Big Idea 1: The process of evolution drives the diversity and unity of life.

Enduring understanding 1.C: Life continues to evolve within a changing environment.

Essential knowledge 1.C.3: Populations of organisms continue to evolve.

a.Scientific evidence supports the idea that evolution has occurred in all species.

The Fossil Record

- Fossils provide a window into the past.
- The fossil record reveals...
  - organisms have changed over time
  - many past organisms are unlike today's organisms
  - many organisms have gone extinct
  - relationships between organisms
  - emergence of new traits and the loss of others
  - age of the organisms

The Fossil Record

- Keep in mind the fossil record is an incomplete picture into the past.
- Fossils are by nature rare...
  - organisms must die in the right place and the right time to be preserved
  - even if the preservation occurred, geological changes destroyed many of them
  - fossils are biased remains, environmental biases and structural biases
    - *for example most remains are limited to hard shells, bone and teeth*

The Fossil Record

- None the less the fossil record still reveals a wealth of information about our past.

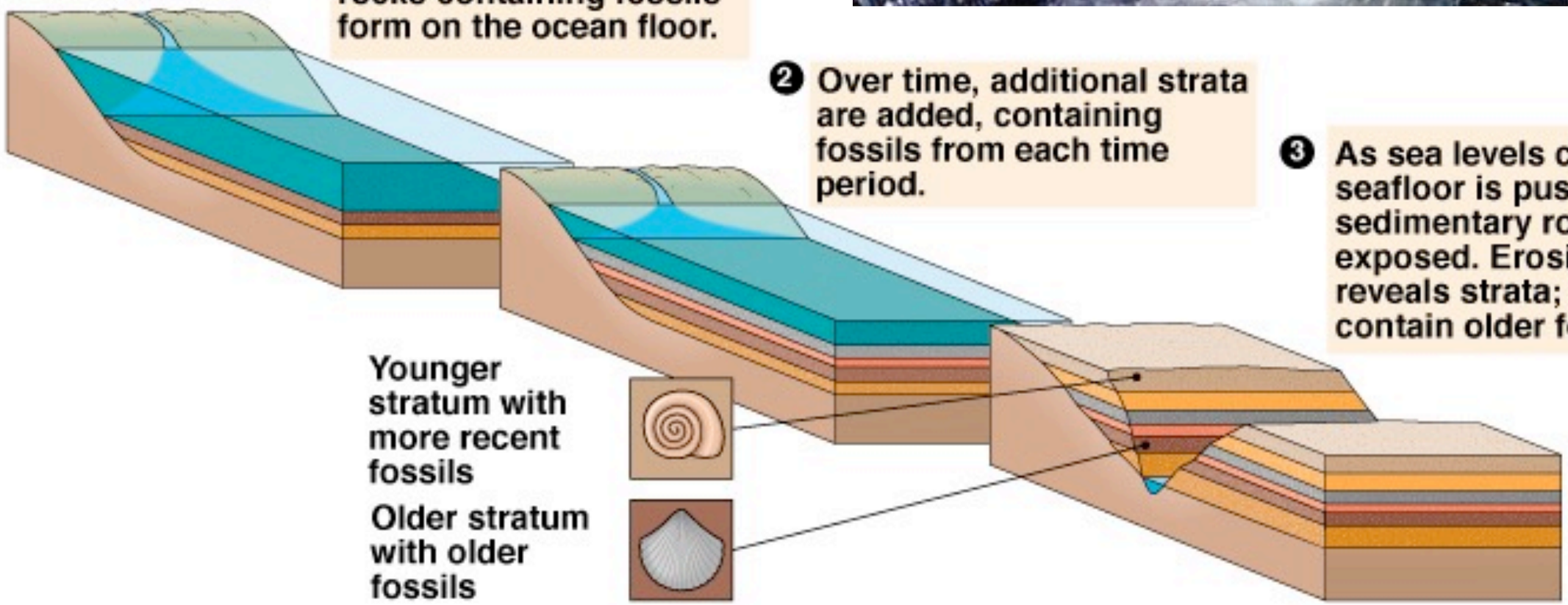
Evolution of Whale Video

Fossil Formation Review

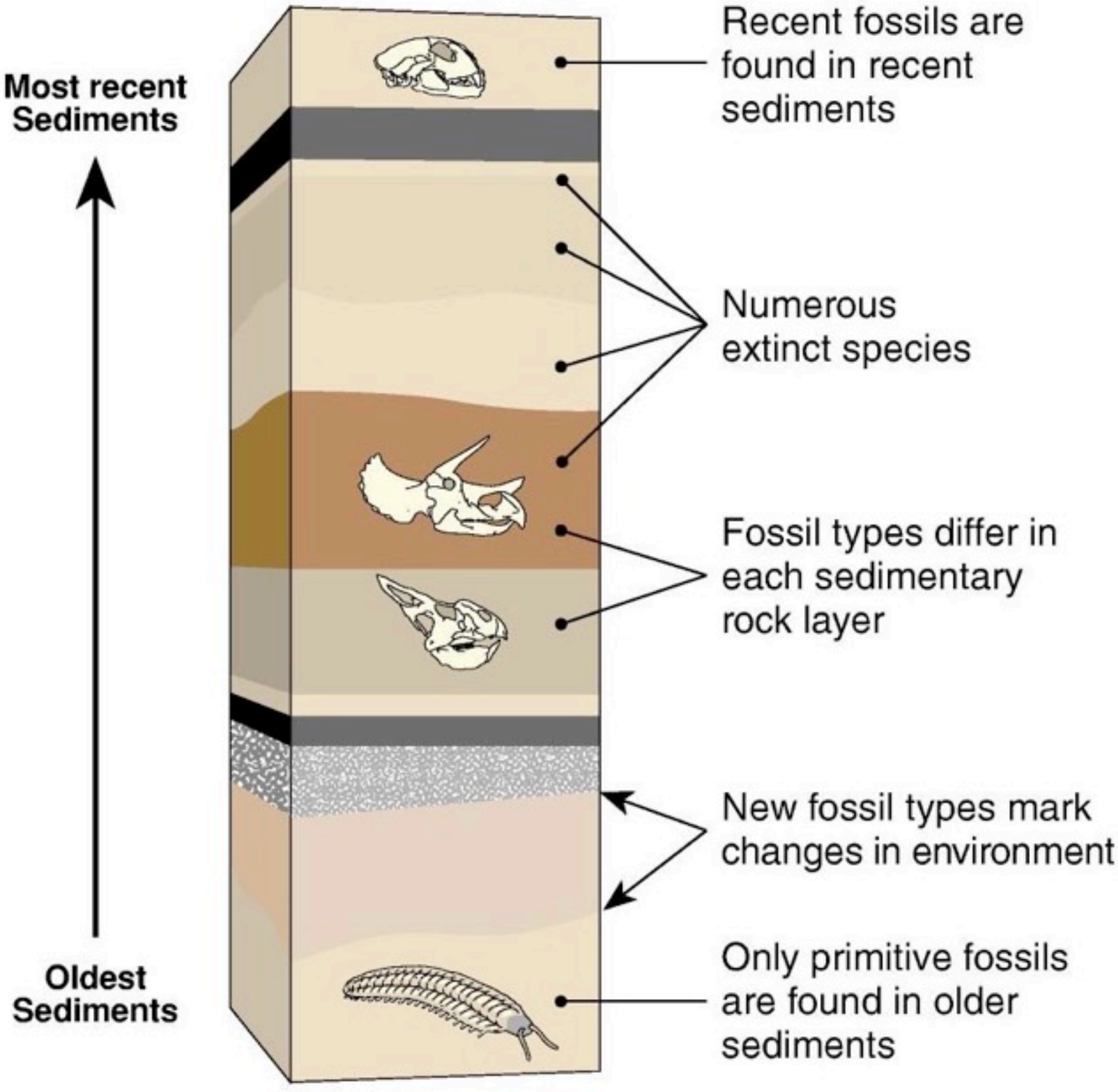
❶ Rivers bring sediment to the ocean. Sedimentary rocks containing fossils form on the ocean floor.

