  - Faster metabolism
  - Reproductive strategies

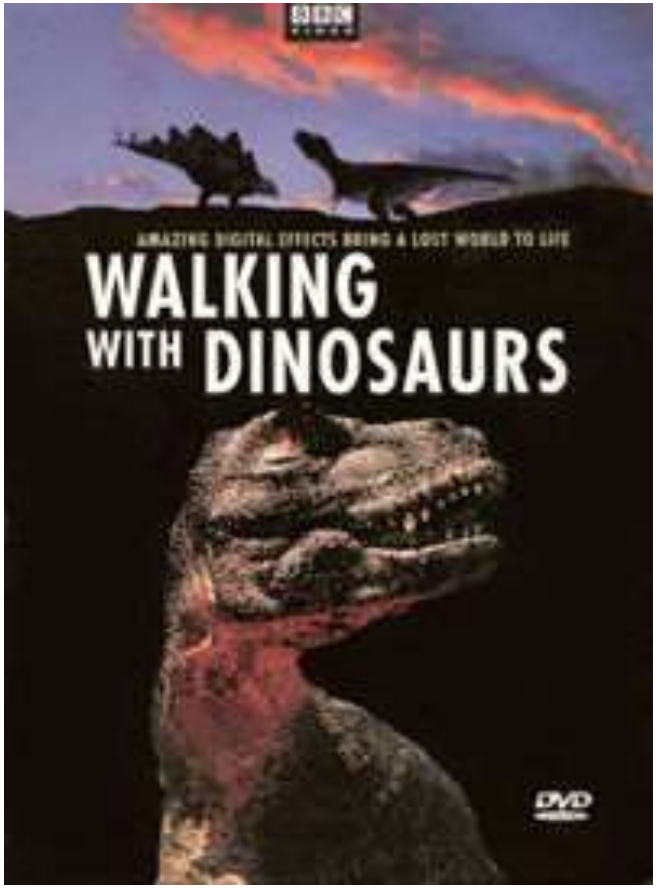
Question: Putting it all together

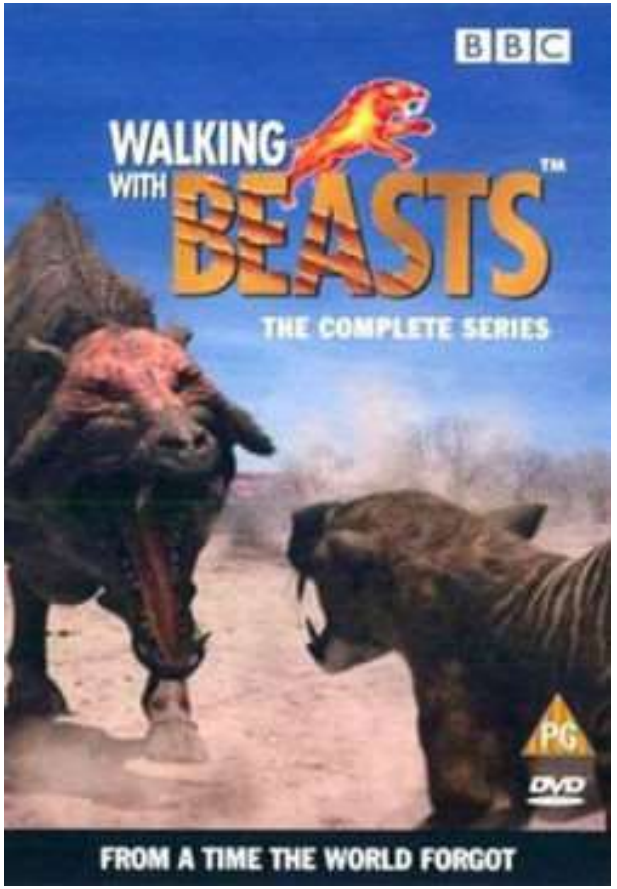
Can you put the images below in order from oldest to most recent?

