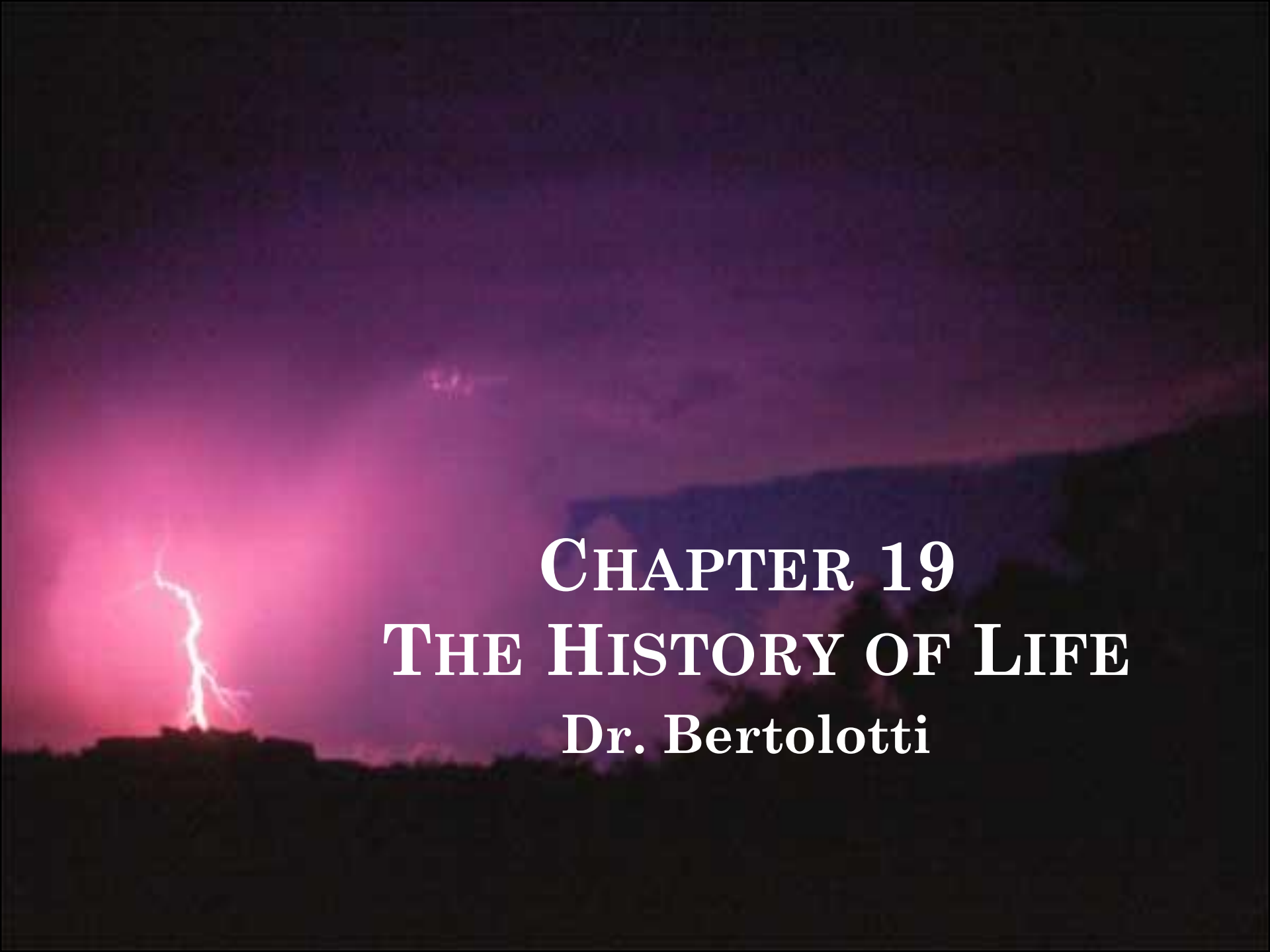


Chapter 19
The History of Life

Dr. Bertolotti

Essential Question:

How do fossils help biologists understand the history of life on earth?

What do fossils reveal about ancient life?

Fossils and Ancient Life

- **Paleontologists**: scientists who study fossils
- **Fossil record** is the information about past life, including the structure of organisms, what they ate, what ate them, in what environments they lived, and the order in which they lived
  - The fossil record provides evidence about the history of life on Earth. It also shows how different groups of organisms, including species, have changed over time.
  - 99% of all species that have ever lived on Earth are now **extinct** (a term used to refer to a species that has died out)