❷ Over time, additional strata are added, containing fossils from each time period.

❸ As sea levels change and the seafloor is pushed upward, sedimentary rocks are exposed. Erosion by rivers reveals strata; older strata contain older fossils.



Fossil Trends Review



PHYLOGENY

Main Idea:

New information continues to revise our understanding of the tree of life.

From Two Kingdoms to Three Domains

- Early taxonomists placed all life into one of two kingdoms: plants and animals!

- In the 1960's, with growing and gained acceptance, the five kingdom taxonomic scheme took hold.
  - Monera, Protista, Fungi, Plants and Animals
  - The scheme was highlighted by two fundamentally different cell types prokaryotic and eukaryotic cells

From Two Kingdoms to Three Domains

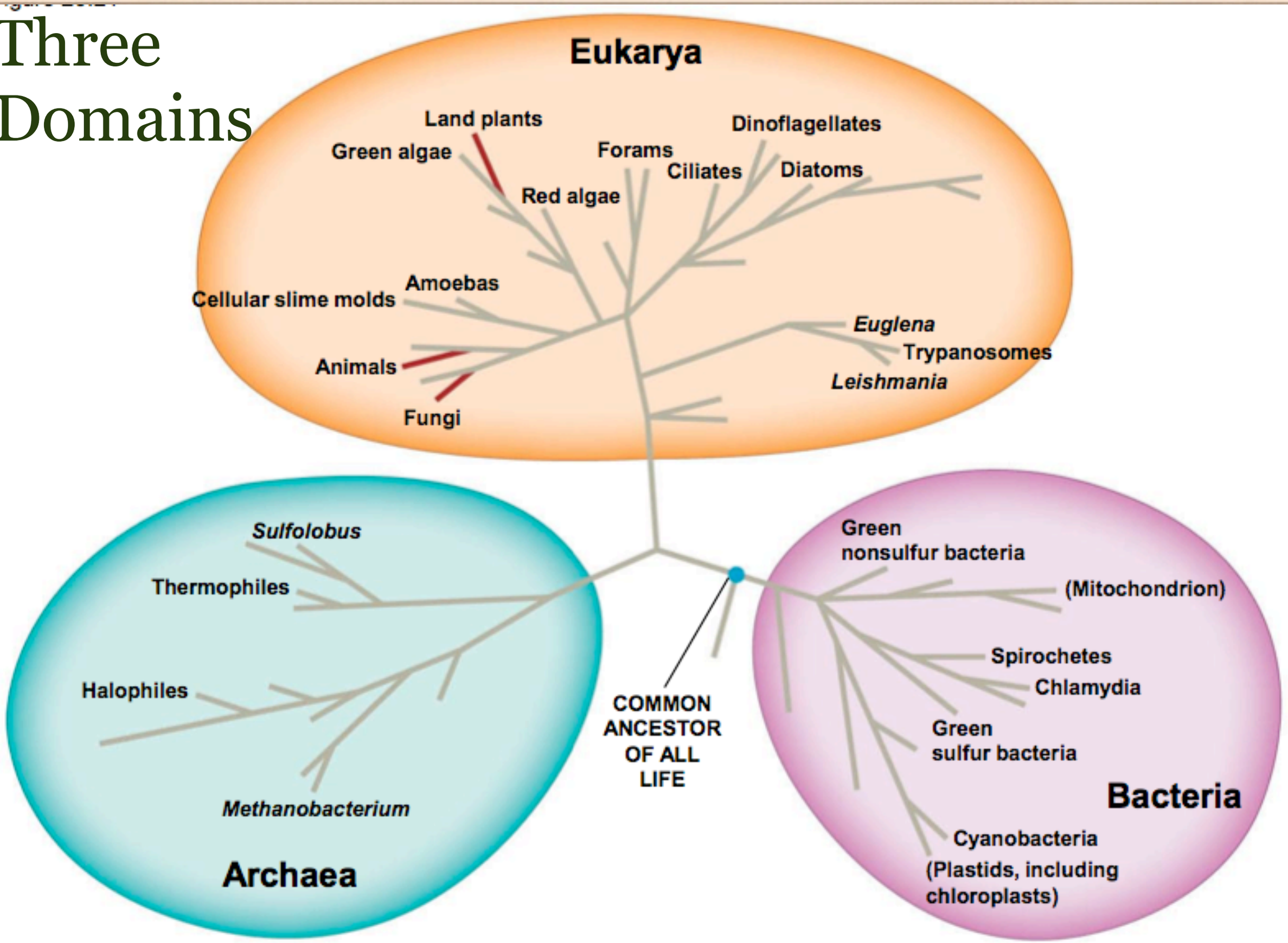
- However, phylogenies based on genetic data soon revealed problem, some prokaryotes differed from each other as much as they differed from eukaryotic cells.

