ORIGINS

LIFE ON PLANET EARTH

VIEWPOINTS ON LIFE'S ORIGINS

Controversial topics in the origin of life

Heterotrophic origin Complex prebiotic chemistry and simple metabolism	**Autotrophic origin** Simple chemical ambient and complex metabolism
Genetics first Early, spontaneous, self-replicative polymers	**Metabolism first** Primitive bioenergetic mechanisms
Cells as latecomers Cells as mere compartments for replicators	**Cells as early invents** Cells as necessary elements for bioenergetics

Int. Microbiol.

THEORIES OF LIFE ORIGINS

- SPONTANEOUS GENERATION – LIFE CAN COME FROM NONLIVING THINGS.
- BIOGENESIS – LIFE ONLY COMES FROM OTHER LIVING THINGS
- COSMOGENESIS – LIFE ON EARTH CAME FROM ANOTHER PART OF OUR SOLAR SYSTEM OR GALAXY
  - METEORITES CONTAIN ORGANIC COMPOUNDS
  - CONDITIONS NECESSARY FOR LIFE MAY HAVE EXISTED ON OTHER PLANETS OR MOONS
- SPECIAL CREATION – ALL RELIGIOUS BELIEFS

Spontaneous Generation

ABIOGENESIS- creation without life.

Spontaneous Generation was the mistaken idea that life can arise from non-living materials. We now believe the cell theory. The cell theory states that all cells come from pre-existing cells.

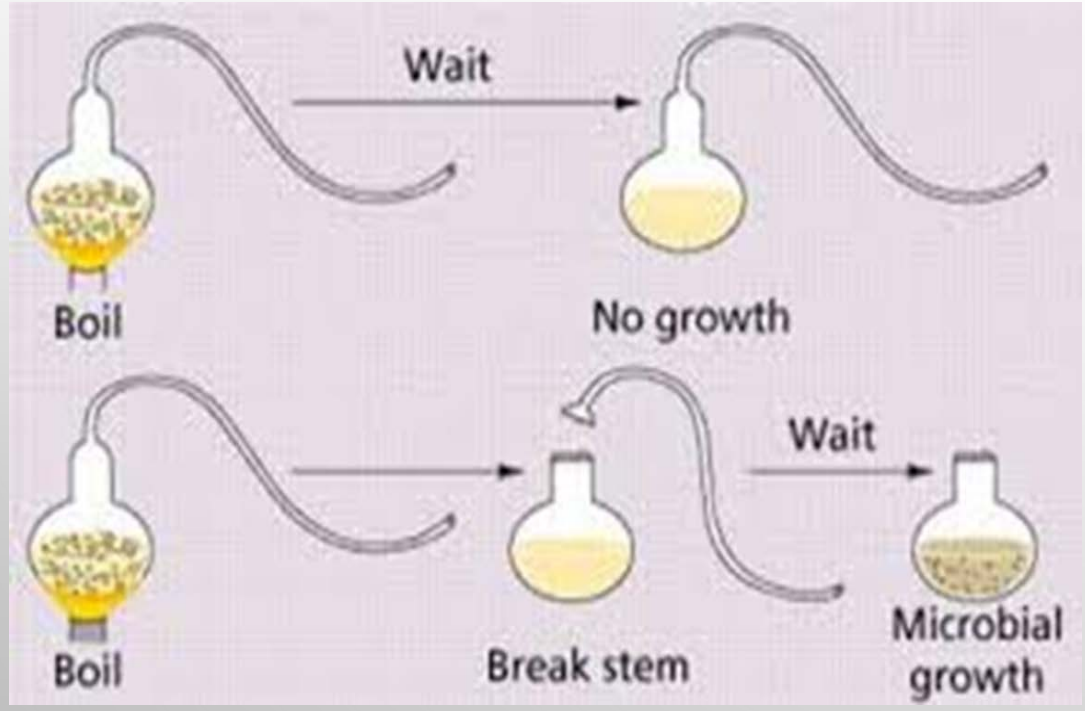
- Ancient Egyptians believed that eels and frogs came from the mud of the Nile.
- Aristotle "active principle" responsible for life:

  fleas come from sweat

  mice come from garbage

  flies and maggots come from dead and decaying meat

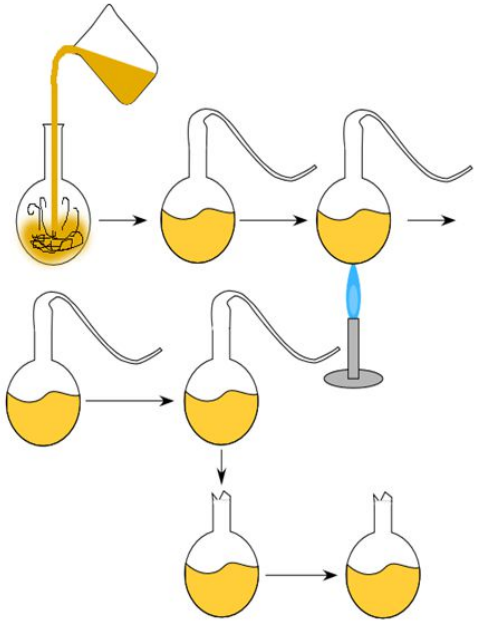
BIOGENESIS: PASTEUR EXPERIMENT



Key Scientists – Origin of Life

Louis Pasteur (1822-1895)

- Experiment: Boiled broth and enclosed it in an "S" curved neck flask. It was open and exposed to air, however not directly. Exposed for 1 year, no microorganisms; Removed "S" curve and exposed it for 1 day! = microorganisms
- **Conclusion**: Spontaneous generation was disproved and biogenesis theory was substantiated. (Confirmed, make real or actuated) Contamination came from other microorganisms, not "air".
- Modern biologists support biogenesis, the idea that "living organisms only come from other living organisms."
- That then brings up the question of *how life began on Planet Earth.*
- If Life can only come from life, we know at some point there had to be a start to "life"…
  - Where would you start looking for early life?

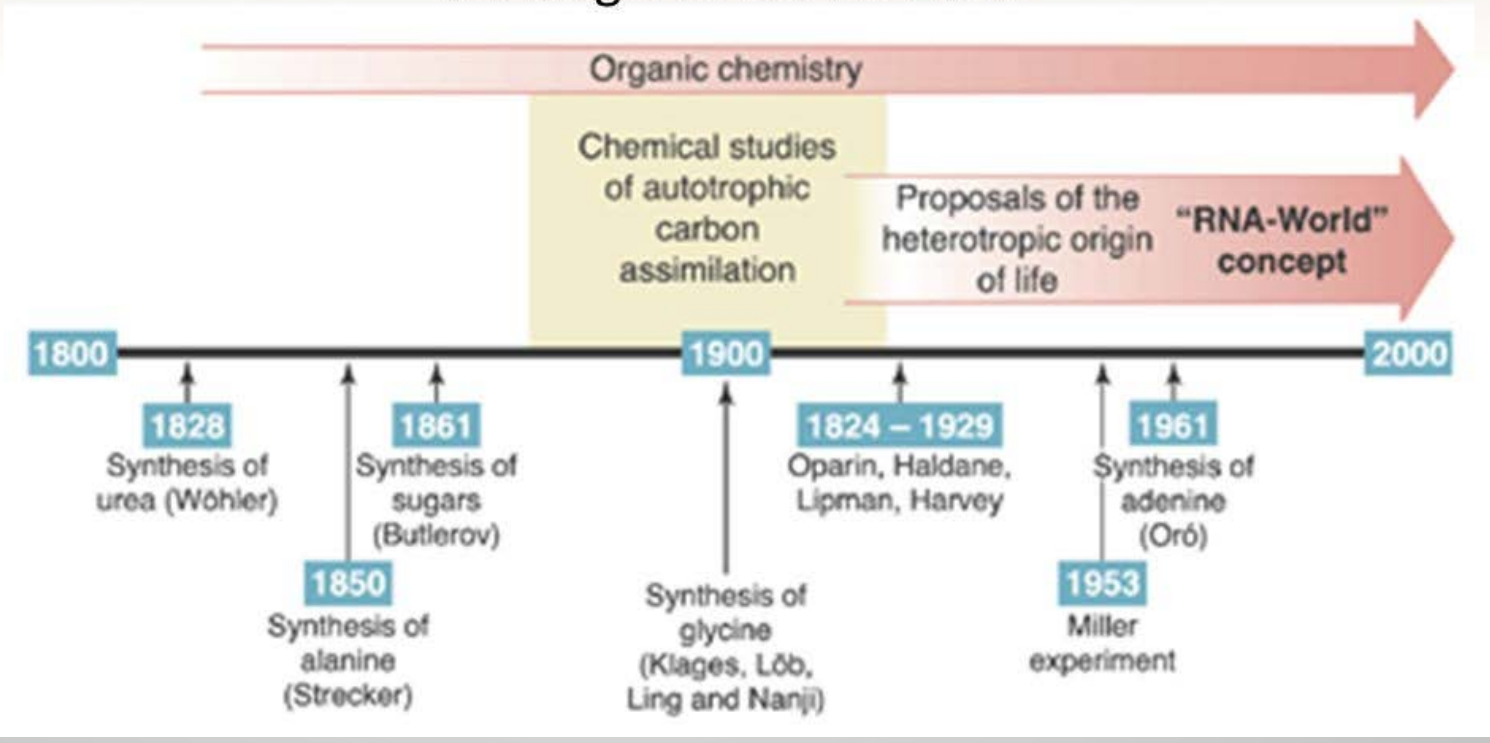


Four Stage Hypothesis

* 1) Abiotic synthesis of small organic molecules; amino acids, nucleotides
* 2) Joining of these molecules into polymers; proteins, nucleic acids
* 3) Origin of self-replicating molecules that made inheritance possible
* 4) Packaging into Protobionts--droplets with membranes and an inner chemical composition different than its surrounding

History of Chemistry for the Origin of Life

The RNA World refers to a hypothetical stage in the origin of life on Earth



PRIMITIVE SOUP

Primordial Soup Theory

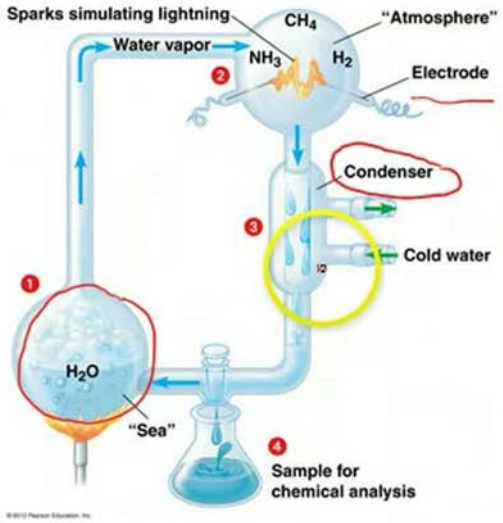
- Russian Chemist A.I. Oparin and English Geneticist J.B.S. Haldane in 1920.
- basic building blocks of life came from simple molecule then energized by lightning and the rain from the atmosphere created the "organic soup".
- The first organisms would have to be simple heterotrophs. In order to survive, they consume other organisms for energy. They would become autotrophs by mutation. Evidence now suggest the first organisms were autotrophs.