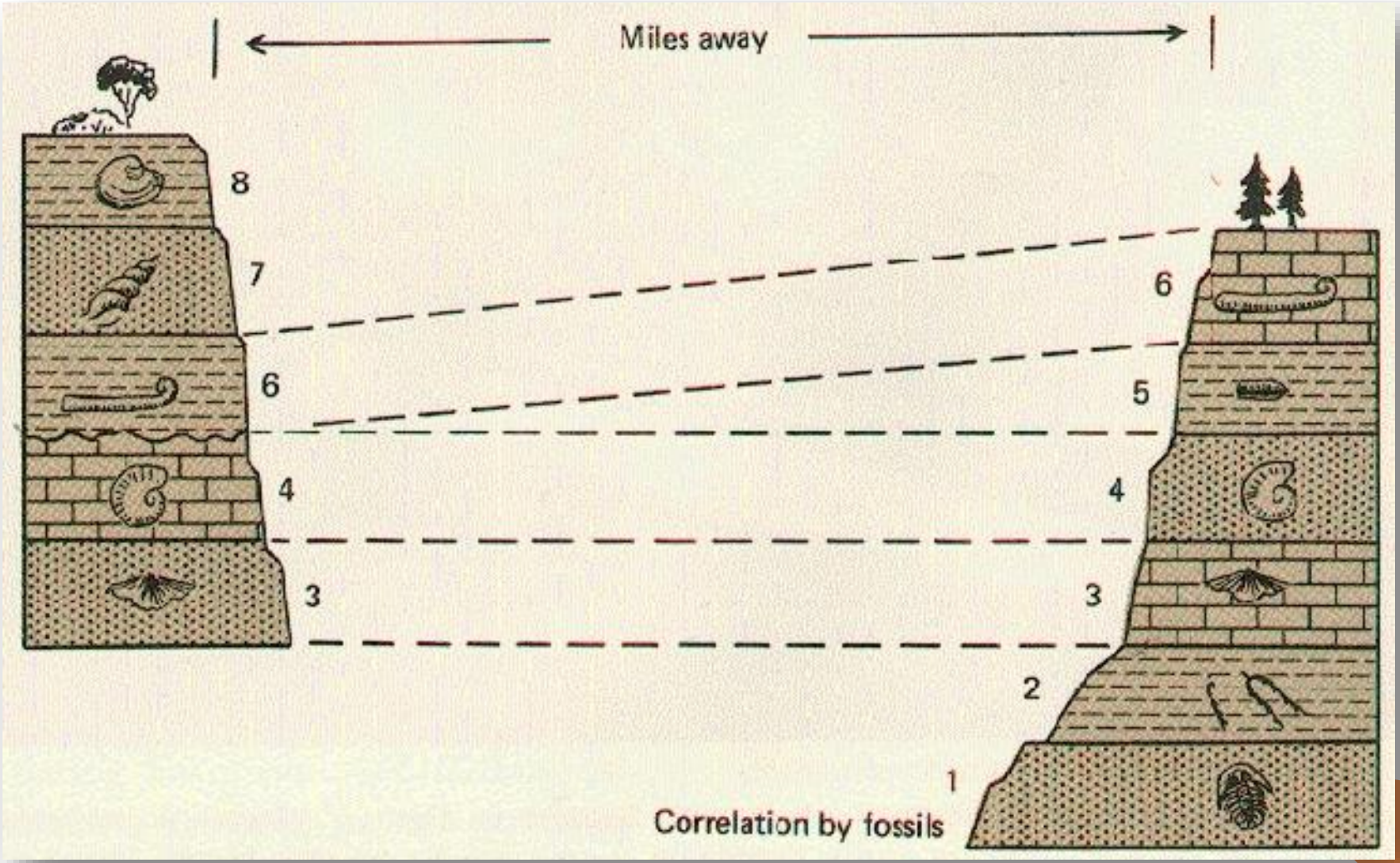
QUESTION AND ANSWER

WHAT DO FOSSILS REVEAL ABOUT ANCIENT LIFE?

How do we date events in earth's history?

- The techniques used to date rocks and fossils include:
  - **1. Relative dating**
    - In **relative dating**, the age of the fossil is determined by comparing its placement with that of fossils in other layers of rock
    - Only an approximation of age is provided, not an absolute age
    - **Index fossils** are distinctive fossils used to establish and compare the relative ages of rock layers and the fossils they contain.
      - Is easily recognized and occurs in only a few layers but is found in many places
      - Example, trilobites
  - **2. Radiometric dating**
    - **Radiometric dating** relies on radioactive isotopes, which decay, or break down, into stable isotopes at a steady rate. E.g., Carbon-14
      - Uses the proportion of radioactive to stable isotopes to calculate the age of a sample
      - Provides the fossil's absolute age in years
      - Uses different radioactive isotopes to determine ages of rocks and fossils depending on age of fossils
    - **Half-life** is the time required for half of the radioactive atoms in a sample to decay.

Index Fossils



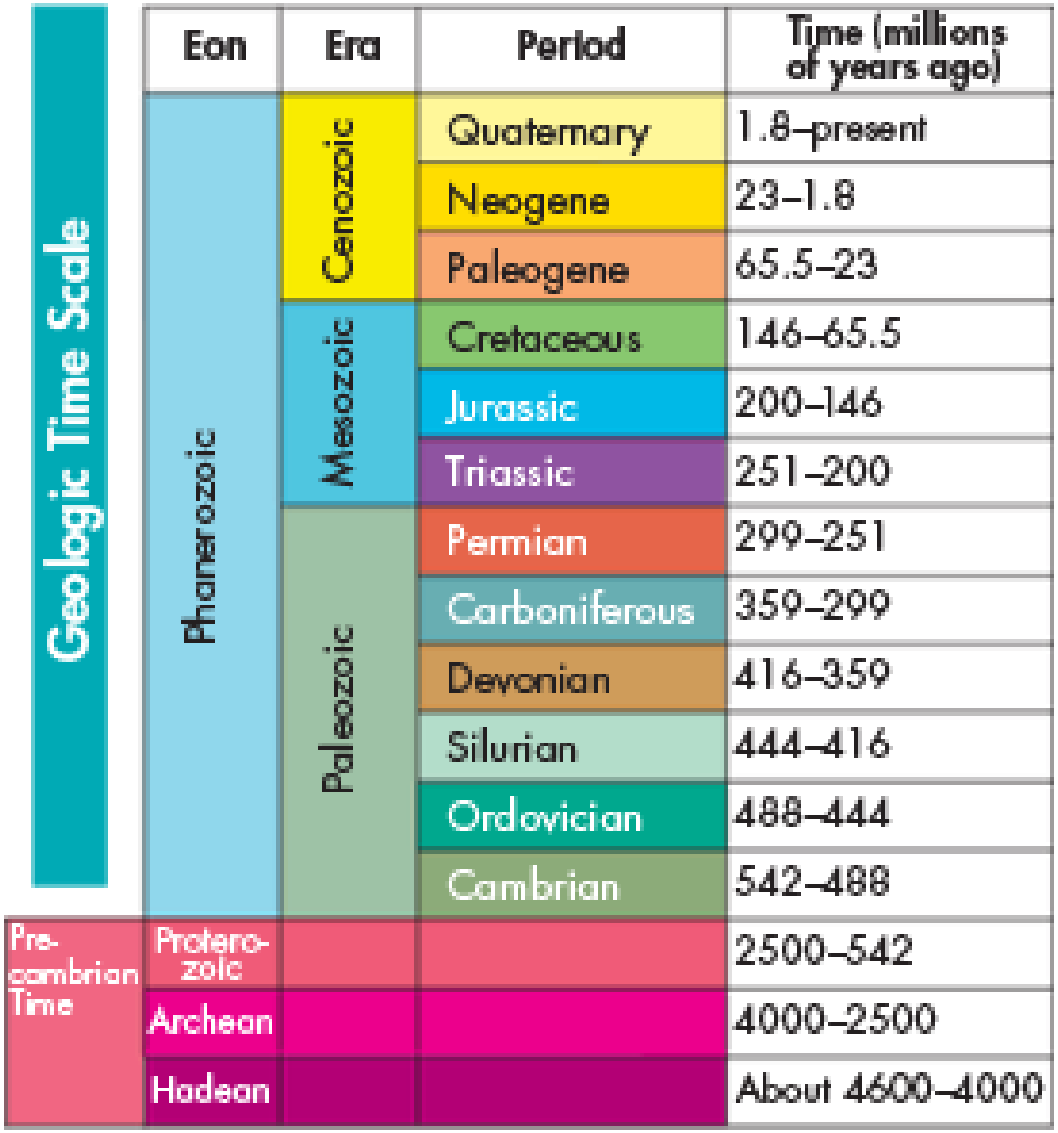
QUESTION AND ANSWER

How do we date events in earth's history?