- Biologists responded by adopting three domains- **Bacteria, Archaea and Eukarya**

  - ...a taxonomic level above kingdoms

  - 4 kingdoms are still recognized, but Monera is now obsolete because it has members in two different domains (“protista is also now crumbling apart”)

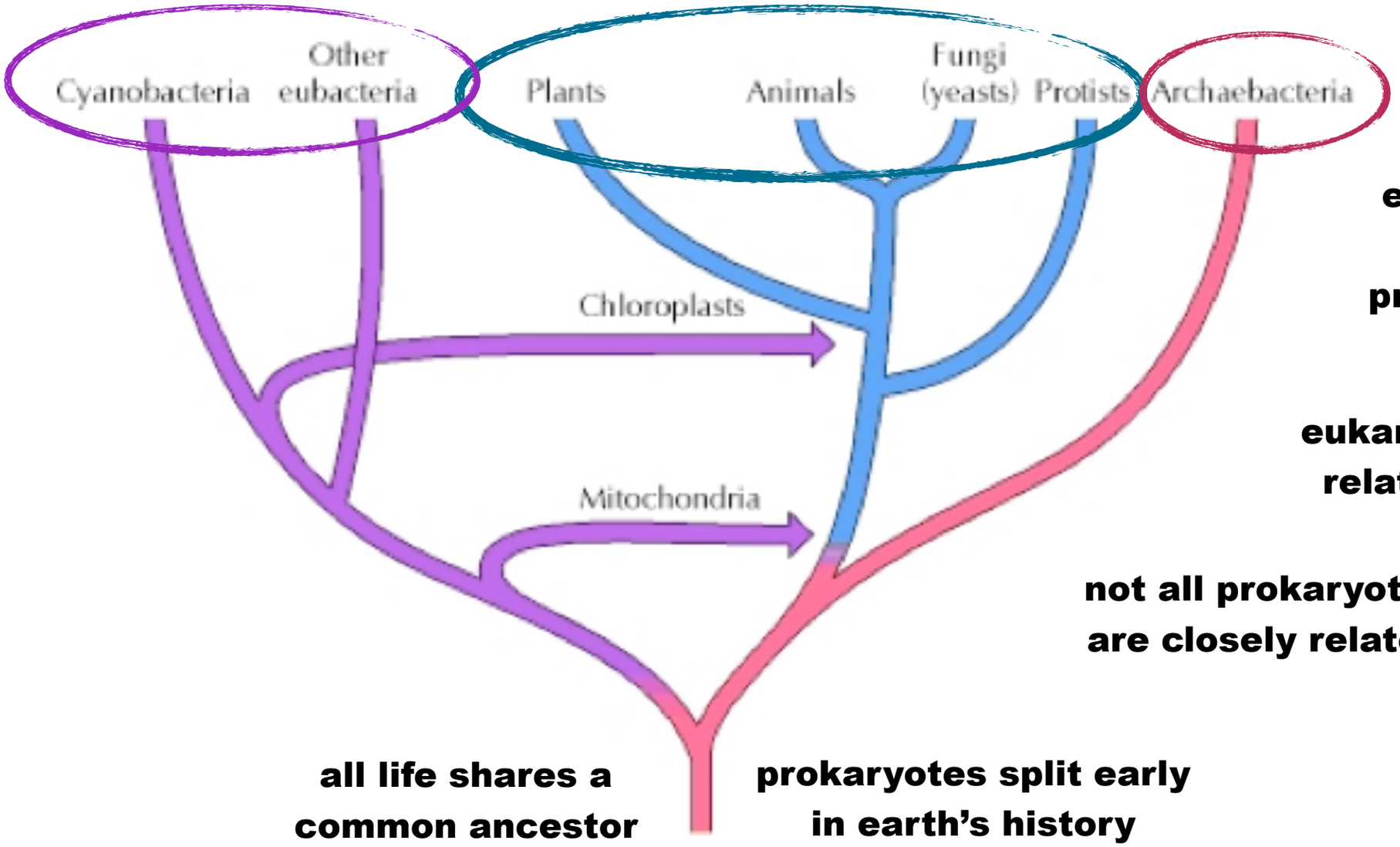
Three Domains



The Tree of Life

- Originally the most inclusive groups included 2, then 5 kingdoms.
- Today, our most inclusive groups include 3 domains, with many kingdoms.

Eubacteria Eukaryotes Archaea



archaea are more closely related to eukaryotes than eubacteria

eukaryotes are more closely related each other than prokaryotes are to each other