A) B-A-C
B) C-B-A
C) A-C-B
D) C-A-B

All available streaming on Netflix

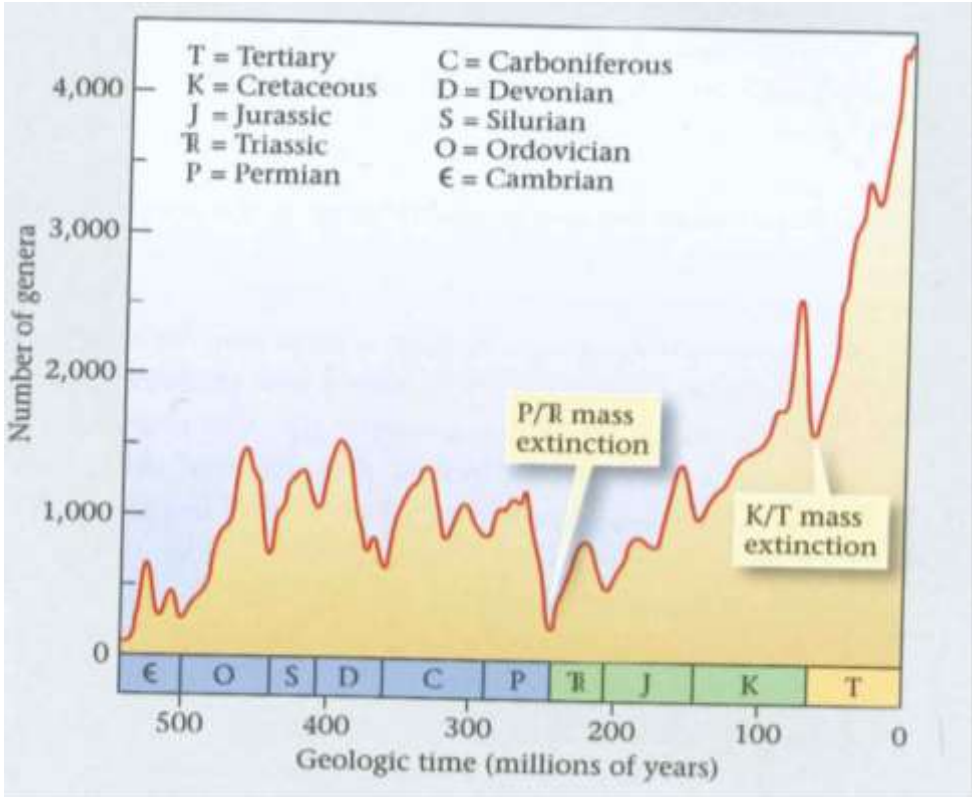






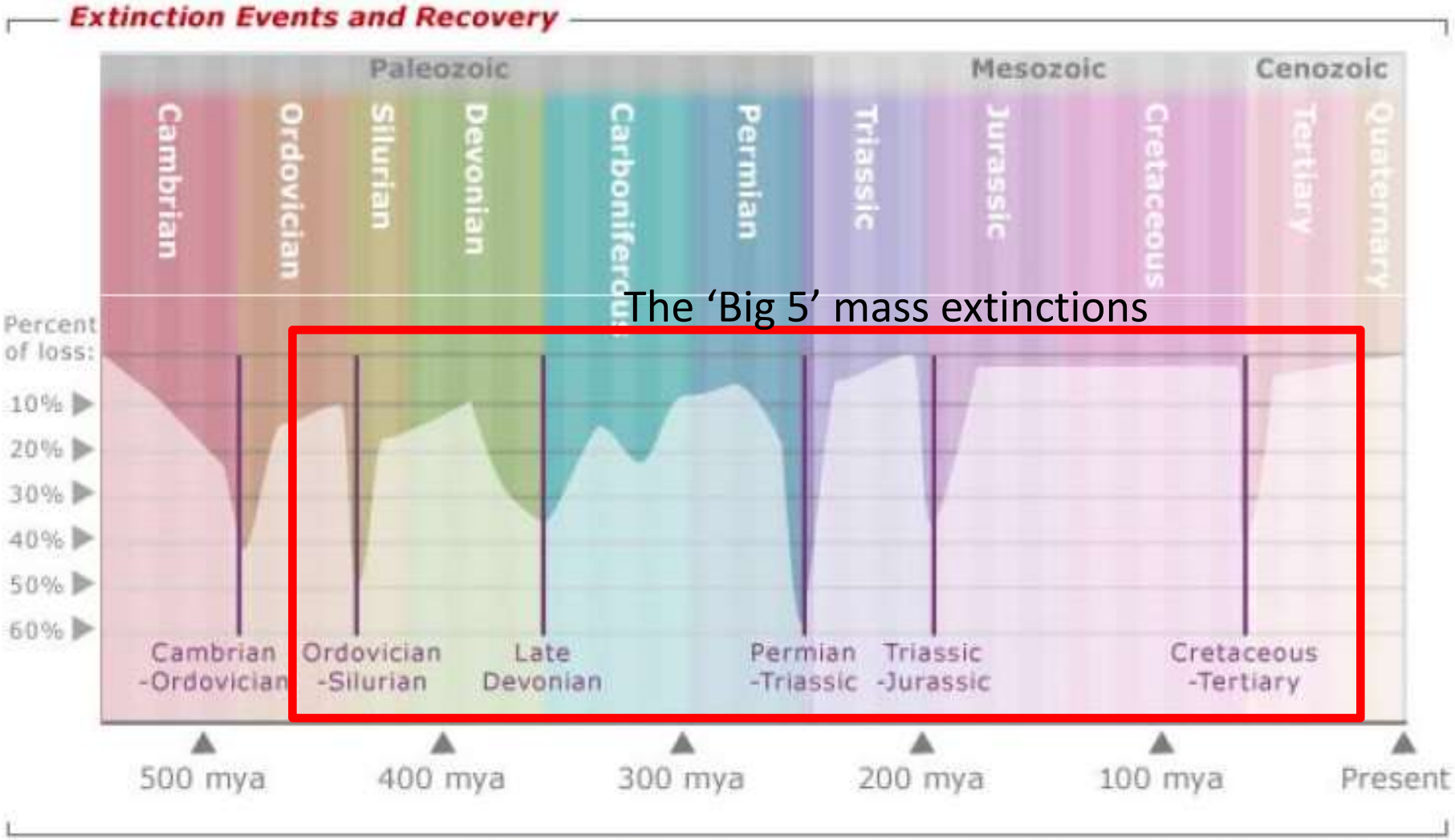
Phanerozoic (542 Myrs – today)