What are the major divisions in earth's history?

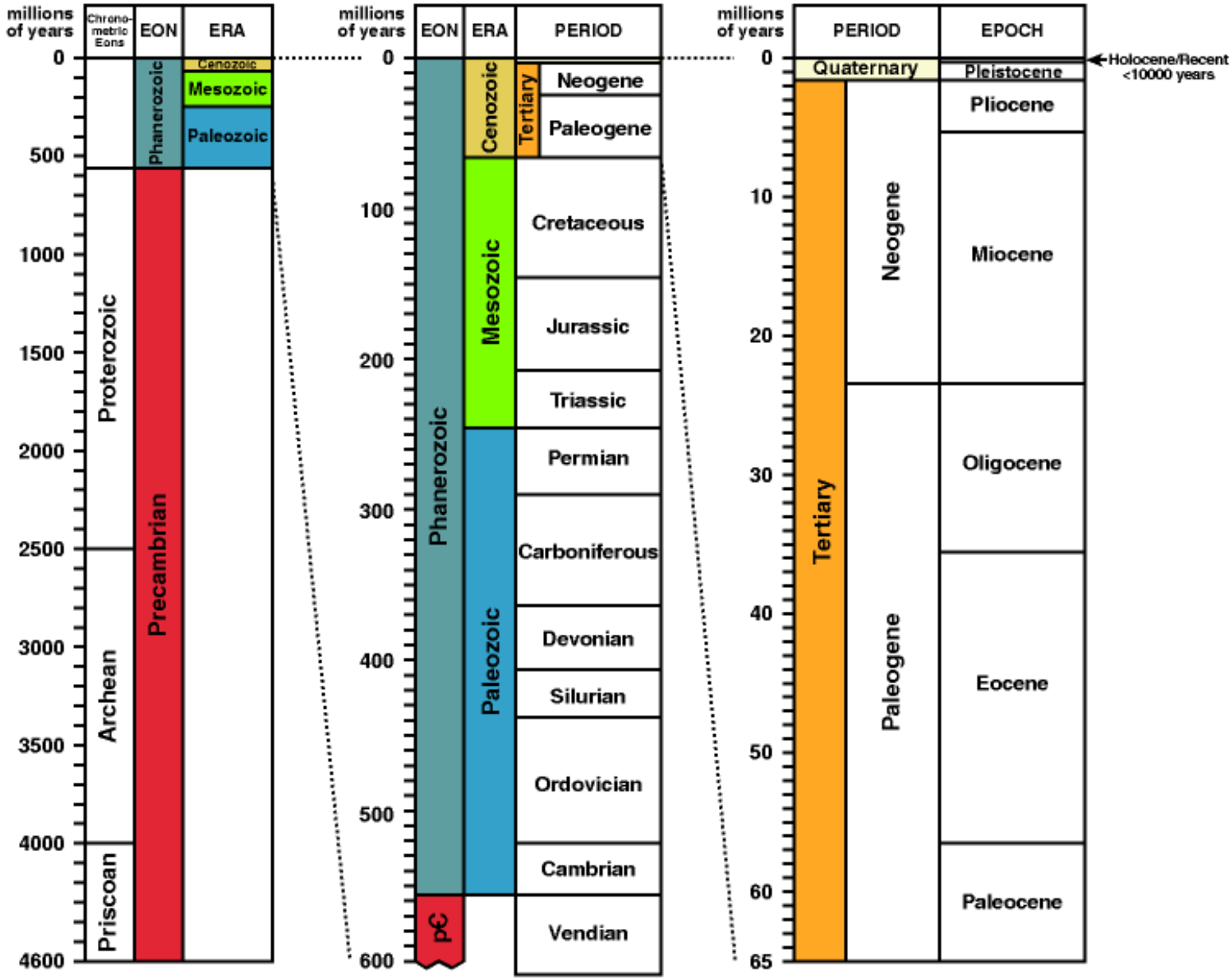
- **Geologic time scale** is a scale used by paleontologists to represent evolutionary time
  - Is based on both relative and absolute dating
  - The major divisions of the geologic time scale are **eons, eras, and periods** (from largest to smallest)
  - Pre-Cambrian Time is the longest division of Earth's history
    - Within Pre-Cambrian time, there are 3 eons: Hadean, Archean, and Proterozoic.
    - Then there is Phanerozoic Eon.
      - There are 3 eras after Pre-Cambrian time: Paleozoic, Mesozoic, and Cenozoic
        * Cenozoic is the most recent era