eukaryotes are directly related to eubacteria

not all prokaryotes are closely related

all life shares a common ancestor

prokaryotes split early in earth's history

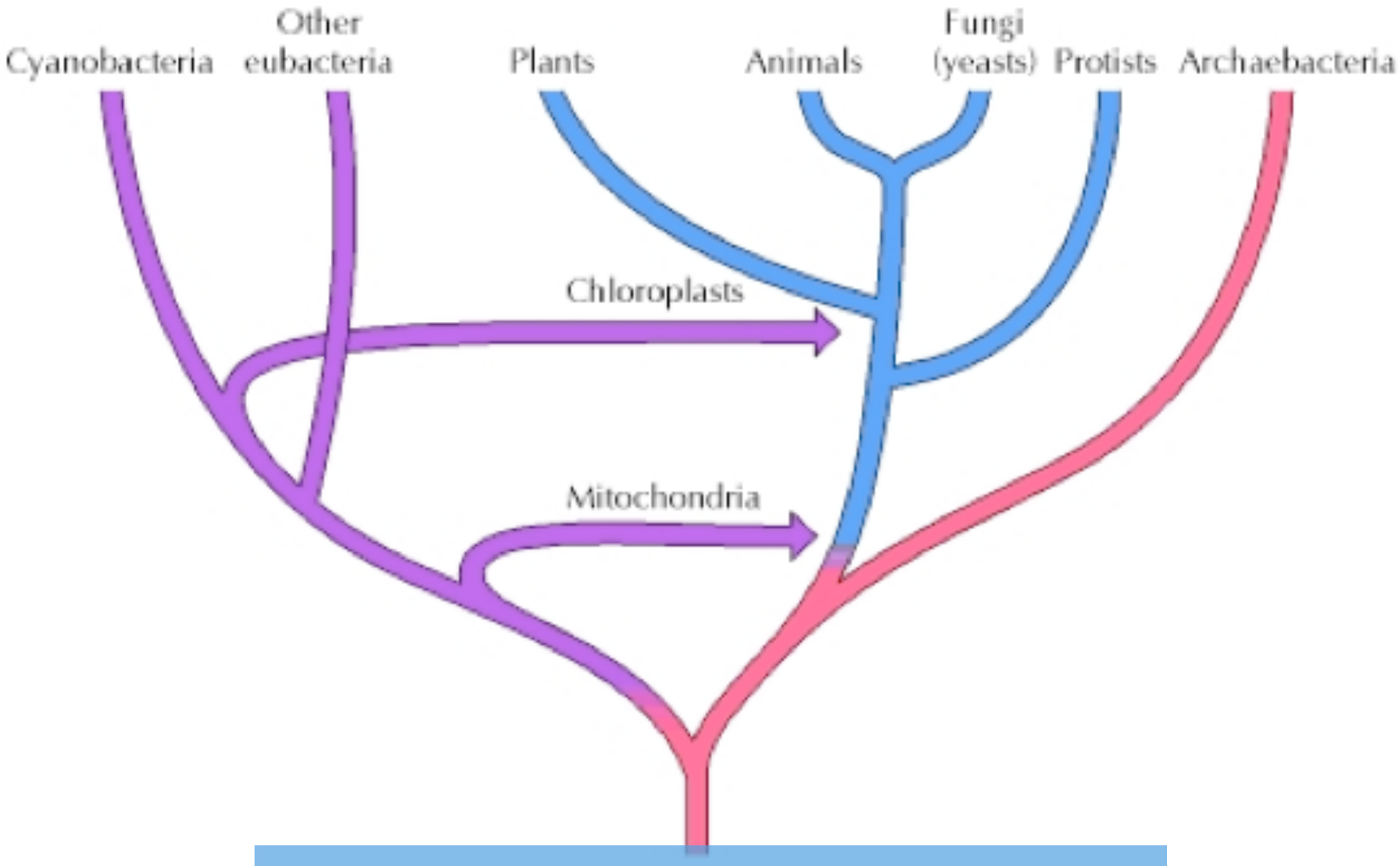
The Tree of Life

- Physiological, structural, molecular and genetic evidence has been used in generating the tree of life. (Here are <u>some</u> examples)

Descriptions	**Explanations**		
Differences	**Eukaryotes**	**Archaea**	**Eubacteria**
Reproduction	**Mitosis/ Meiosis**	**Binary Fission**	**Binary Fission**
Multicellularity Exists	**+**	**-**	**-**
Nucleus	**+**	**-**	**-**
Membrane Bound Organelles	**+**	**-**	**-**
Microtubules/Filaments	**+**	**-**	**-**
Peptidoglycan Cell Wall	**-**	**-**	**+**
Chromosome shape	**linear**	**circular**	**circular**
Chromosome number	**multiple**	**single**	**single**

The Tree of Life

- Evidence suggests that all life shares a universal common ancestor.



The Tree of Life

- Traits of the...

Universal Common Ancestor

prokaryotic
-no membrane bound organelles

simple metabolism

cell membrane
-made of lipids

cytosol
-different from outside solution

makes simple proteins

simple genetic material
-RNA

prokaryotic

Unicellular
-self contained functions

reproduced
-asexually

small
-high SA:V ratio

ability to mutate and adapt

anaerobic or aerobic depending on site of evolution

chemotrophic
-likely heterotrophic may have been autotrophic

aquatic

Essential knowledge 1.C.3: Populations of organisms continue to evolve.

b. Scientific evidence supports the idea that evolution continues to occur.

To foster student understanding of this concept:

- Chemical resistance (mutations for resistance to antibiotics, pesticides, herbicides or chemotherapy drugs occur in the absence of the chemical)
- Emergent diseases
- Observed directional phenotypic change in a population (Grants' observations of Darwin's finches in the Galapagos)
- A eukaryotic example that describes evolution of a structure or process such as heart chambers, limbs, the brain and the immune system

Chemical Resistance

- Recall Pesticide Evolution
- Recall HIV Evolution
- Antibiotic Resistance

Emerging Viruses

- Viruses that suddenly appear or suddenly catch the medical communities attention because of its effects
- Extending its territory through globalization plays a huge role
- Also results from a virus expanding its host range

Darwin's Finches

- http://www.hhmi.org/biointeractive/origin-species-beak-finch

Eukaryotic Evolution

- Evolution of Limbs

- https://www.hhmi.org/biointeractive/great-transitions-origin-tetrapods

Further Topics Related to 1.C.3.b

ORIGIN OF SPECIES

Main Idea

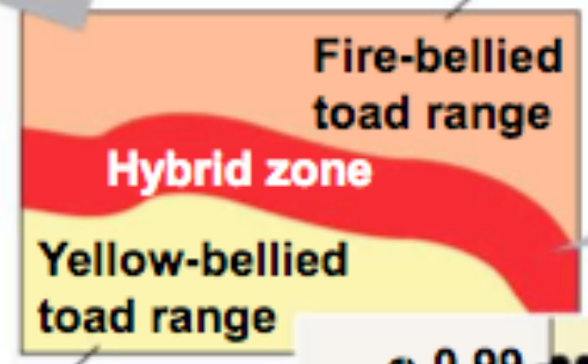
Hybrid zones occur when different species meet and mate, producing some offspring of mixed ancetsry.