- Over time new species evolve while others become extinct. Change in the number of species = origination rate - extinction rate
- Background extinction rates = ~15 species per year (different in past)
- But…extinction rates can increase due to various factors
- If enough species become extinct over a period of time we call this a mass extinction



Phanerozoic (542 Myrs – today)

- Mass extinctions have been common through Earth history



http://www.personal.psu.edu/staff/d/r/drs18/biscilmages/extinctionEvents.jpg

Mass Extinctions: Possible Causes

What do you think could cause a mass extinction event?

(Can you think of at least 4?)

Mass Extinctions: Possible Causes

What are they?

Possible effects?

How to identify in geological record?

Duration

Mass Extinctions: Possible Causes

1. Impact Events

What are they?

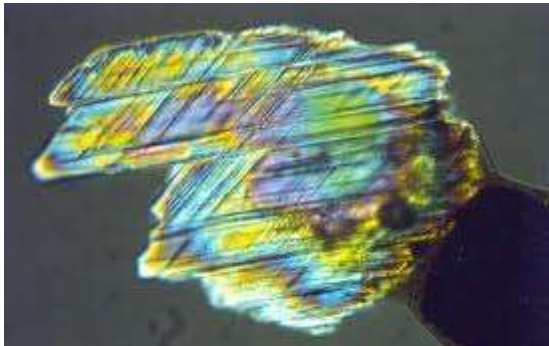
Impacts of large meteorites or comets

Possible effects?

Blast wave igniting forest fires, megatsunamis, shockwaves leading to earthquakes and volcanic eruptions, dust blasted into atmosphere causing 1) global cooling and reduction in photosynthesis (also known as nuclear winter) and 2) acid rain and rapid greenhouse effect

How to identify in geological record?