Geologic Time Scale

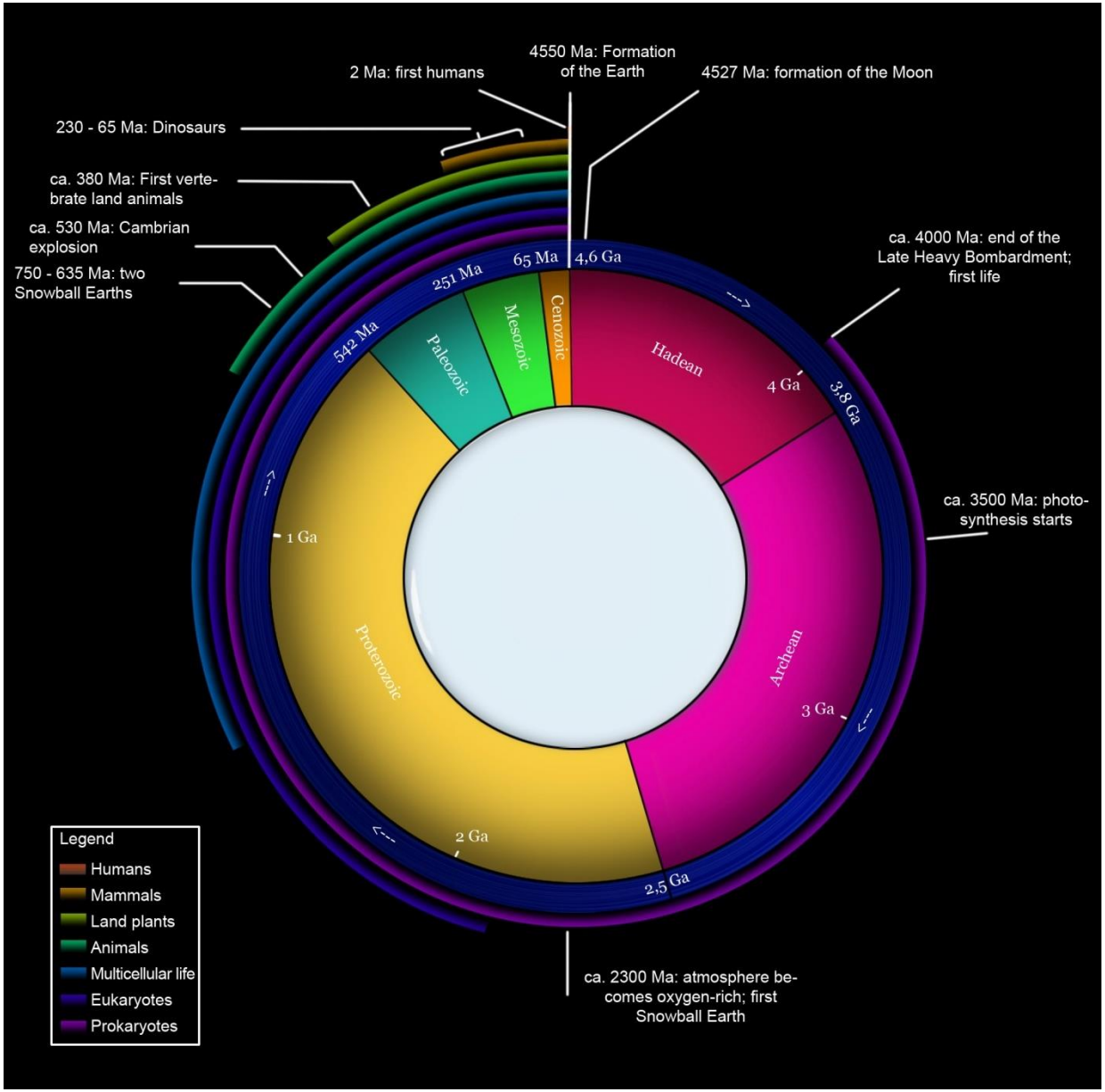


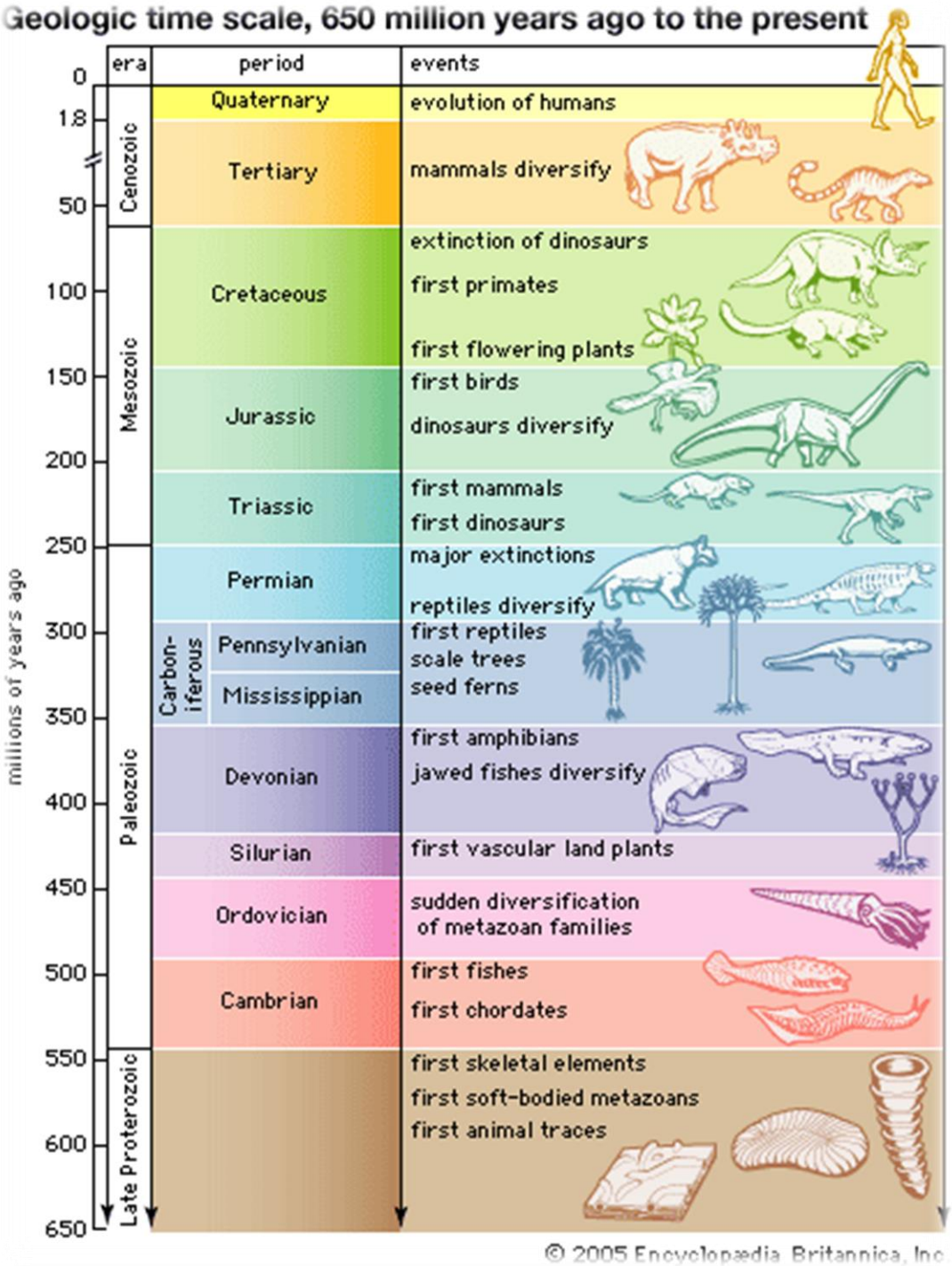
Eon	Era	Period	Time (millions of years ago)
Phanerozoic	Cenozoic	Quaternary	1.8–present
		Neogene	23–1.8
		Paleogene	65.5–23
	Mesozoic	Cretaceous	146–65.5
		Jurassic	200–146
		Triassic	251–200
	Paleozoic	Permian	299–251
		Carboniferous	359–299
		Devonian	416–359
		Silurian	444–416
		Ordovician	488–444
		Cambrian	542–488
Precambrian Time	Proterozoic		2500–542
	Archean		4000–2500
	Hadean		About 4600–4000