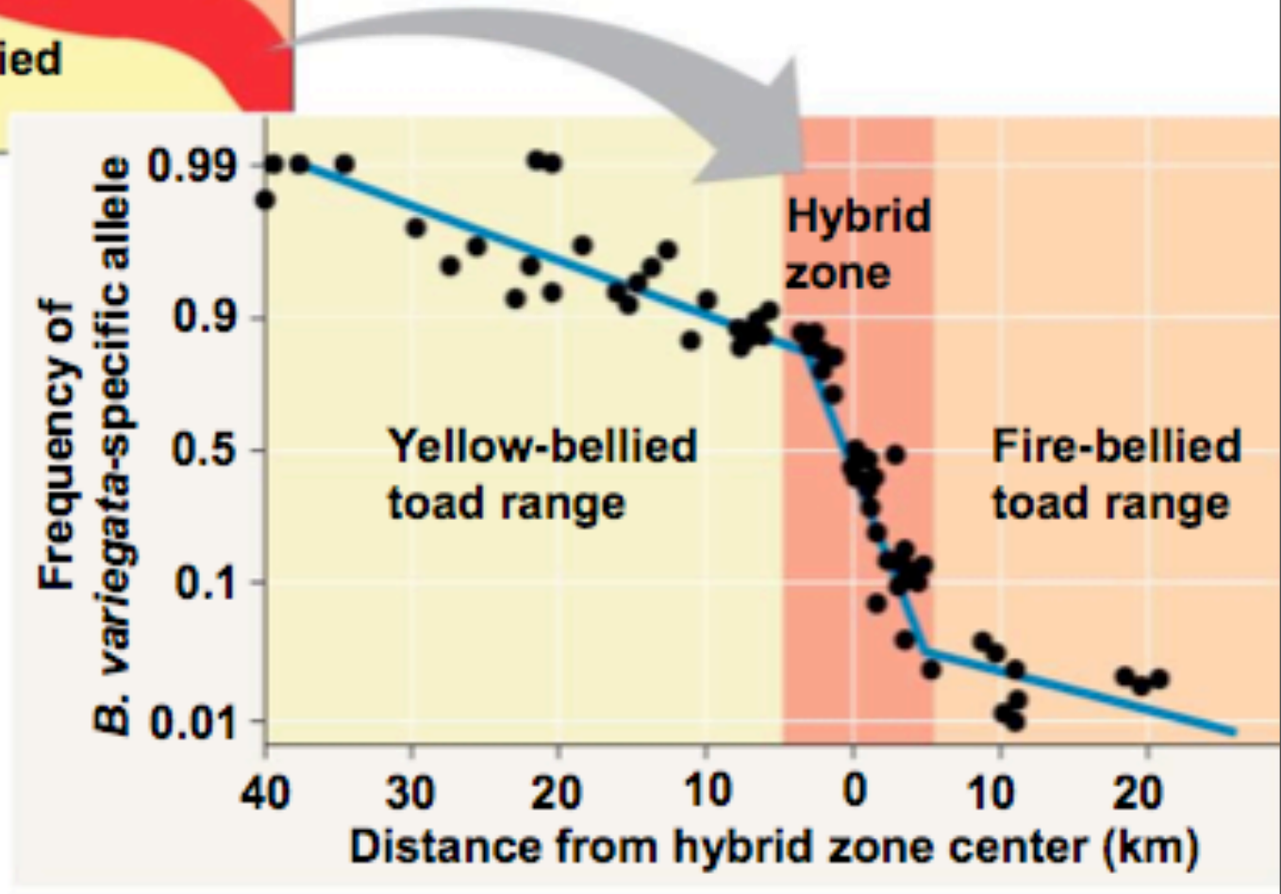
Patterns within Hybrid Zones

- **Hybrid Zone**- a region in which members of different species meet and mate, producing *some* offspring of mixed ancestry.
- Hybrid zones can have simple or complex patterns.
- Many plant species have a complicated patterns that occur in irregular "patches" across the landscape with particular sets of conditions.
- Other hybrid zones occur as simple narrow bands like the example of on the next slide.

Yellow-bellied toad, *Bombina variegata*

Fire-bellied toad, *Bombina bombina*





Patterns within Hybrid Zones

What causes this pattern of allele frequencies across a hybrid zone?

- Hybrid toads have increased embryonic mortality and morphological abnormalities.
- Since hybrids have poor survival and reproductive rates, they produce few viable offspring.
- As a result hybrid toads rarely serve a conduit that passes alleles from species to another.
- Outside the hybrid zone natural selection may be acting on different traits within the parent species keeping them genetically different.