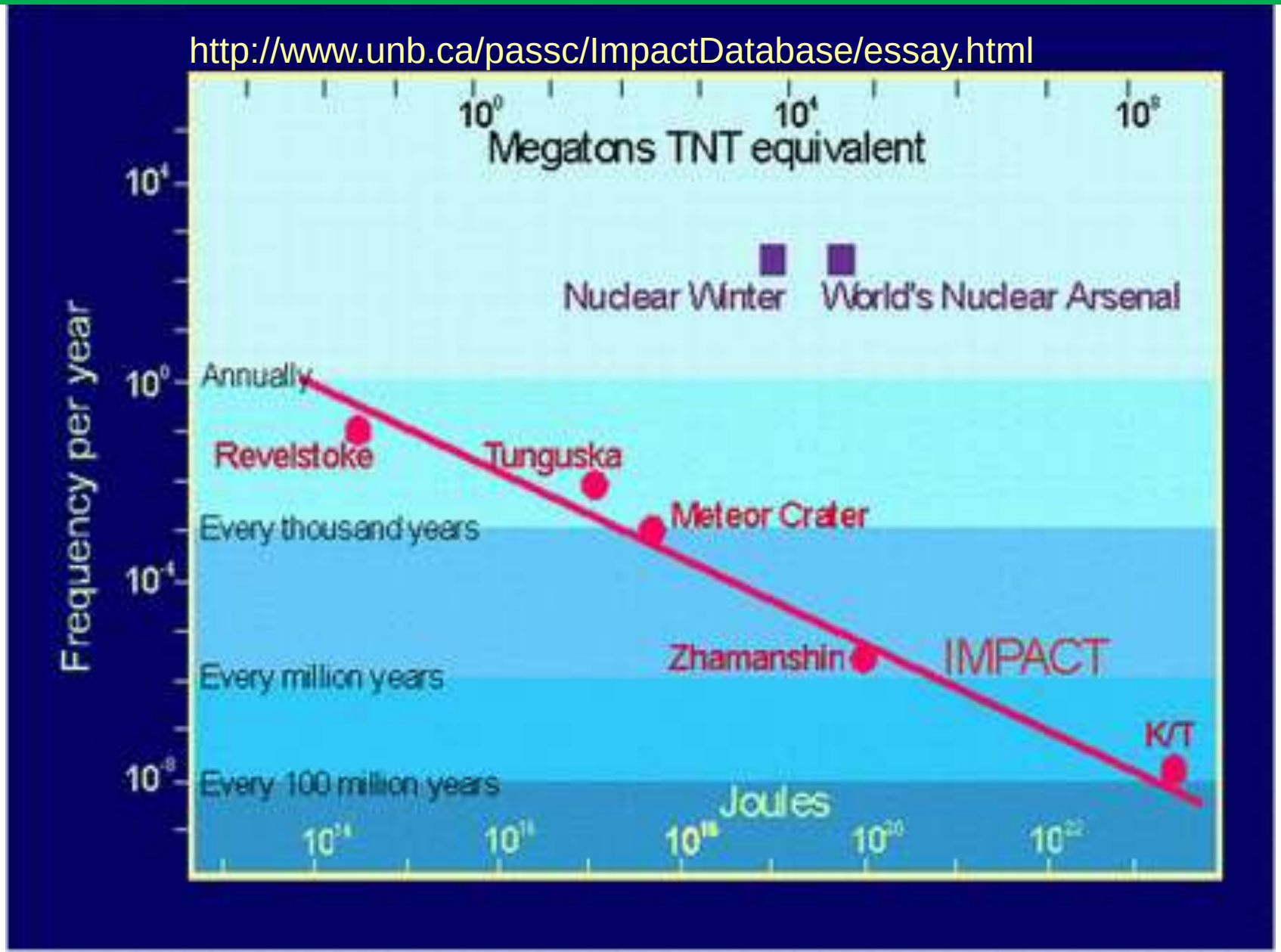
Impact crater, presence of unusual elements in sediments around the world e.g. iridium, 'shocked' quartz, and tektites



Duration – very fast!!

Mass Extinctions: Possible Causes

http://www.unb.ca/passc/ImpactDatabase/essay.html



Mass Extinctions: Possible Causes

- Tunguska, Siberia
- 1908
- Probably 10m meteor/comet fragment exploded 5-10km above surface of Earth
- Equivalent to 5-30 Megatons (1000 x Hiroshima bomb)
- Flattened 770 square miles of trees (80 million) trees)

Mass Extinctions: Possible Causes

2. Volcanism (flood basalt eruptions)

What are they?

Very large scale volcanic activity on land or ocean, can cover greater than 100,000 km^2 with up to 10 km thick lava flows

Possible effects?

Produce 1) dust and particulate aerosols – block light so collapse food chains and cause cooling, 2) emit sulfur oxides leading to acid rain, 3) emit CO2 leading to greenhouse effect and global warming. Can lead to dramatic reduction in oxygen in ocean (because water warmer and due to increased nutrient input leading to more primary productivity)