Geologic Time Scale



Geologic Time Scale as a clock




Geologic time scale, 650 million years ago to the present
era
period
events
millions of years ago
0
18
50
100
150
200
250
300
350
400
450
500
550
600
650
Cenozoic
Mesozoic
Paleozoic
Late Proterozoic
Quaternary
evolution of humans
Tertiary
mammals diversify
Cretaceous
extinction of dinosaurs
first primates
first flowering plants
Jurassic
first birds
dinosaurs diversify
Triassic
first mammals
first dinosaurs
Permian
major extinctions
reptiles diversify
Carbon-iferous
Pennsylvanian
Mississippian
first reptiles
scale trees
seed ferns
Devonian
first amphibians
jawed fishes diversify
Silurian
first vascular land plants
Ordovician
sudden diversification of metazoan families
Cambrian
first fishes
first chordates
first skeletal elements
first soft-bodied metazoans
first animal traces
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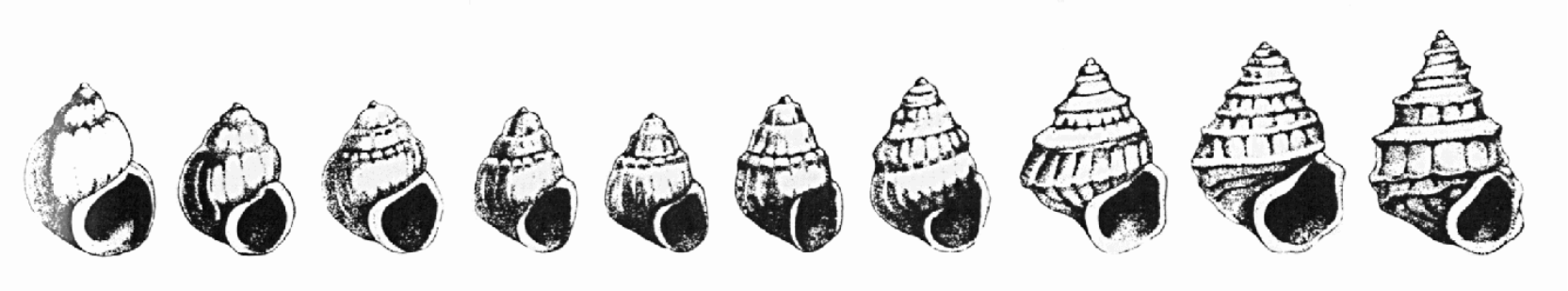
QUESTION AND ANSWER

WHAT ARE THE MAJOR DIVISIONS IN EARTH'S HISTORY?

How fast does evolution take place?

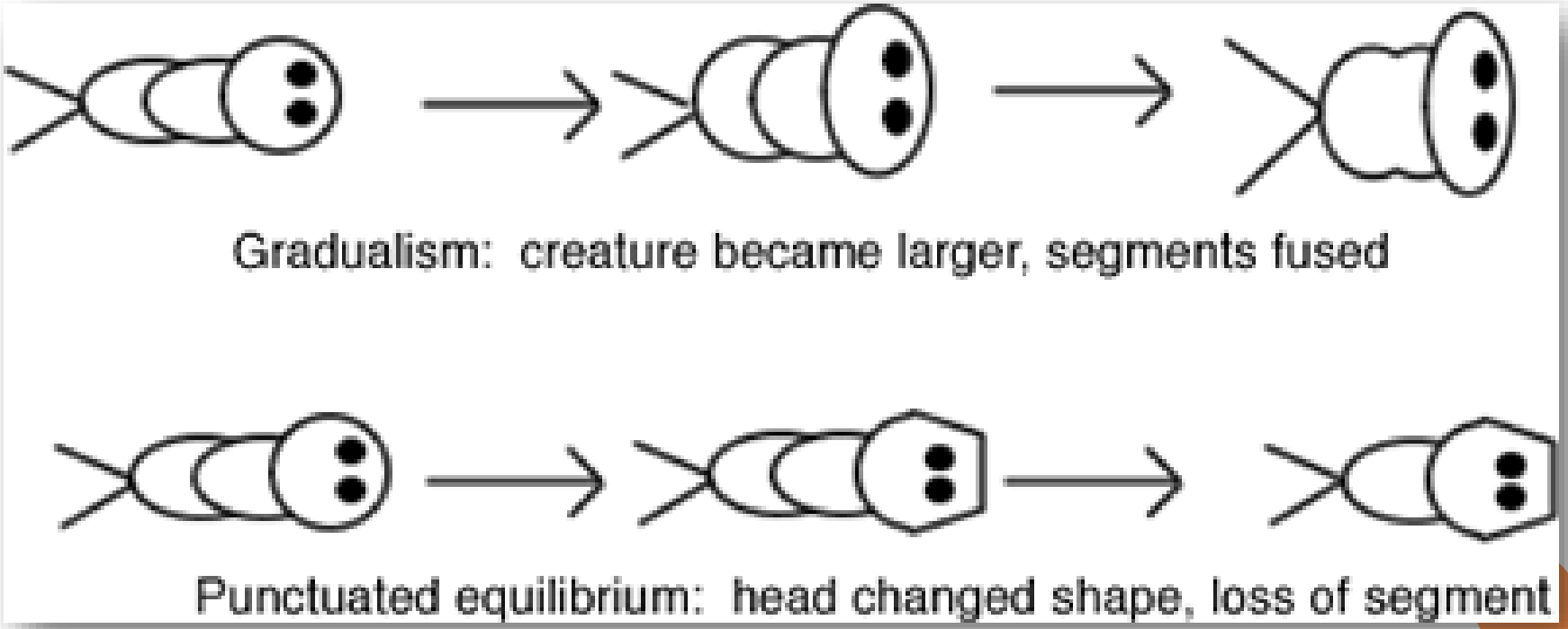
GRADUALISM

- **Gradualism**: the evolution of a species by gradual accumulation of small genetic changes over long periods of time
  - This is a slow and steady change