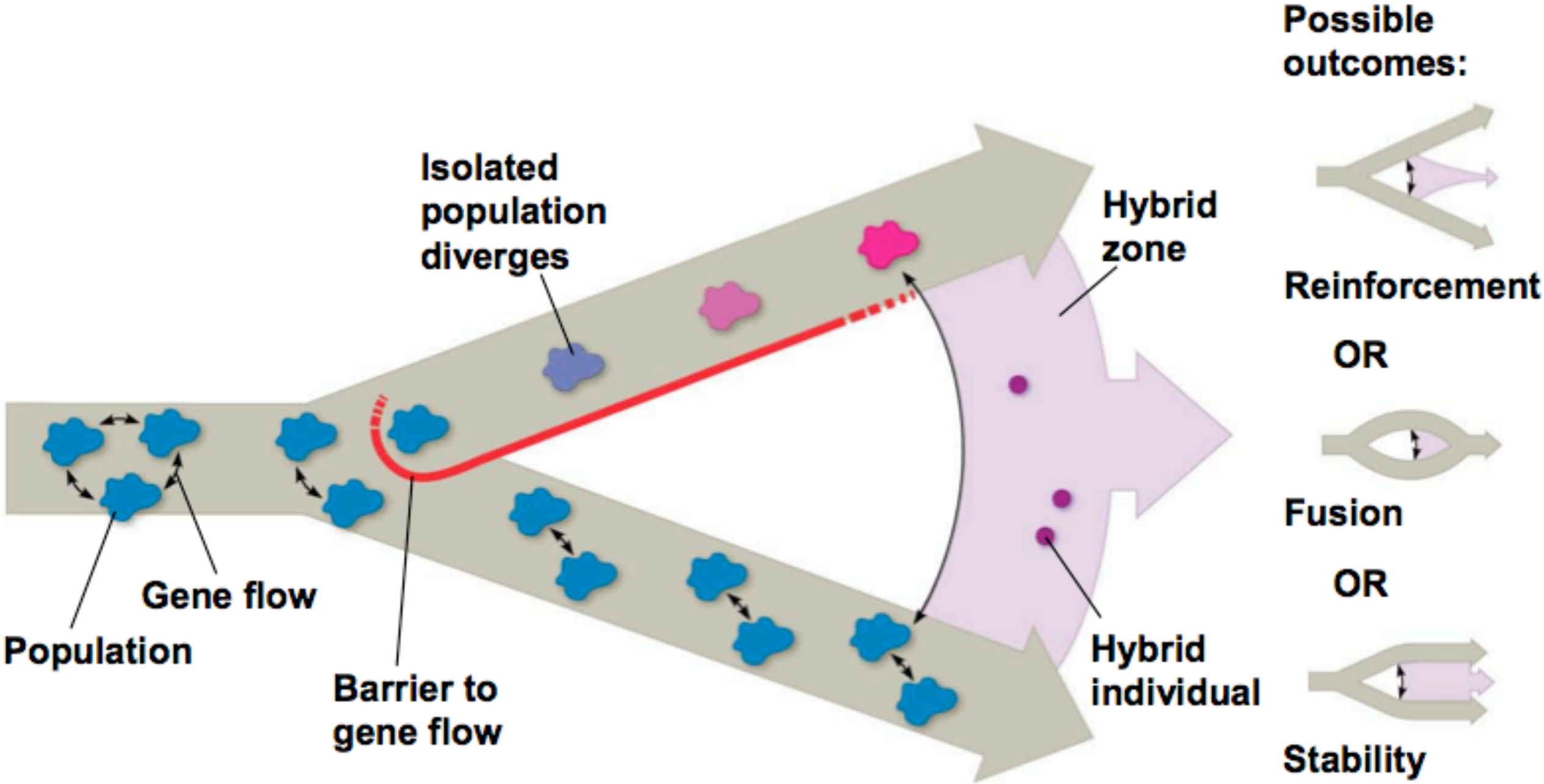
Hybrid Zones Over Time

What will become of the hybrids over time?

- Option 1: The hybrids become isolated from parent species and form their own new species.

OR

- Option 2: **Reinforcement**, hybrids gradually cease to be formed.
- Option 3: **Fusion**, the hybrids bring together the two parent species and they become one.
- Option 4: **Stability**, we maintain the hybrid zone over time (no change).


Possible outcomes:
Isolated population diverges
Hybrid zone
Reinforcement
OR
Fusion
OR
Stability
Gene flow
Population
Barrier to gene flow
Hybrid individual

Reinforcement:
Strengthening Reproductive Barriers

- When hybrids are less fit than members of the parent species,
- we might expect natural selection to strengthen the prezygotic barriers to reproduction
- thus reducing the number of hybrids over time.
- Because this process "reinforces" reproductive barriers, it is called **reinforcement**.

Females choosing between these males:

closely related species

Sympatric pied male

males look different

Sympatric collared male

because males are different females of each species do not make mistakes, they mate with their own species

thus reproductive barriers are stronger in sympatric populations

(none)

Females choosing between these males:

closely related species

Allopatric pied male

males look similar

Allopatric collared male

because males are similar females of each species make mistakes, and sometimes mate with the other species

Fusion: Weakening Reproductive Barriers

- When reproductive barriers are weak, gene flow may occur so much that the two parent populations become one.
- 200 of the 600 cichlid species have been lost over the last thirty years
- some were naturally driven to extinction by predators like the Nile perch but many were lost as a result of fusion.

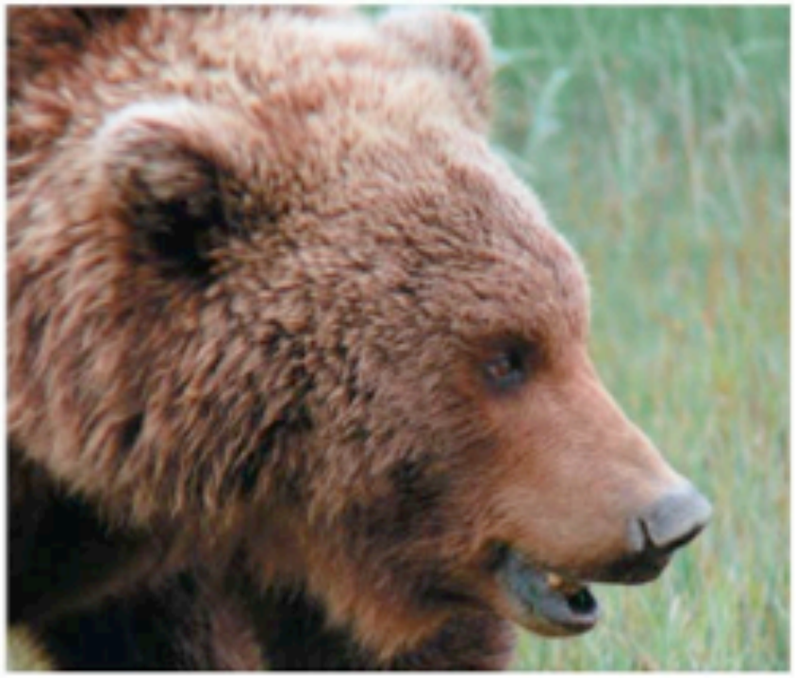
Females sexually selected males by color when water was clear