Synthesis of Organic Compounds on Early Earth

- Oparin & Haldane:
  - Early atmosphere = H_2O vapor, N_2, CO_2, H_2, H_2S methane, ammonia
  - Energy = lightning & UV radiation
  - Conditions favored synthesis of organic compounds - a "primitive soup"

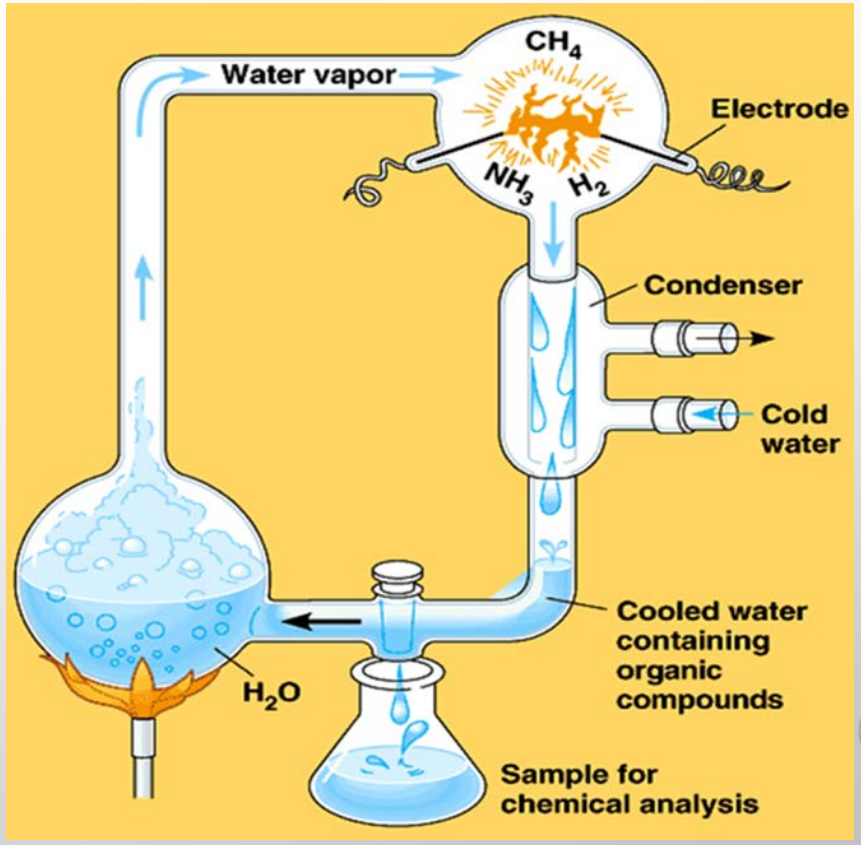
ABIOTIC SYNTHESIS

Miller's Experiments: Creating organic molecules via abiotic synthesis (1)

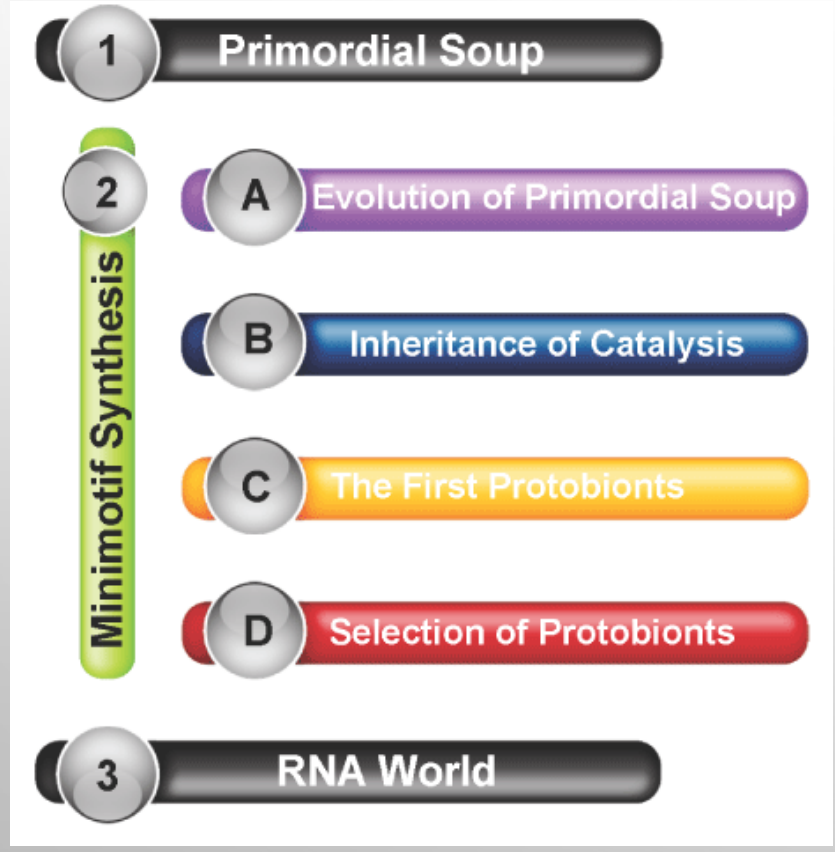


The following is evidence for the hypothesis of the origin of life:

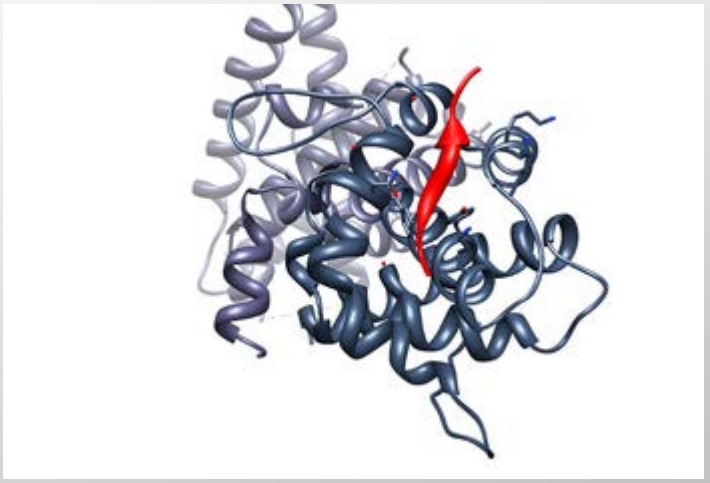
- This was possible in an oxygen deprived atmosphere (reducing atmosphere)
- Miller identified hydrocarbons and amino acids