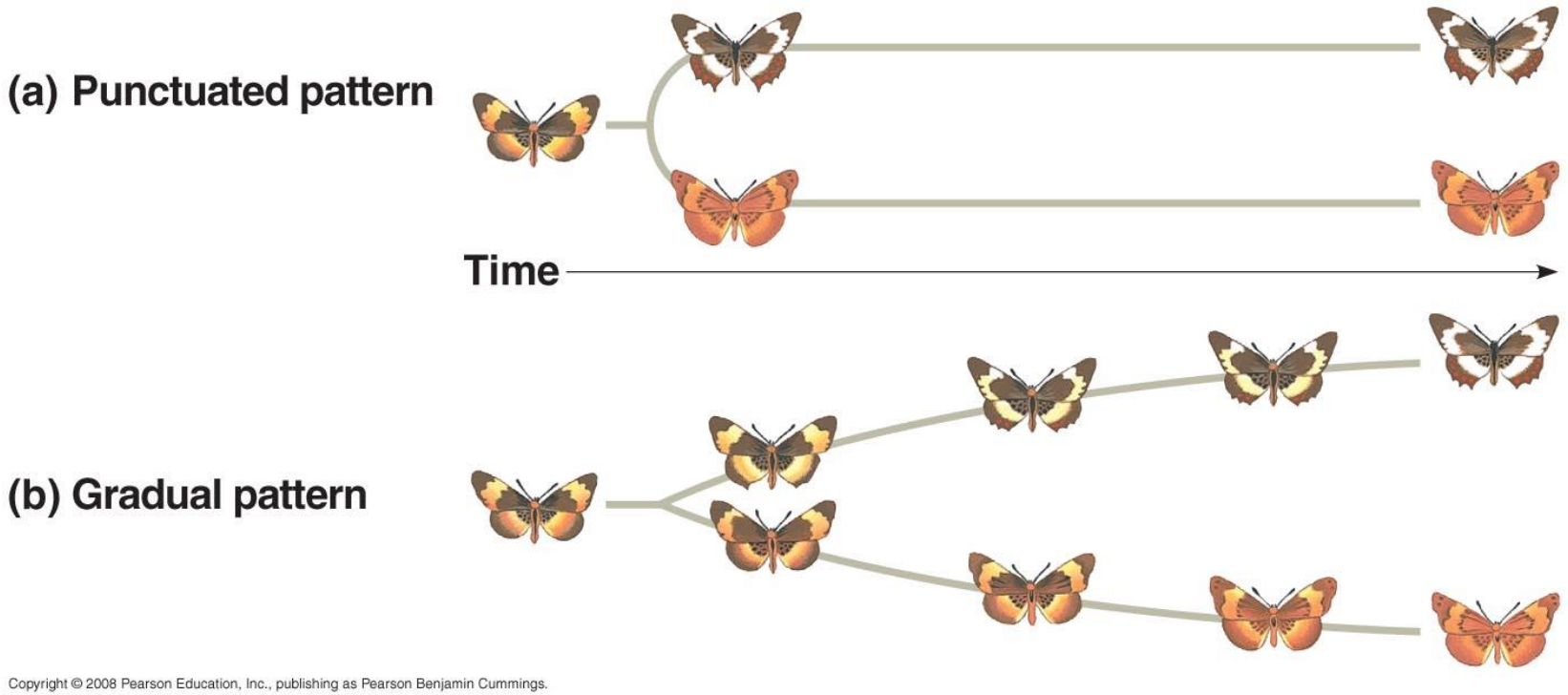


Punctuated equilibrium

- **Punctuated equilibrium** refers to the pattern of evolution in which long stable periods are interrupted by brief periods of more rapid change



Punctuated equilibrium vs. gradualism



QUESTION AND ANSWER

How fast does evolution take place?

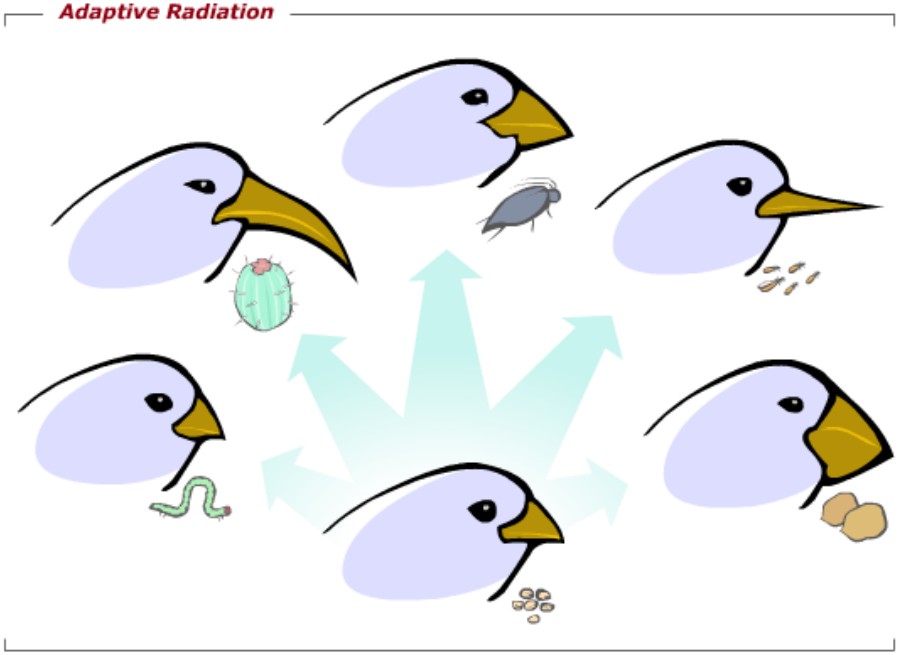
What are two patterns of macroevolution?

Patterns of Evolution

- **Macroevolution** refers to large scale evolutionary patterns and processes that occur over long periods of time
- The **3** important patterns of macroevolution are:
  - 1) Adaptive radiation or divergent evolution
  - 2) Coevolution
  - 3) Convergent evolution

Adaptive Radiation

- **Adaptive radiation** is a process by which a single species or small group of species evolves over a relatively short time into several different forms that live in different ways
  - May occur when species migrate to a new environment
  - Each species display variation on the group's ancestral body plan



Coevolution

- **Coevolution** is the process by which 2 species evolve in response to changes in each other
  - The relationship between two coevolving organisms often becomes so specific that neither organism can survive without the other. Thus, an evolutionary change in one organism is usually followed by a change in the other organism
    - Example: plants and herbivorous insects

Convergent evolution

- **Convergent evolution** refers to the process by which unrelated organisms independently evolve similarities when adapting to similar environments

QUESTION AND ANSWER

WHAT ARE TWO PATTERNS OF MACROEVOLUTION?