Pundamilia nyererei

Pundamilia pundamilia

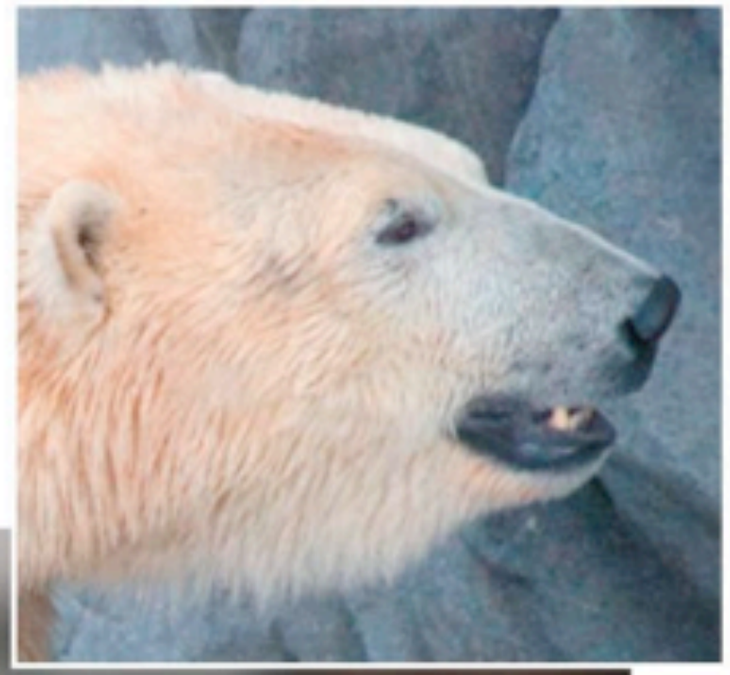
Pollution has caused the water to become murky and females are no longer able to distinguish between color of males

Pundamilia "turbid water,"
hybrid offspring from a location with turbid water



Grizzly bear *(U. arctos)*

Polar bear *(U. maritimus)*



Hybrid "grolar bear"

A similar story may be happening to the polar bears at this time

Grizzly/Polar bear hybrids have been documented (in the wild)

Can you form a hypothesis for how and why this occurring? Which species is at risk for extinction? Why?

Stability: Continuation of Hybrids

- Many hybrid zones are stable and continue to exist.
- Consider the *Bombina* toad example this hybrid zone has existed for over 20 years, likely explained by the narrow nature of the zone.
- You see since the zone is so narrow each parent species runs into each other with such frequency that it maintains gene flow but hybrids are so poor that fusion can not take place.
- On the other hand if the zone was wide there might be limited enough gene flow in the middle to allow reinforcement.

PHYLOGENY

Main Idea:

Molecular clocks will help evolutionary biologists understand relationships among all organisms, even those with no fossil record.

Molecular Clocks

- **Molecular clocks** are "yardsticks" for measuring absolute time of evolutionary change based on the observation that some genes and other regions of genomes appear to evolve at constant rates.

  - *The assumption is that the number of nucleotide substitutions in orthologous genes is proportional to the time that has elapsed since the species branched from their common ancestor.*

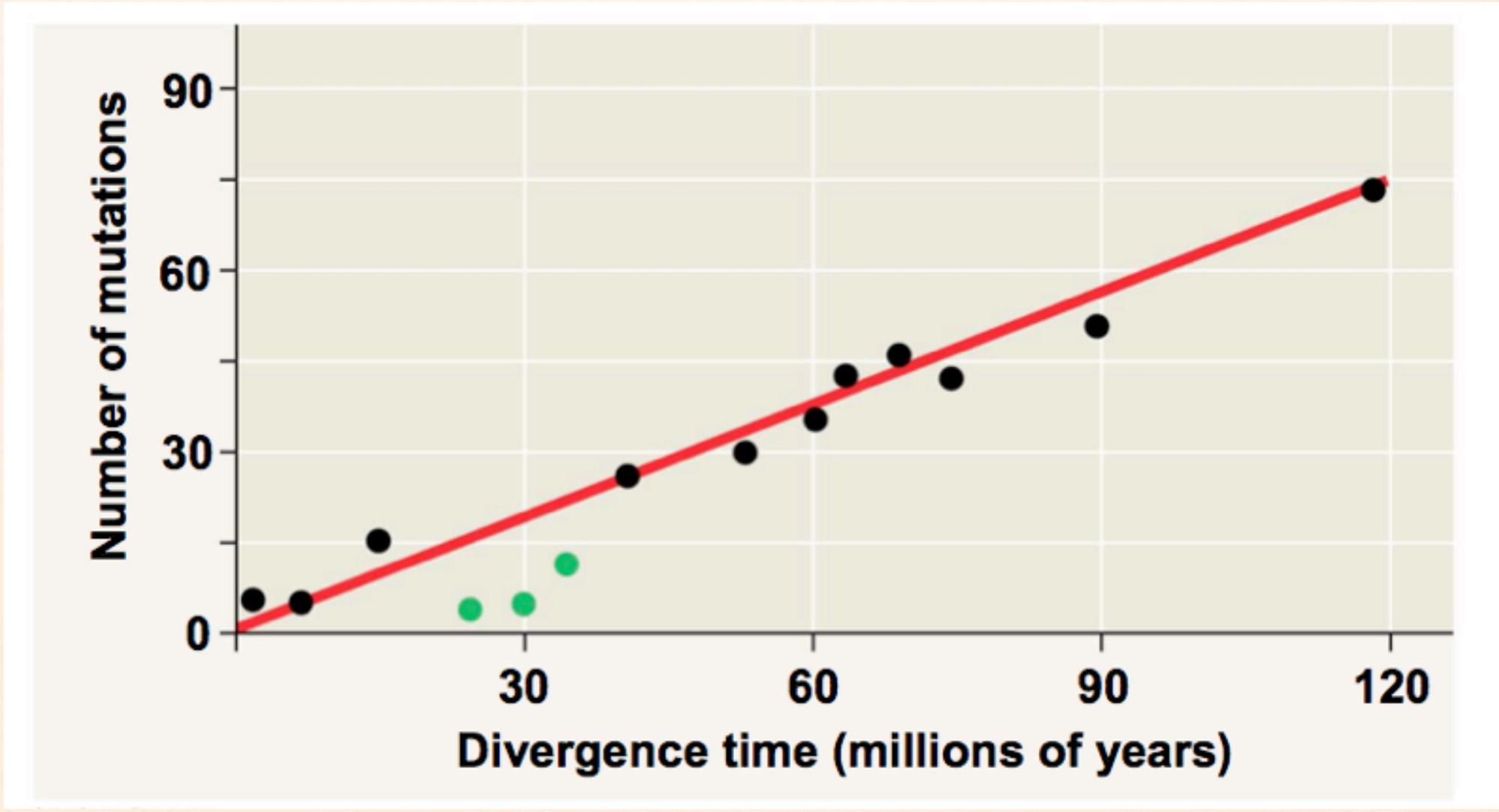
  - *In paralogous genes nucleotide substitutions are proportional to the time since the genes became duplicated*

Molecular Clocks

- We can calibrate the molecular clock of a gene that has a reliable rate of evolution by graphing the number of genetic differences (nucleotide, codon or amino acids) against dates of evolutionary branch points that are known from the fossil record.