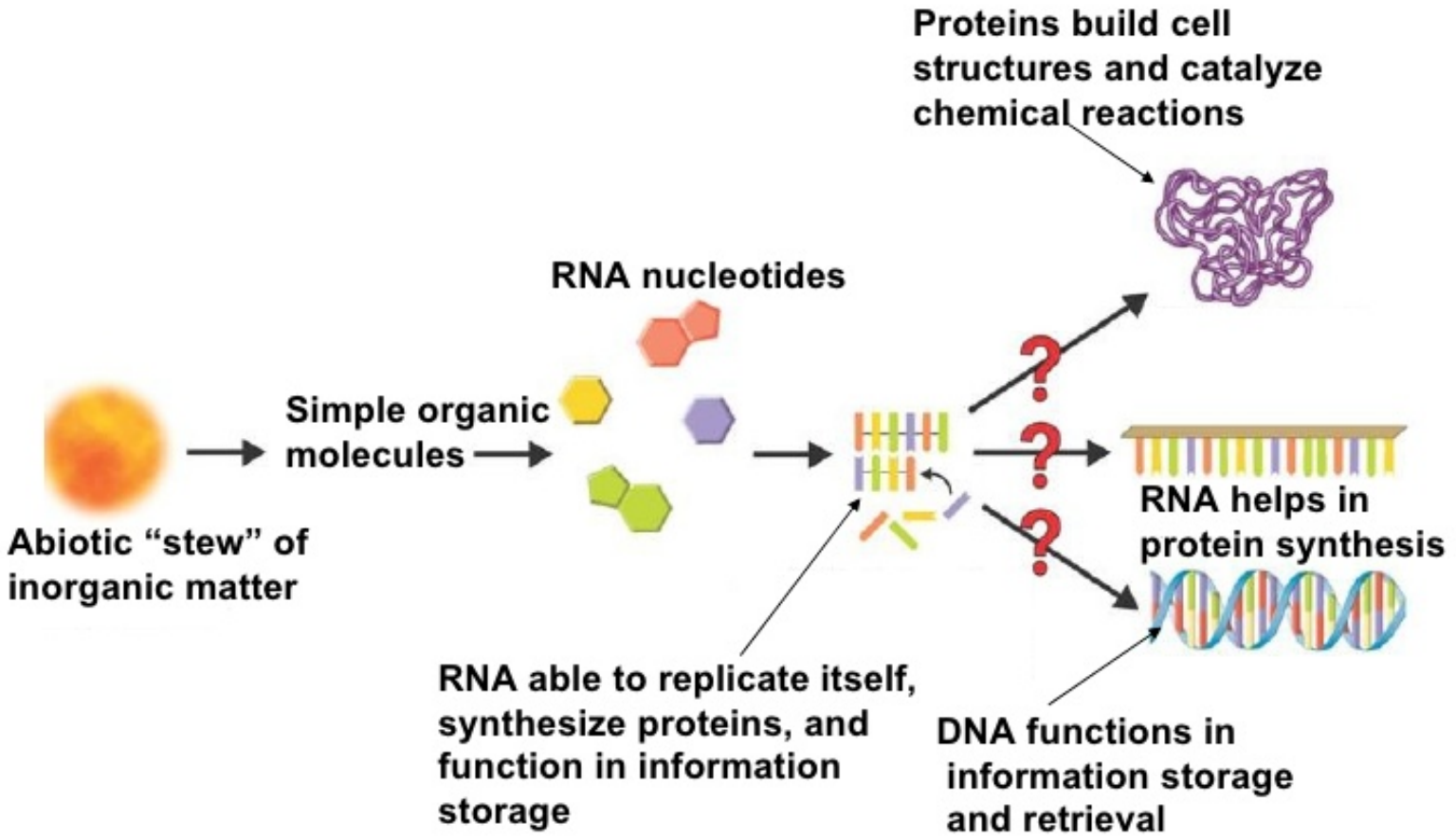
MINIMOTIF SYNTHESIS HYPOTHESIS



- SHORT STRETCHES
- LINEAR
- PROTEIN SEQUENCE
- INTERACTIONS
- HIGHLY CONSERVED
- CONVERGENT EVOLUTION

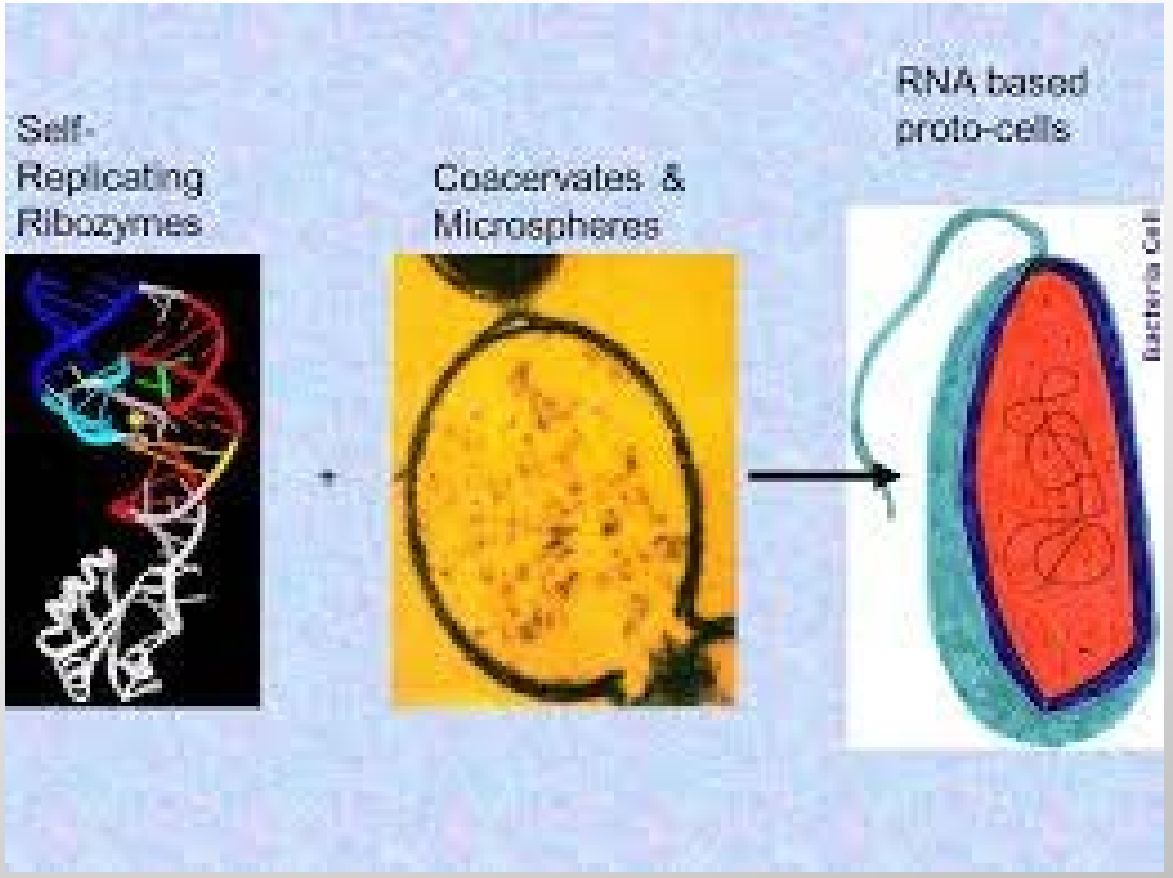


RNA and the Origin of Life



RNA

- REPLICATION
- RIBOZYMES
- PROTOCELLS



SINGLE CELLED ORGANISMS

Early Fossilized Cells/ Unicellular Organisms

- Cyanobacteria and Stromatolites
  - **Archean,** from 3.8 to 2.5 Bya

(a)

Figure 06A: Record of stromatolite deposits and microbial fossils

(b)

Figure 06B: Record of stromatolite deposits and microbial fossils

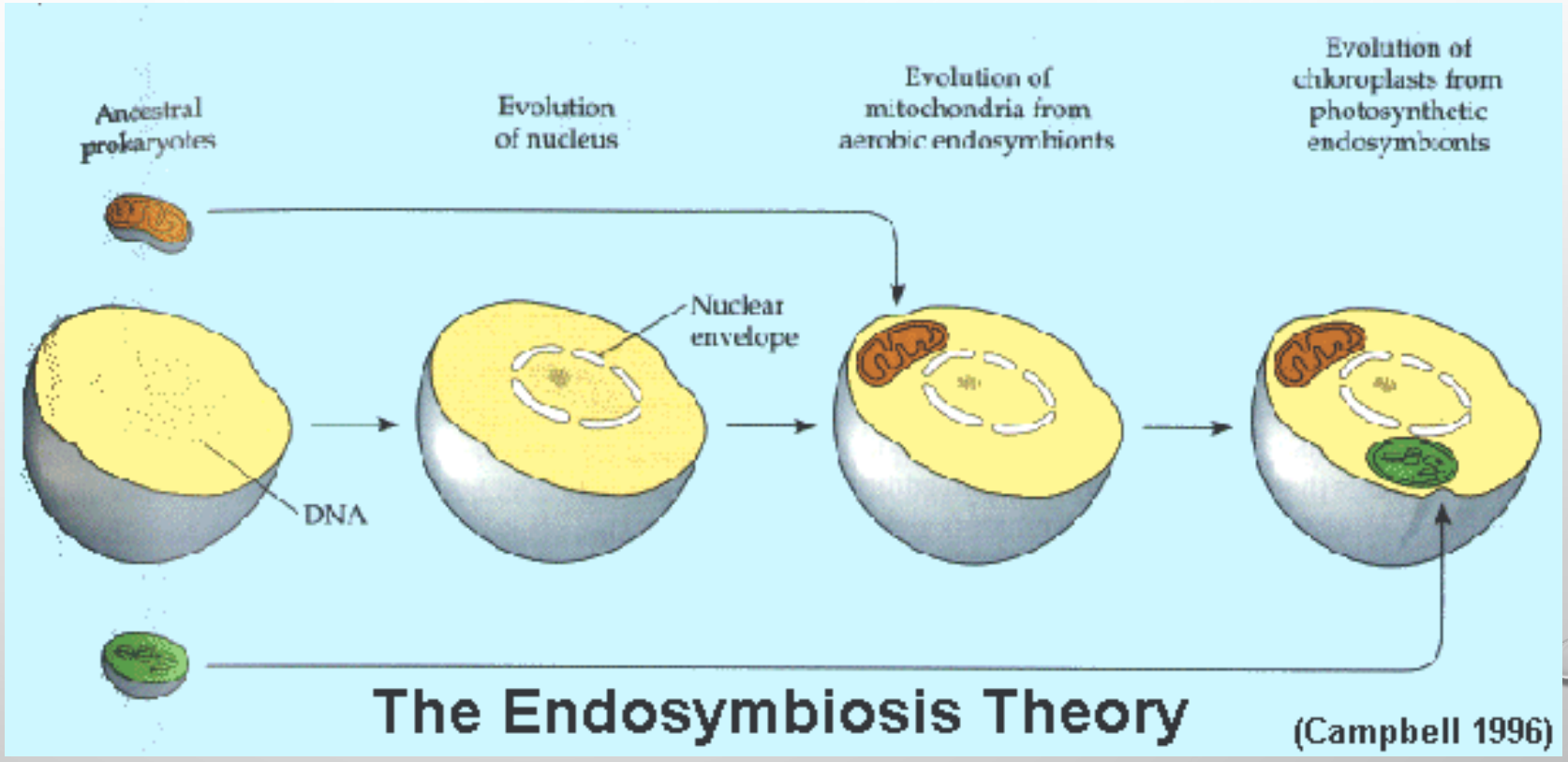
Courtesy of J. William Schopf, Professor of Paleobiology & Director of IGPP CSEOL