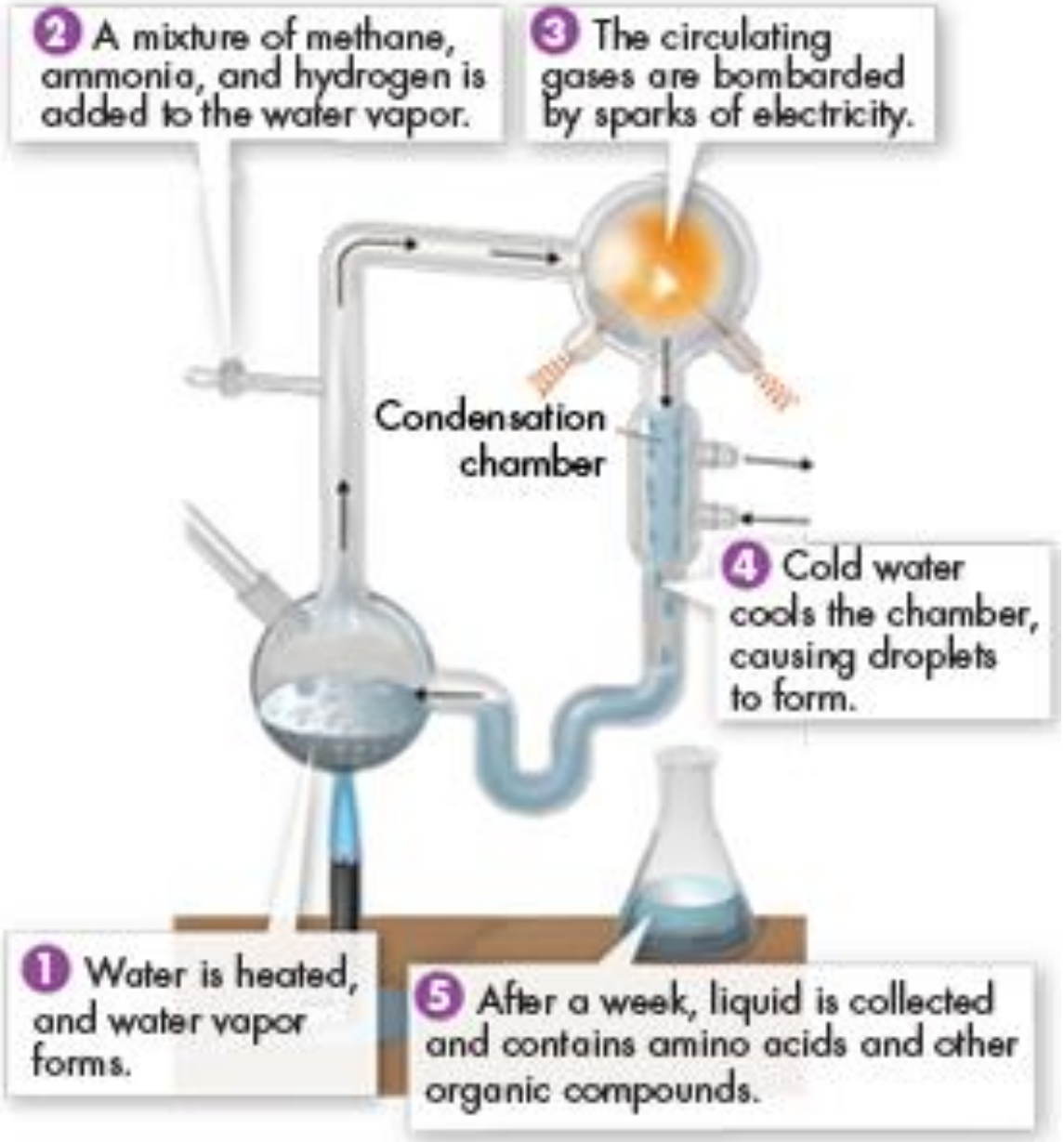
What do scientists hypothesize about early earth and the origin of life?

Early Earth

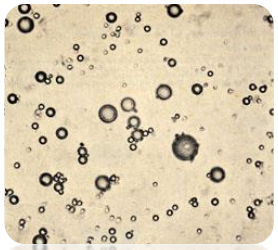
- Earth is estimated to be about 4.6 billion years old.
- Atmosphere was very harsh.
  - Very hot.
  - Lots of water vapor in the atmosphere.
  - Volcanic activity.
  - NO BREATHABLE OXYGEN GAS!
  - Carbon dioxide, ammonia, hydrogen gas, were present

Earth's Early History

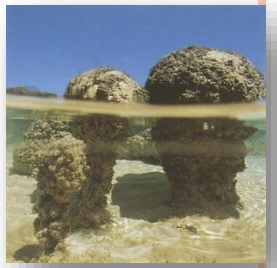
- Earth is 4.6 billion years old
- Earth's early atmosphere probably contained hydrogen cyanide, carbon dioxide, carbon monoxide, nitrogen, hydrogen sulfide, and water vapor
  - Earth's early atmosphere contained little to no oxygen
- Miller and Urey simulated the conditions on Earth in a lab setting
  - They filled a flask with hydrogen, methane, ammonia, and water and passed electric sparks to simulate lightning
  - Over a few days amino acids were formed
  - Miller and Urey's experiments suggested how mixtures of the organic compounds necessary for life could have arisen from simpler compounds present on a primitive Earth


2 A mixture of methane, ammonia, and hydrogen is added to the water vapor.
3 The circulating gases are bombarded by sparks of electricity.
Condensation chamber
4 Cold water cools the chamber, causing droplets to form.
1 Water is heated, and water vapor forms.
5 After a week, liquid is collected and contains amino acids and other organic compounds.