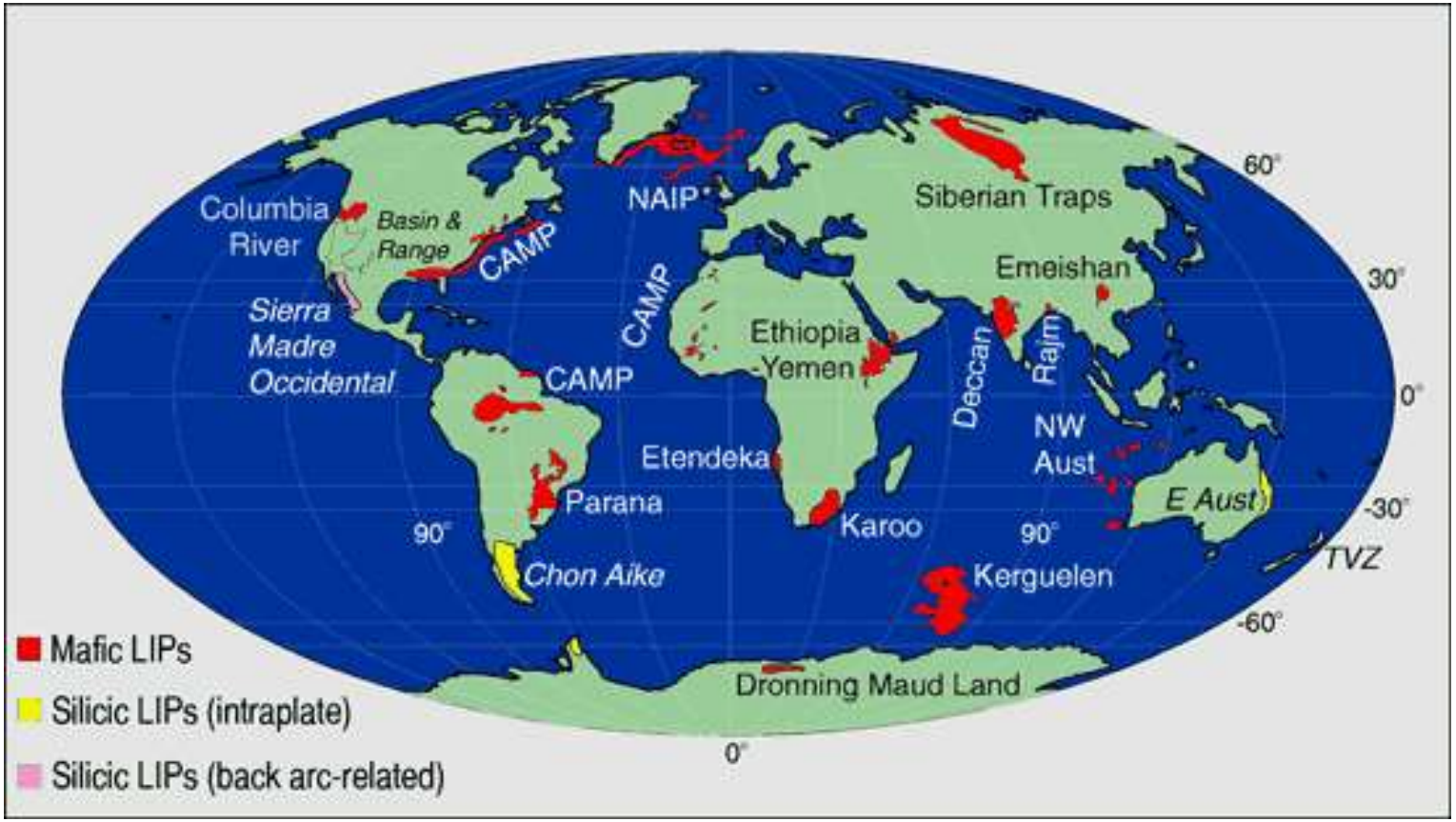
How to identify in geological record?

Large volumes of lava flows in a relatively short time

Duration – usually sporadic for less than 1 million years

Large Igneous Provinces

Very large accumulations of igneous rocks (greater than 100,000 km^2) in a short geological time (few million years or less)



Mass Extinctions: Possible Causes

3. Sea level falls

What are they?

Sea level falls as a result of glaciation or due to plate tectonic processes.

Possible effects?

Rapid reduction of productive shallow water habitats.

How to identify in geological record?

By looking at sequences of sediment along the edges of continents and by looking for evidence of glaciation on land or reconstructions of plate tectonic activity.

Duration – thousands to hundreds of thousands of years

Mass Extinctions: Possible Causes

4. Significant rapid climate changes

What are they?

Significant changes in global climate on small enough timescales that animals and/or plants do not have time to adapt

Possible effects?

Rapid change in types of habitat and ecological niches. Also changes in atmospheric and ocean circulation contribute to rapid changes in types of habitat. Initial warming can lead to release of methane from ocean sediments which leads to further rapid warming and low ocean oxygen levels. Cooling and glaciation remove available land area and lower sea level.

How to identify in geological record?

Changes in sediment type. Also isotopes can provide information about the amount of warming/cooling and changes in carbon cycle/storage

Duration – tens of thousands to millions of years

How do we work out the cause of a mass extinction?

Our proposed cause of a mass extinction has to:

- Explain which species lost and survived
- Explain pattern of loss through time
- Based on events or processes that we can show happened

Just like a detective at a crime scene, we have to identify what happened, when it happened, propose a theory to explain why it happened and search for evidence to prove or disprove the theory

Question

What might have caused the mass extinction at 65 Myrs which killed the dinosaurs?

a) Impact event

b) Flood volcanism

c) Sea level fall

d) Climate change

e) Some combination of the above

Phanerozoic (542 Myrs – today)

Cambrian – Ordovican (542-444 Myrs)

Paleogeography – Rodinia was breaking up creating passive margins, sea level was high so large shallow seas but cooled at end of Ordovician