12.4 Early Single-Celled Organisms

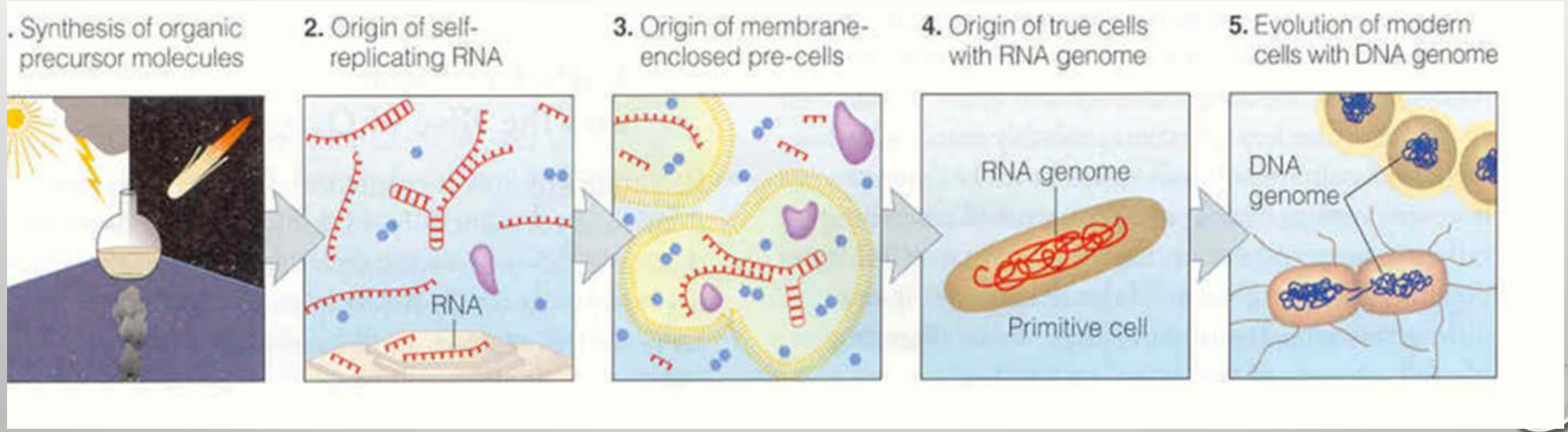
- Microbes have changed the physical and chemical composition of Earth.
  - The oldest known fossils are a group of marine cyanobacteria.
    - added oxygen to atmosphere
    - deposited unique minerals

EUKARYOTES

- ENDOSYMBIOSIS



LIFE ORIGIN SUMMARY



PALEONTOLOGY

The Fossil Record

- Paleontology is the study of the fossil record to document life's early history
  - Documents patterns within species living at a specific time and area
  - Documents extinctions and new arrivals
  - Documents evolution of life as the environment of Earth changed
- Index (Key) Fossils are those found in similar strata over a wide area... used for relative dating

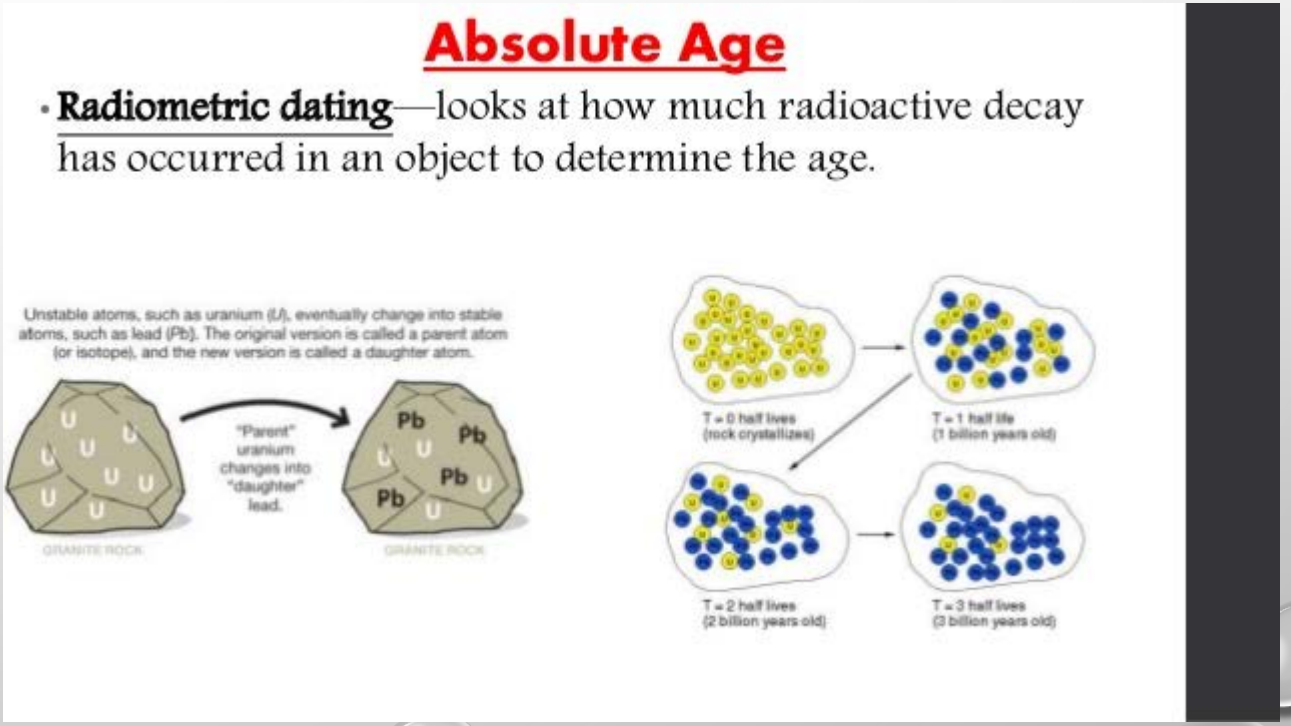
CLASSIFICATION OF FOSSILS

- **Macrofossils**
- Plant fossils
- Vertebrate fossils
- Invertebrate fossils
- **Microfossils**
- **Nanofossils**