- The average rates of change can be inferred from such graphs and can be used to estimate the dates of events that cannot be discerned from the fossil record, such as the origin of Silverswords on Hawaii.

Accumulated mutations in seven proteins has increased over time in a consistent manner for most mammals. The green dots represent primates, whose proteins appear to have evolved more slowly than those of other mammals. The divergence time for data point was based upon fossil evidence.



Of course, no gene marks time with absolute precision. Molecular clocks are only accurate in a statistical sense of showing a fairly smooth average rate of change

Neutral Theory

- **Neutral theory** states that much evolutionary change in genes and proteins has no effect on fitness and is not influenced by natural selection

- The harmful mutations are removed quickly and if the rest have no effect on fitness then the rate of molecular change in these genes and proteins should be regular like a clock.

  - Differences in the clock rate for different genes are a function of how important the gene is.

Neutral Theory

- If an exact amino acid sequence that a gene codes for is necessary for survival then most mutations will be harmful and few will be neutral.
  - ...thus such genes would evolve slowly
- But if an exact amino acid sequence that a gene codes for is less critical for survival then most mutations will be neutral and few will be harmful.
  - ...thus such genes would evolve more quickly

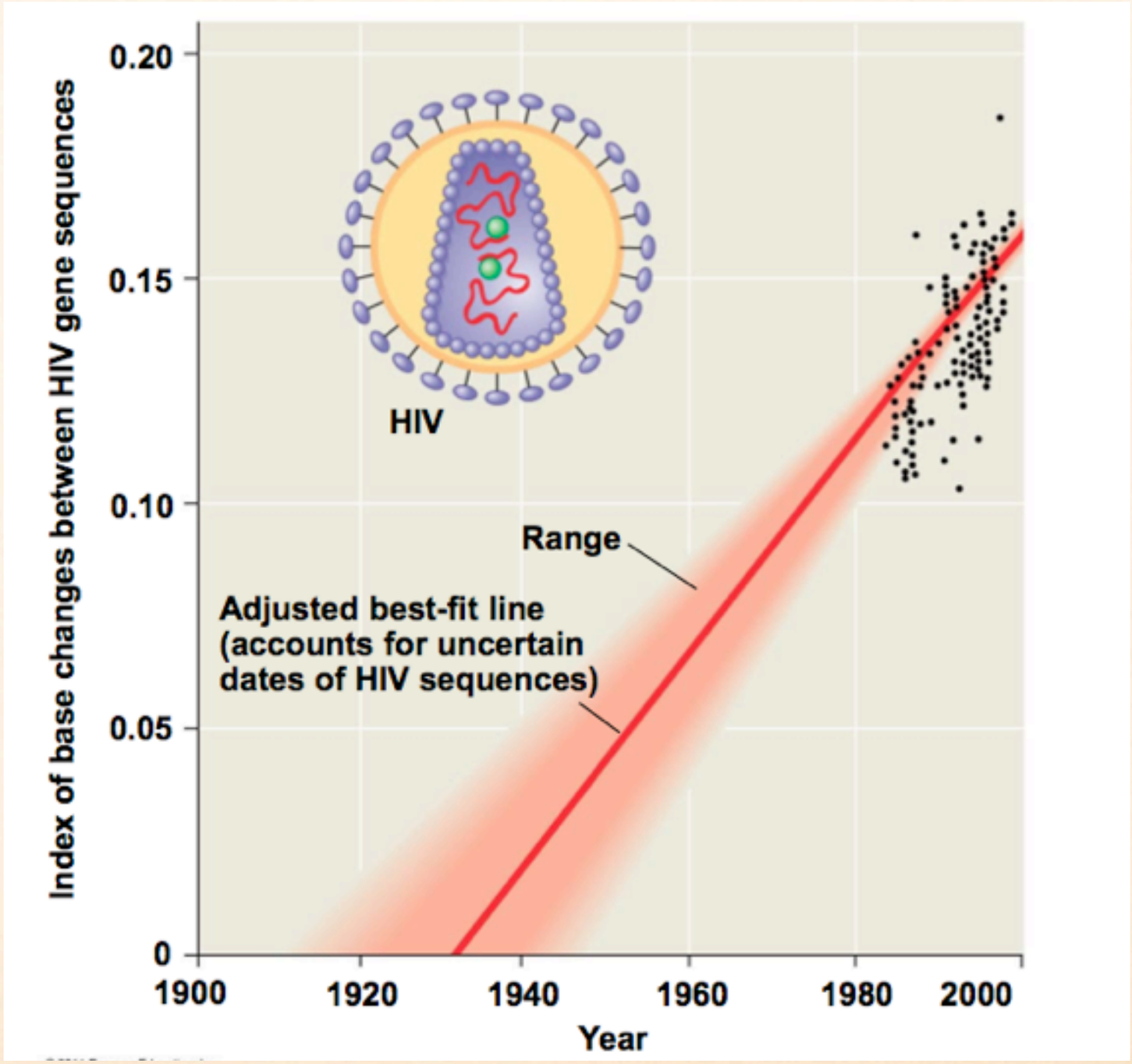
Problems with Molecular Clocks

- The molecular clock does not run as smoothly as neutral theory predicts
- Irregularities result from natural selection in which some DNA changes are favored over others
- Estimates of evolutionary divergences older than the fossil record have a high degree of uncertainty
- The use of multiple genes may improve estimates

Applying a Molecular Clock: HIV

- Phylogenetic analysis shows that HIVis descended from viruses that infect chimpanzees and other primates
- HIV spread to humans more than once
- Comparison of HIV samples shows that the virus evolved in a very clocklike way

- Application of a molecular clock to one strain of HIV suggests that that strain spread to humans during the 1930s



Learning Objectives

LO 1.25 The student is able to describe a model that represents evolution within a population. [See **SP 1.2**]

LO 1.26 The student is able to evaluate given data sets that illustrate evolution as an ongoing process. [See **SP 5.3**]