Life – restricted to the oceans but at the end of the Ordovician land plants began to colonize shores

Earth history

- Ordovician-Silurian
- Late Devonian
- Permian-Triassic
- Triassic-Jurassic
- Cretaceous-Paleogene

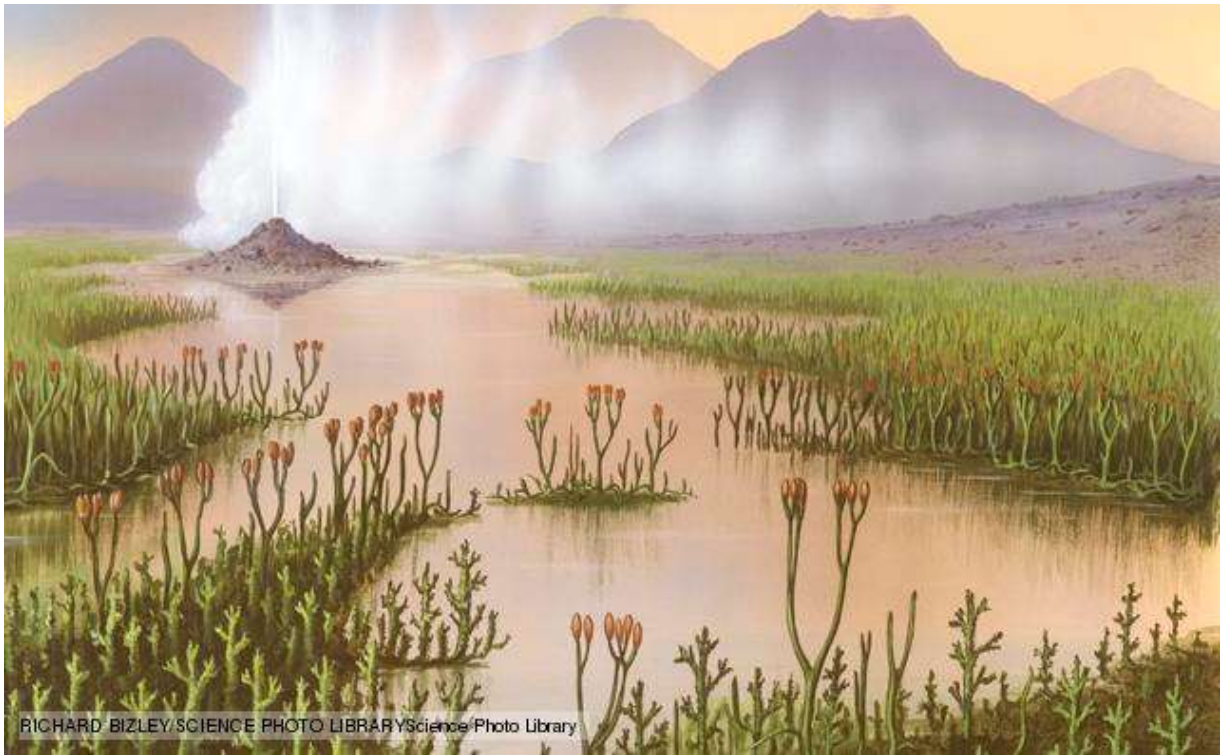
When was it and how long did it take? What died out and what survived? What are the possible causes and what evidence is there in the geological record for what happened? Are there any mysteries still?

Phanerozoic (542 Myrs – today)

Silurian – Devonian (444-359 Myrs)

Paleogeography – climate warmed, sea level high so large shallow seas again, orogeny occurring

Life – new species evolved to fill gaps created by mass extinction. First woody plants so grew larger and supported spiders, insects and crustaceans. First amphibians on land with lungs



Earth history

- Ordovician-Silurian
- Late Devonian
- Permian-Triassic
- Triassic-Jurassic
- Cretaceous-Paleogene

When was it and how long did it take? What died out and what survived? What are the possible causes and what evidence is there in the geological record for what happened? Are there any mysteries still?

Phanerozoic (542 Myrs – today)

Carboniferous – Permian (359-251 Myrs)

Paleogeography – climate cooled, sea level fell, continents near the Equator so tropical conditions, increased collisions resulted in formed supercontinent Pangaea

Life – large coal swamps with giant insects and spiders. First conifer trees. Amphibians then reptiles inhabited land. Reptiles produced eggs with shells allowing them to live further from water

Earth history

- Ordovician-Silurian
- Late Devonian
- Permian-Triassic
- Triassic-Jurassic
- Cretaceous-Paleogene

When was it and how long did it take? What died out and what survived? What are the possible causes and what evidence is there in the geological record for what happened? Are there any mysteries still?