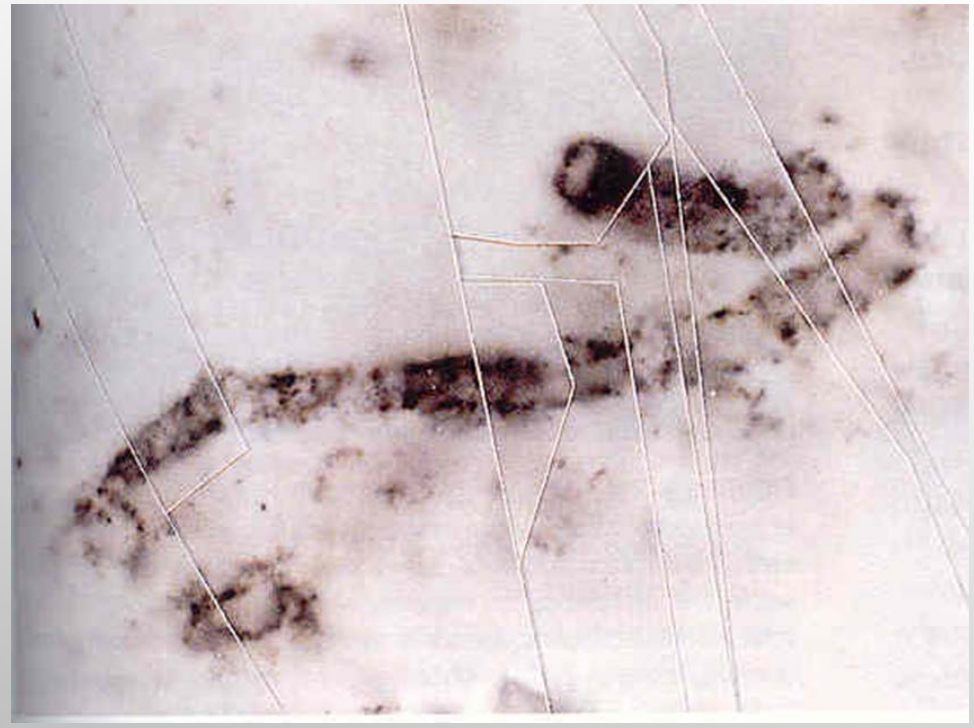
MACROFOSSILS

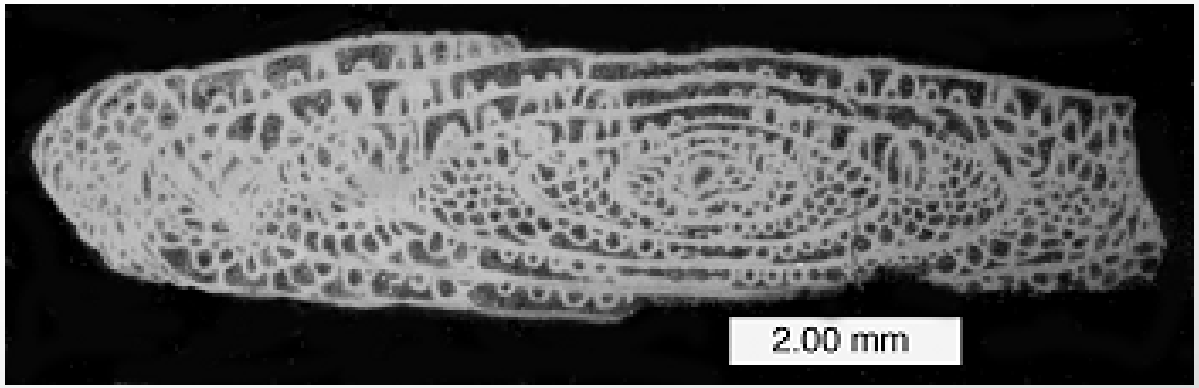
- SEDIMENTARY ROCK

- RADIOMETRIC DATING



MICROFOSSILS: 3.5 BILLION YEARS AGO…

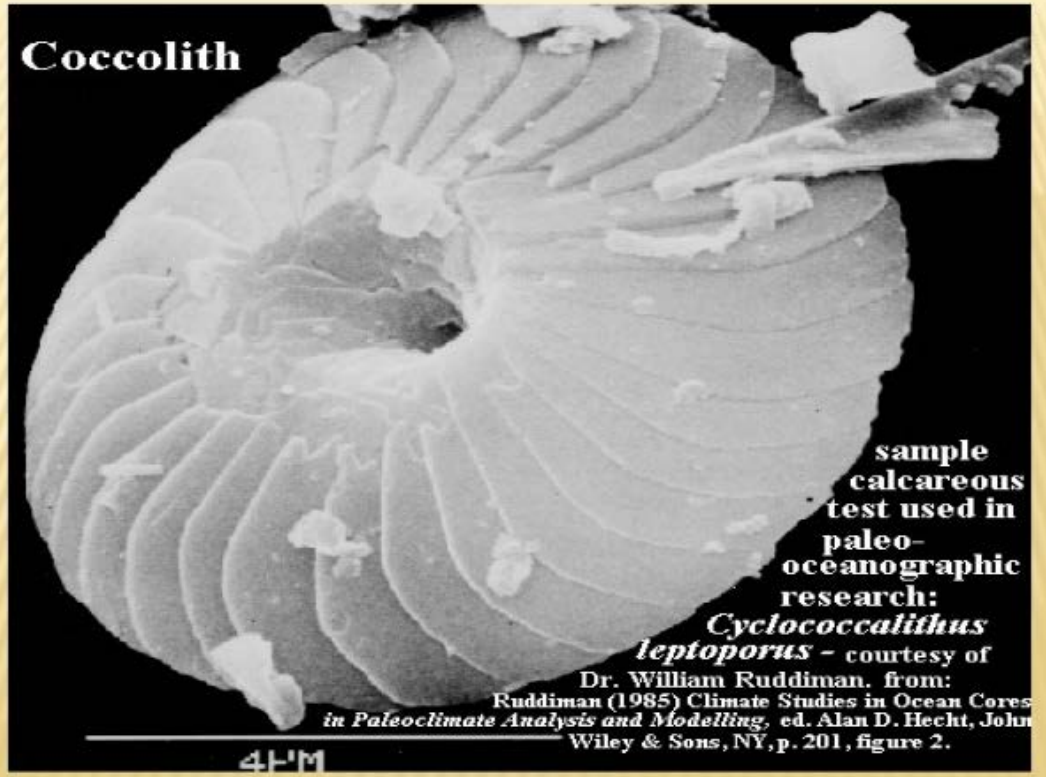




NANOFOSSILS

CALCAREOUS NANO FOSSILS

- These are the remains of golden brown, single celled algae, also known as '**nanos**'.
- It is one of the primary organisms at the base of the food chain.
- Slowly covered by remains of other plants and animals and bits of mud and sand.
- Preserved in rocks; can be part of a **limestone** or **shale**.
- Age: Around 200 m.y. from **triassic.**