The Puzzle of Life's Origins

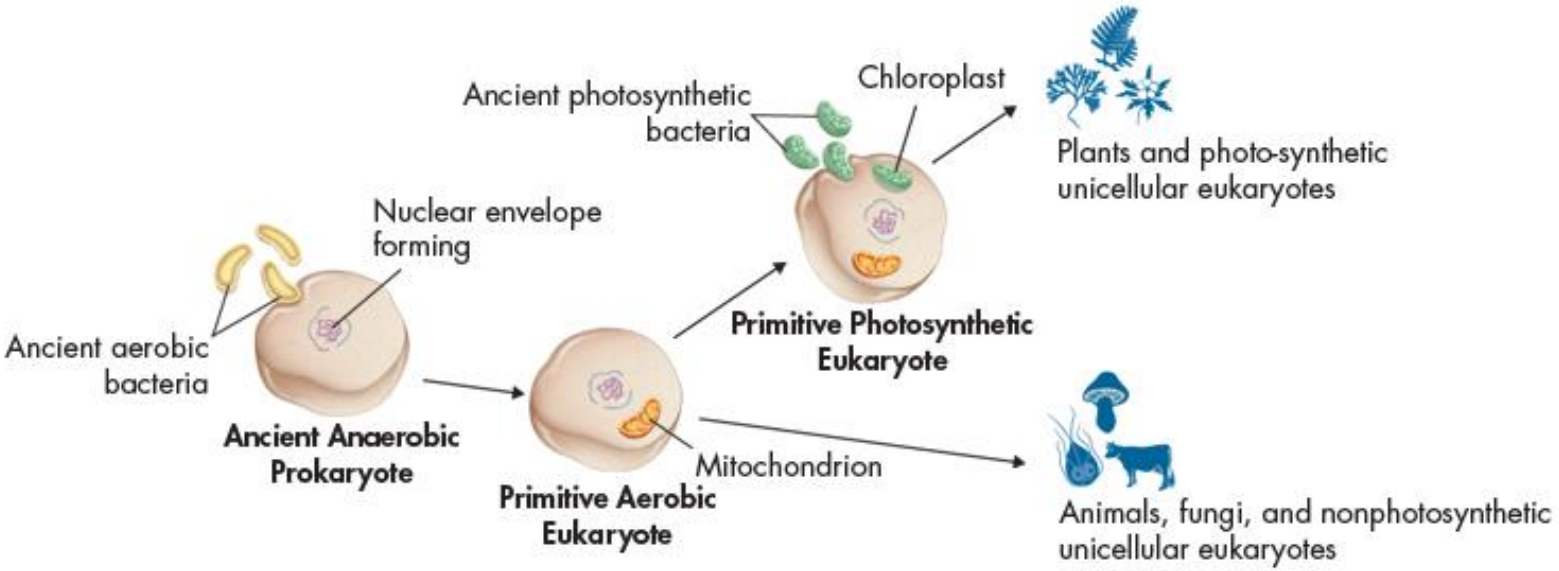


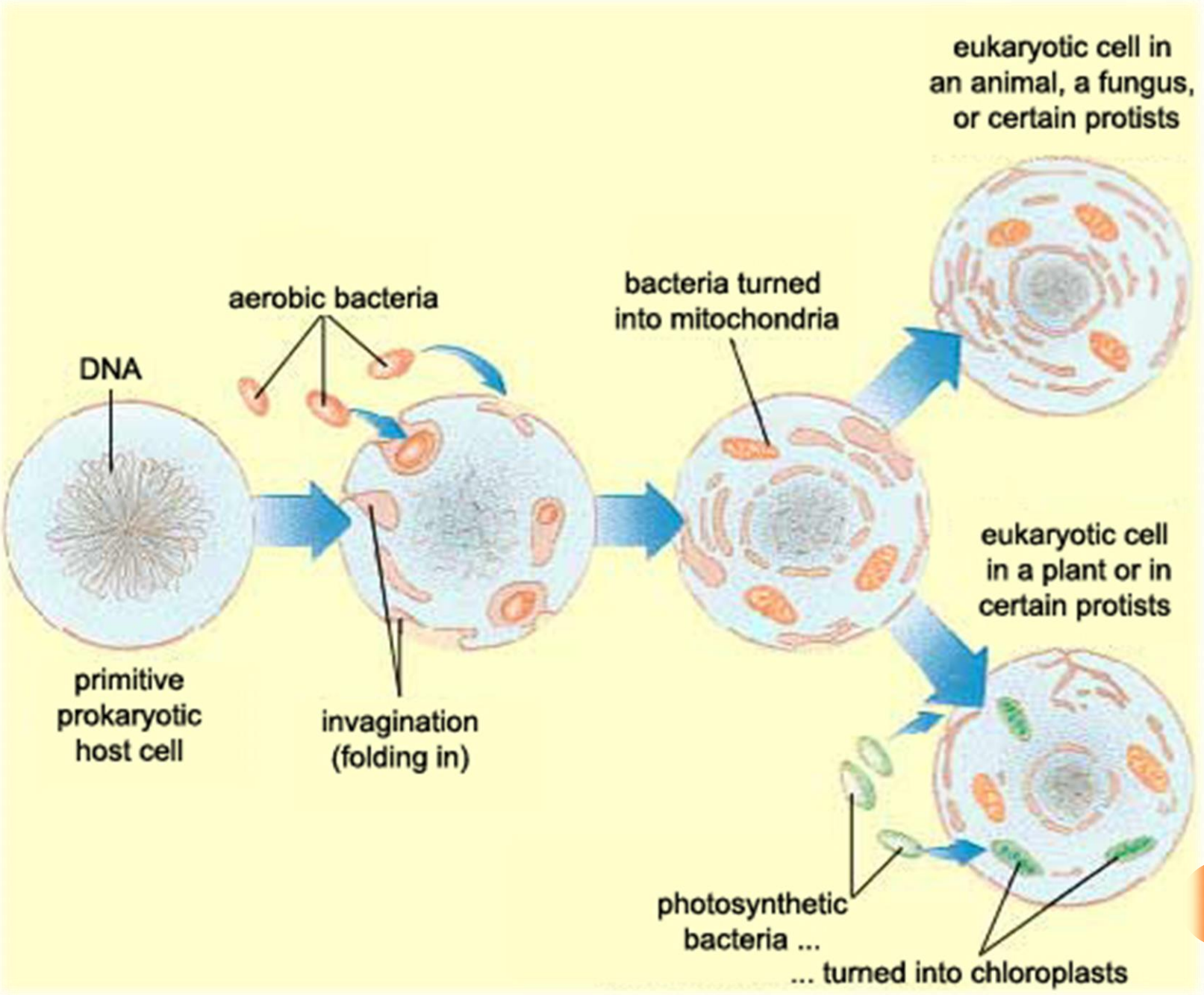
- Under certain conditions, large organic molecules can form tiny bubbles called **proteinoid microspheres**
  - These proteinoid microspheres have some characteristics of living systems
- Microscopic fossils or **microfossils**, of single celled prokaryotic organisms that resemble modern bacteria have been found in rocks more than 3.5 billion years old
  - Evolved in an atmosphere lacking oxygen
  - Photosynthetic bacteria on stromatolites became common, which resulted in the accumulation of oxygen gas
  - The rise of **oxygen** in the atmosphere drove some life forms to extinction, while other life forms evolved new, more efficient metabolic pathways that used oxygen for respiration



Origin of Eukaryotic cells

- **The endosymbiotic theory** is a theory that eukaryotic cells formed from a symbiosis among several different prokaryotic organisms
  - The endosymbiotic theory proposes that eukaryotic cells arose from living communities formed by prokaryotic organisms




eukaryotic cell in
an animal, a fungus,
or certain protists
aerobic bacteria
bacteria turned
into mitochondria
DNA
eukaryotic cell
in a plant or in
certain protists
primitive
prokaryotic
host cell
invagination
(folding in)
photosynthetic
bacteria ...
... turned into chloroplasts

Evolution of Multi-cellular life

- Rich fossil evidence shows that early in the Paleozoic Era, there was a diversity of marine life
- During the Devonian, vertebrates began to invade the land
- The **mass extinction** (event in which many types of living things become extinct at the same time) at the end of the Paleozoic affected both plants and animals on land and in the seas. As much as 95% of the complex life in the oceans disappeared
- Events during the Mesozoic include the increasing dominance of dinosaurs. The Mesozoic is marked by the appearance of flowering plants
- During the Cenozoic, mammals evolved adaptations that allowed them to live in various environments- on land, in water, and even in the air

QUESTION AND ANSWER

WHAT DO SCIENTISTS HYPOTHESIZE ABOUT EARLY EARTH AND THE ORIGIN OF LIFE?

Essential Question:

How do fossils help biologists understand the history of life on earth?