Phanerozoic (542 Myrs – today)

Triassic (251-200 Myrs)

Paleogeography –Pangaea rifted apart and Atlantic Ocean began to form, warm climate then cooled

Life – new varieties of life evolved to replace those lost in mass extinction. Reptiles and corals in ocean, conifer trees and reptiles diversified and true dinosaurs appeared. First ancestors of mammals

Earth history

- Ordovician-Silurian
- Late Devonian
- Permian-Triassic
- Triassic-Jurassic
- Cretaceous-Paleogene

When was it and how long did it take? What died out and what survived? What are the possible causes and what evidence is there in the geological record for what happened? Are there any mysteries still?

Phanerozoic (542 Myrs – today)

Jurassic-Cretaceous (200 - 65 Myrs)

Paleogeography – climate warmed, sea level very high so large shallow seas, break up of Pangaea continued, fast sea floor spreading, active mantle plumes

Life – modern fish appeared. Large reptiles and turtles in ocean. Angiosperms (flowering plants) developed and competed with conifers. Dinosaurs ruled the world! Mammals diversified but remained small and rat-like.

Earth history

- Ordovician-Silurian
- Late Devonian
- Permian-Triassic
- Triassic-Jurassic
- Cretaceous-Paleogene

When was it and how long did it take? What died out and what survived? What are the possible causes and what evidence is there in the geological record for what happened? Are there any mysteries still?

Phanerozoic (542 Myrs – today)

Paleogene to Recent (65 Myrs to today)

Paleogeography – climate gradually cooled allowing large ice sheets to form, continents moved to their current positions and generated Himalayas, Alps etc.

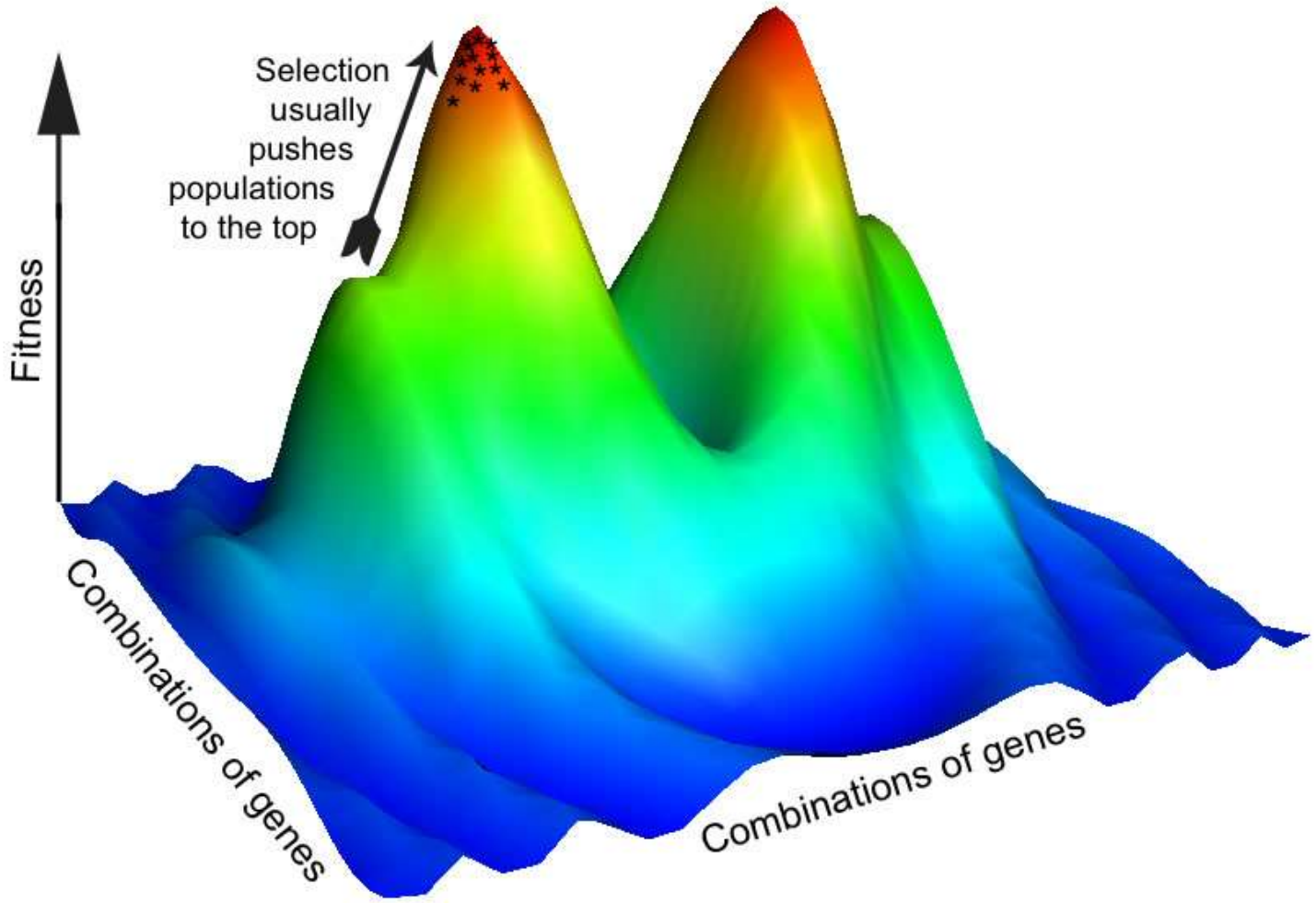
Life – After mass extinction forests of angiosperms and gymnosperms (conifers) quickly grew back. Birds and mammals diversified into niches previously occupied by dinosaurs. First human-like primate at 4Myrs. Loss of giant mammals ~10 kyrs BP.