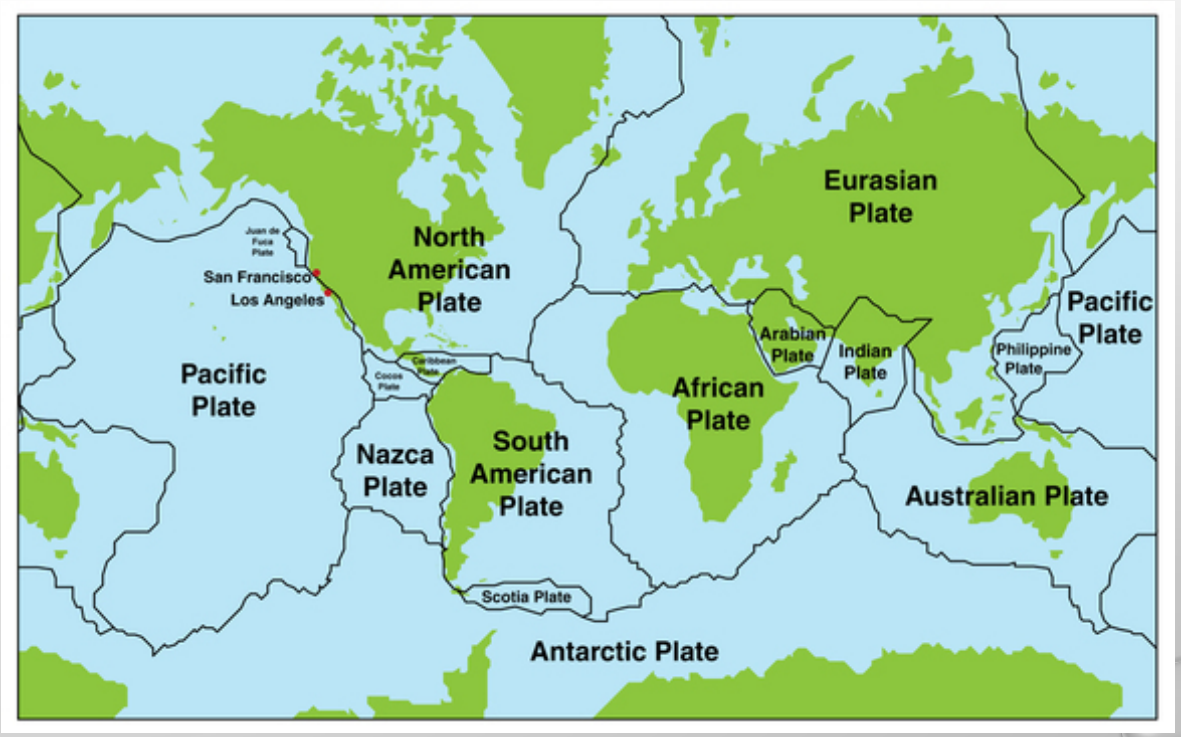
GEOLOGICAL RECORD

PLATE TECTONICS THEORY

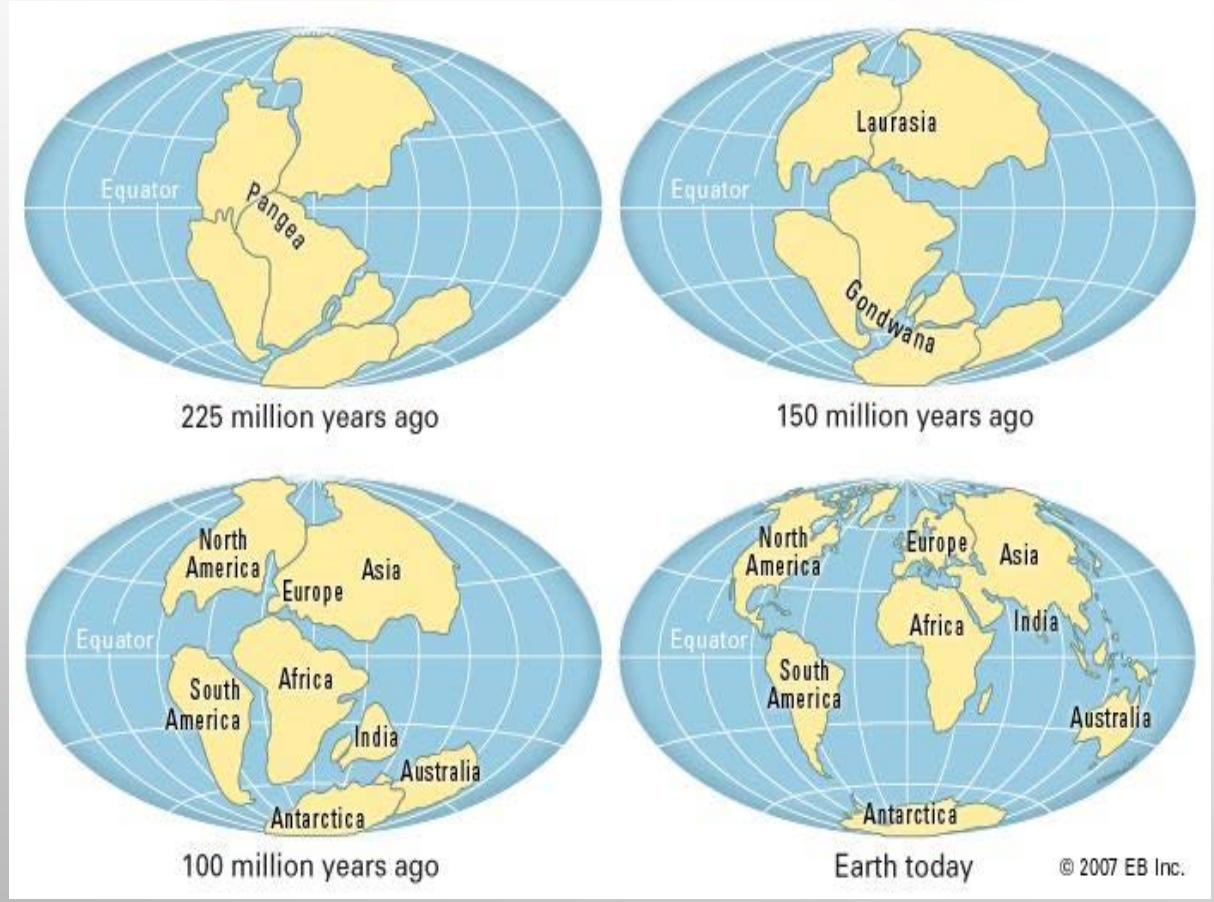
The Theory of Plate Tectonics

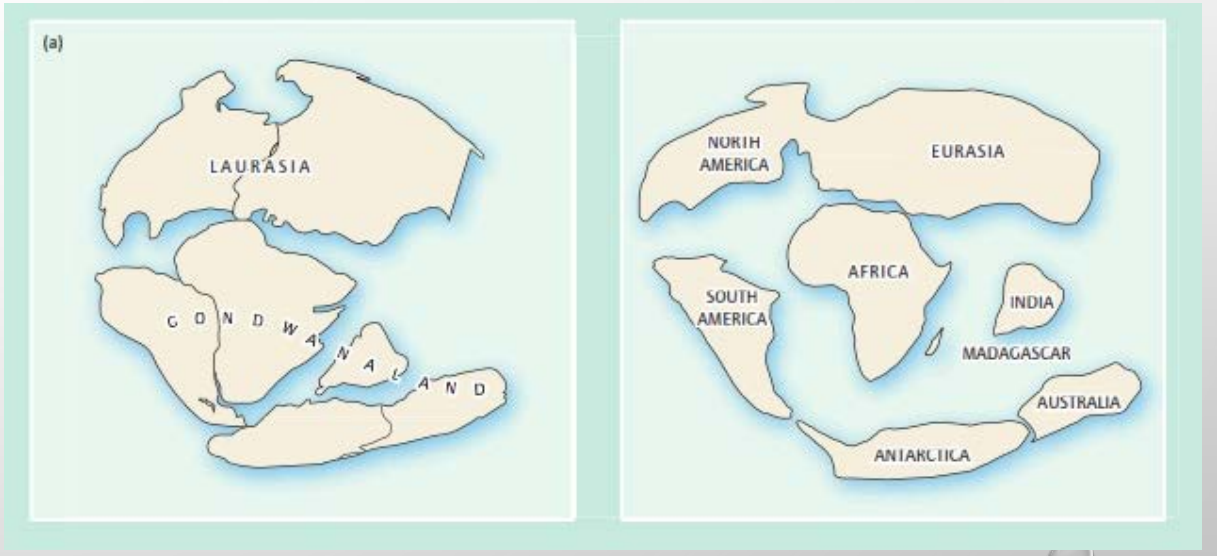
- Is a theory of why and how the continents move.

- The earth consist of two types of crust.
  - –Oceanic Crust
    - Material on the ocean floor
  - –Continental Crust
    - Crust that makes up land masses

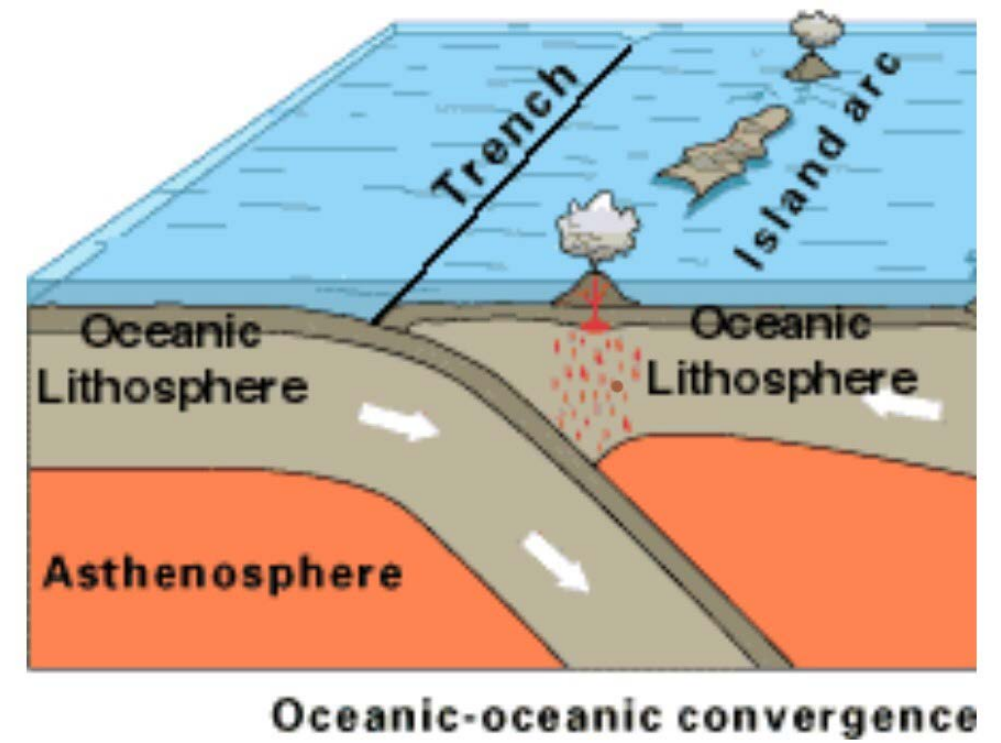


CONTINENTAL DRIFT





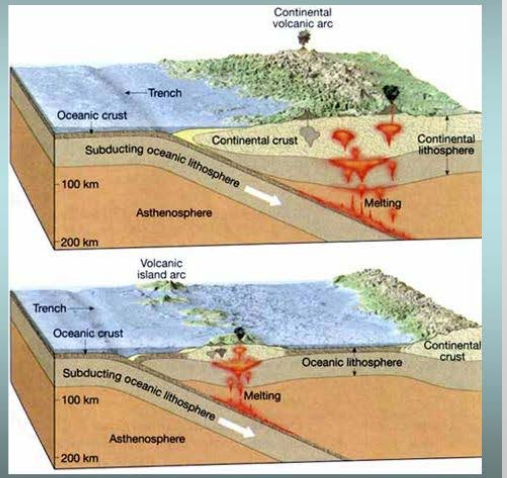
GEOLOGICAL CHANGE



Convergent Plate Boundaries

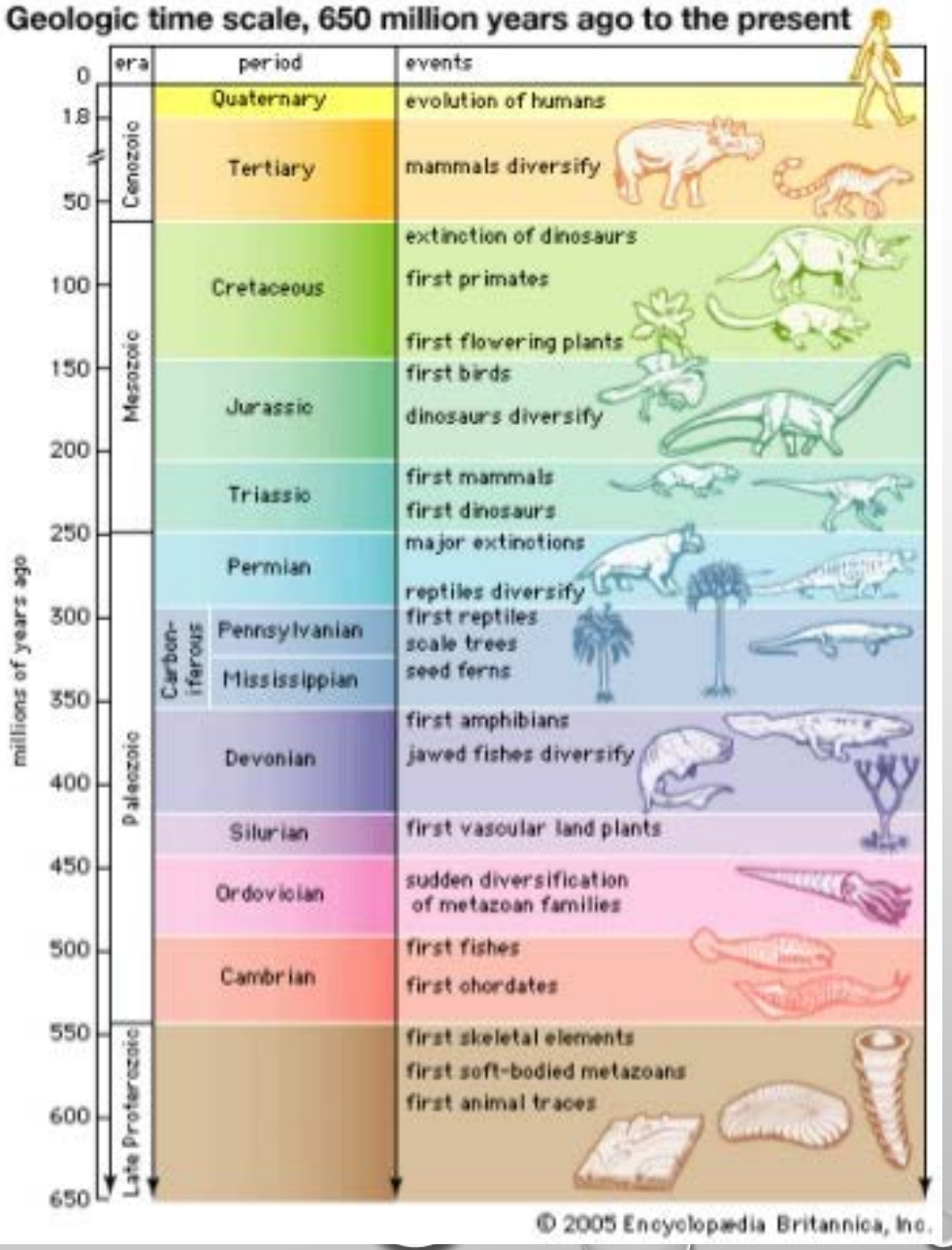
→ ←

- Plates are pushed **together**
- Oceanic crust is **subducted** and absorbed into the mantle creating a **subduction zone**
- Produces a deep-ocean **trench** and **volcanic arc.**



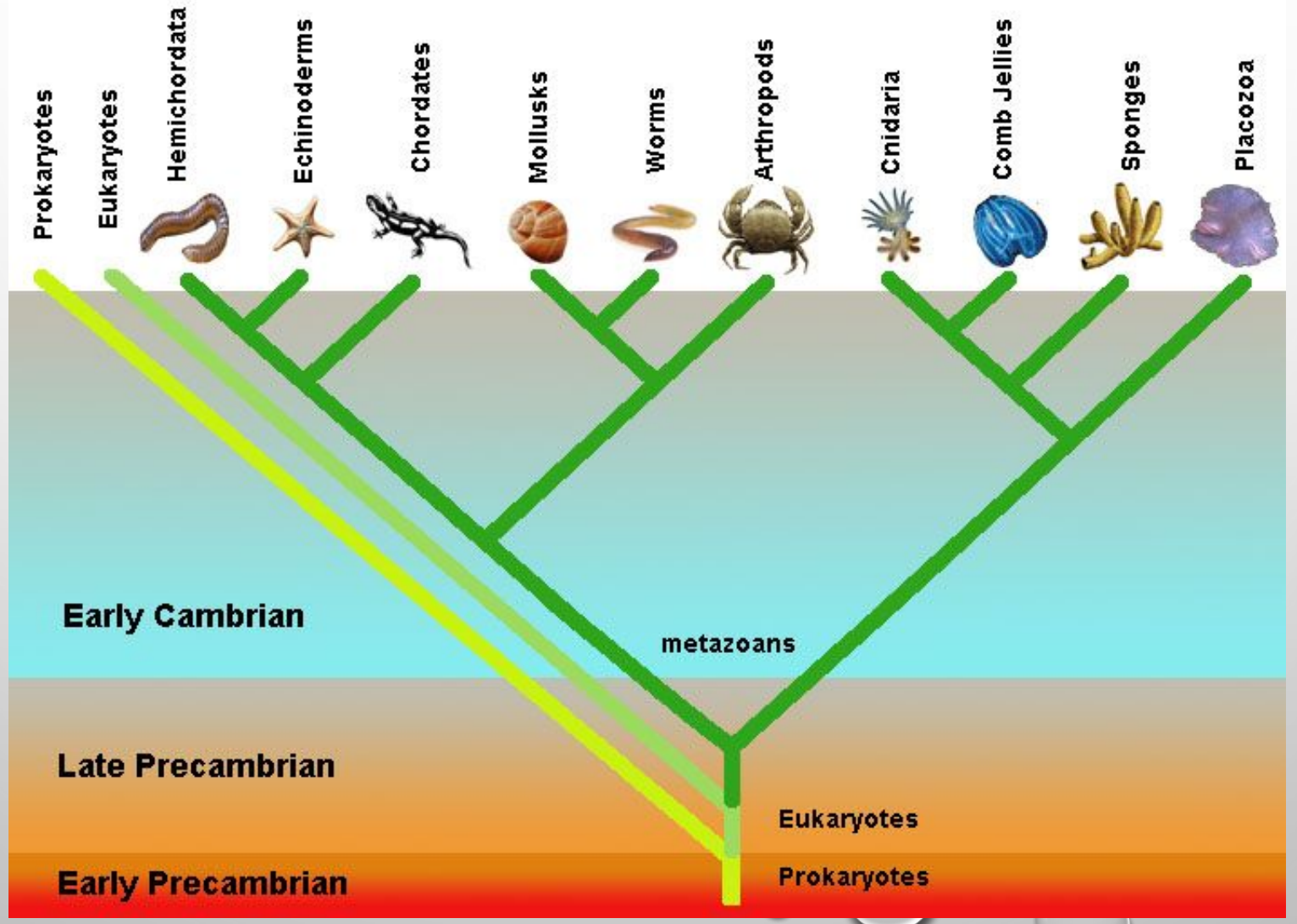
Geologic Time

- Assumes sedimentation occurs evenly and slowly over millions of years
- Large gaps remain in the fossil record – they may be still hidden, have been destroyed, or never existed



The "Cambrian Explosion"

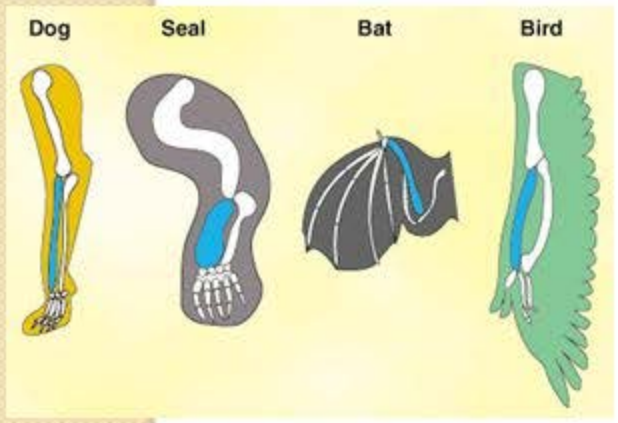
Evidence in the fossil record shows that all major phylla were established in the transition from Late Precambrian to Early Cambrian time

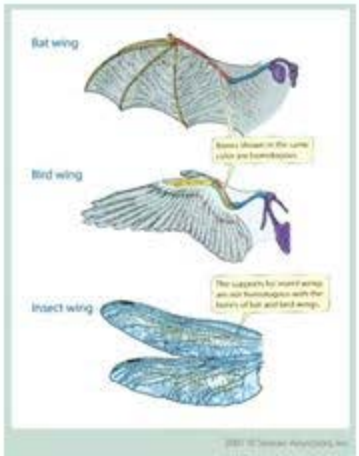


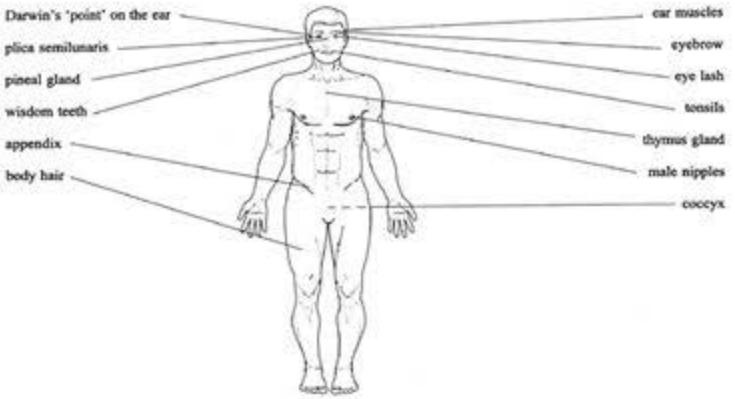
Types of Evidences of Evolution

2. Anatomy

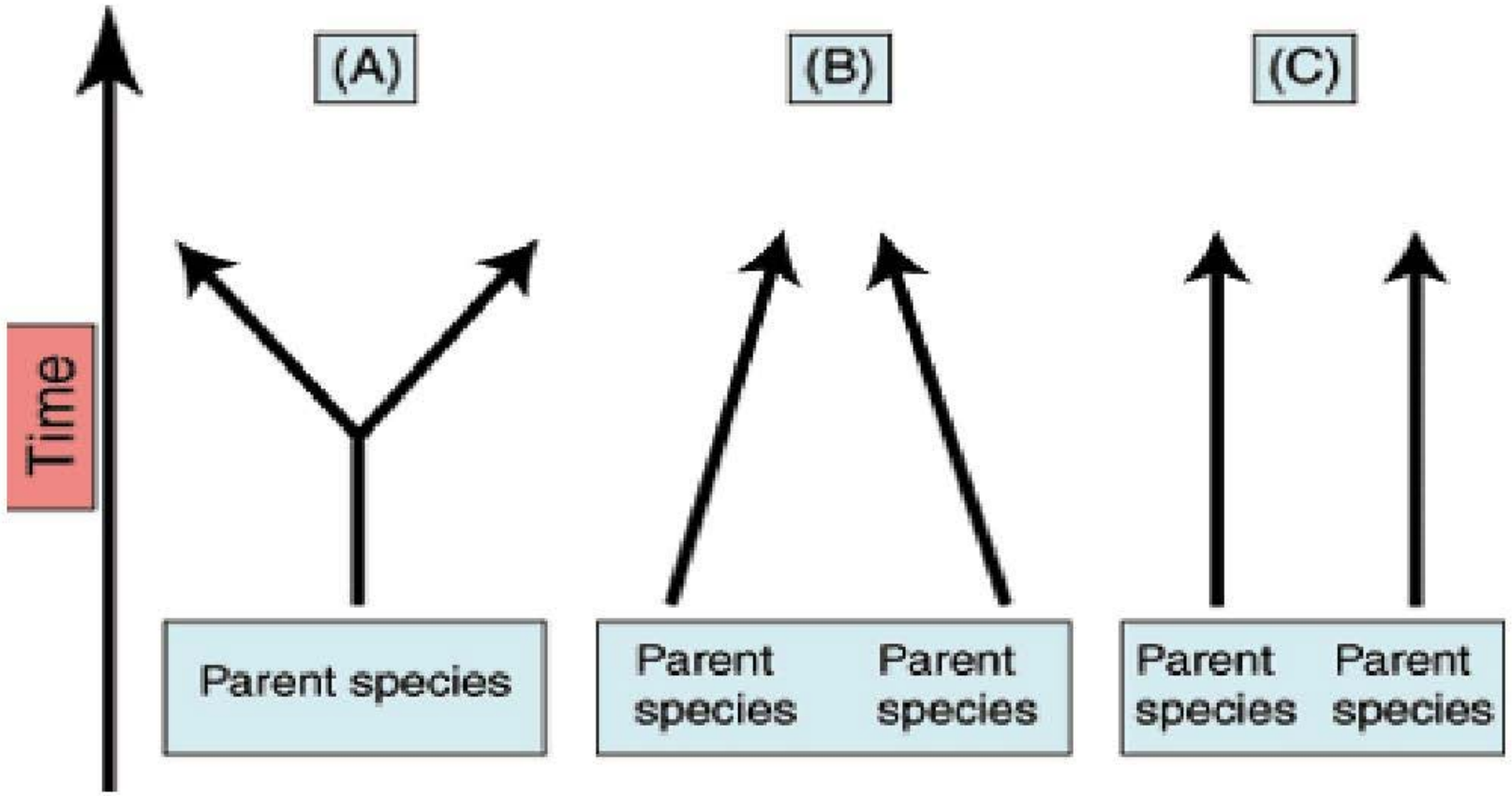
- **Homologous structures** – Similar structures, Different use or function.
- **Analogous structures** – different structure but are similar in function.
- **Vestigial structures** – a body part structure that has no function in a present day organism but was useful to an ancestor. (ex human appendix)