A 6th Mass Extinction Today?

- Humans activities are resulting in loss of biodiversity mostly due to:
  - Hunting/over-harvesting
  - Deforestation and desertification (habitat loss)
  - Pollution
  - Introduced/exotic species
  - Maybe climate change in future?
- Background extinction rate before humans = ~ 15 per year
- Today, in tropical forest extinction rate = ~ 27,000 per year

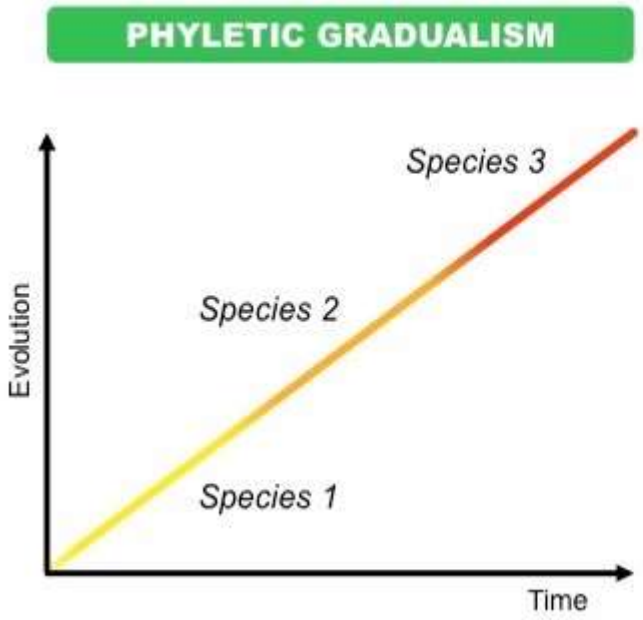
How does life respond?

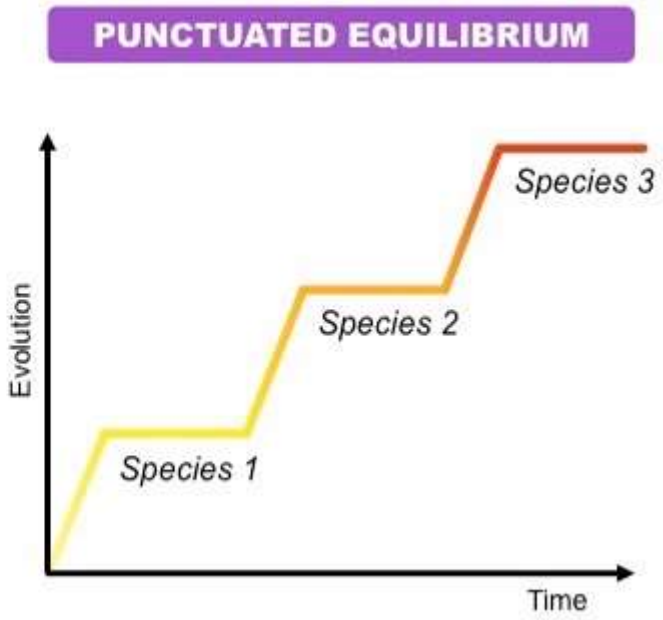
- Life is Lazy: Searches for easiest sources of energy.
- What makes an energy source easy?



How does life respond?

- Gradually or Punctuated?





Question

Which species do you think would be least susceptible to going extinct? Why?

Future of life?

What things do we have to think about?

Future of life?

What things do we have to think about?

- Environment – controlled by plate tectonics, atmosphere composition, climate i.e. likely niches and habitats
- What things will be left after a current extinction event?
- How quickly the process of evolution will change a species?

Unconformity exercise