Types of EVOLUTION
Divergent vs. Convergent



Divergent v. Convergent Evolution

Divergent

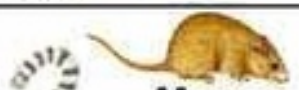
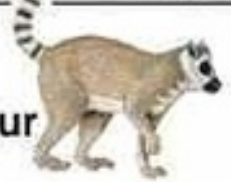
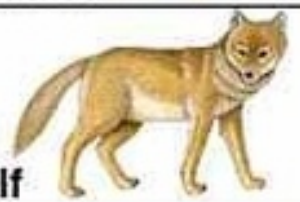
- One species gives rise to many species
- Also known as **adaptive radiation**
- Many species with common ancestor
- Many homologous structures

Convergent

- Similar looking species that do not have a common ancestor
- Similar behavior and appearance due to environmental similarities
- Many analogous structures

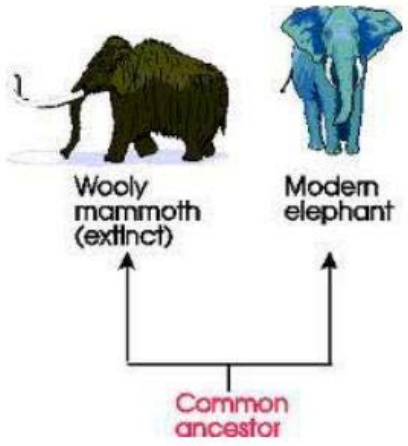
Convergent Evolution

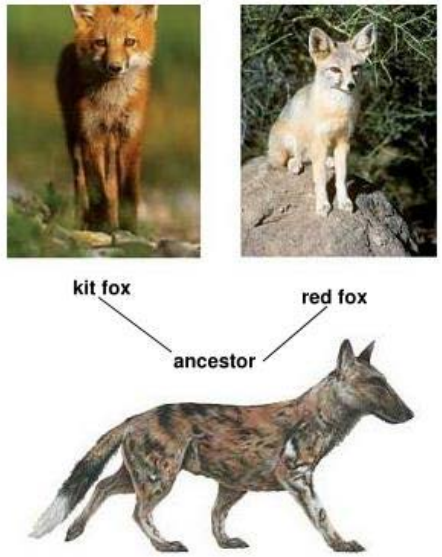
Analogous Structures

Niche	Placental Mammals	Australian Marsupials
Burrower	 Mole	 Marsupial mole
Anteater	 Lesser anteater	 Numbat (anteater)
Mouse	 Mouse	 Marsupial mouse
Climber	 Lemur	 Spotted cuscus
Glider	 Flying squirrel	 Flying phalanger
Cat	 Ocelot	 Tasmanian "tiger cat"
Wolf	 Wolf	 Tasmanian wolf

DIVERGENT EVOLUTION

- Divergent evolution describes evolution toward different traits in closely related species. Divergent evolution can lead to **speciation.**

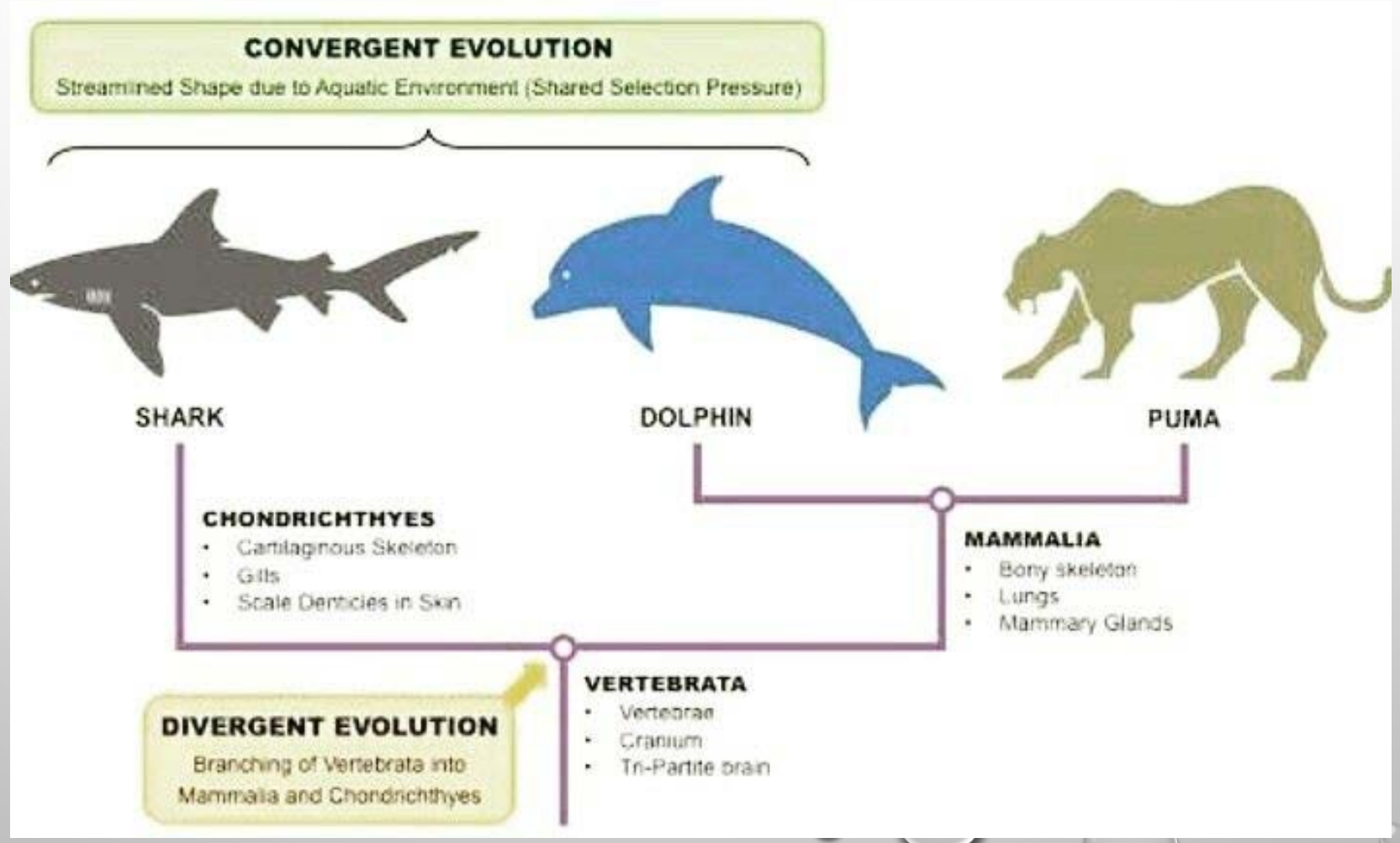




Outcomes of Divergent Evolution

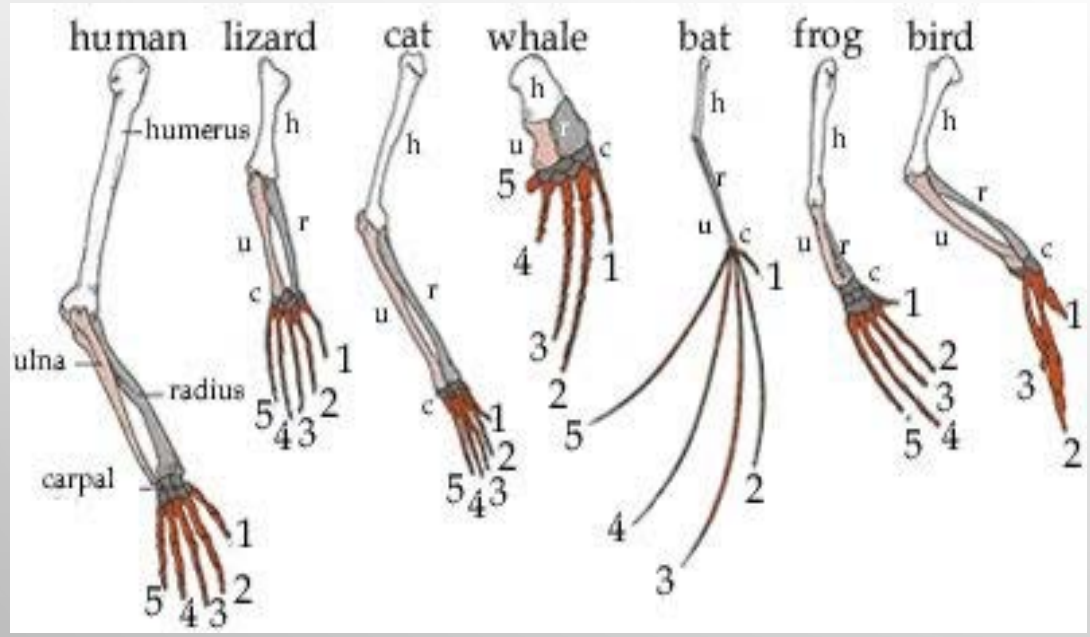
1. Competition between species is minimized as new species fill unique ecological niches
2. New species continue to evolve until most available resources are used

COMPARISONS

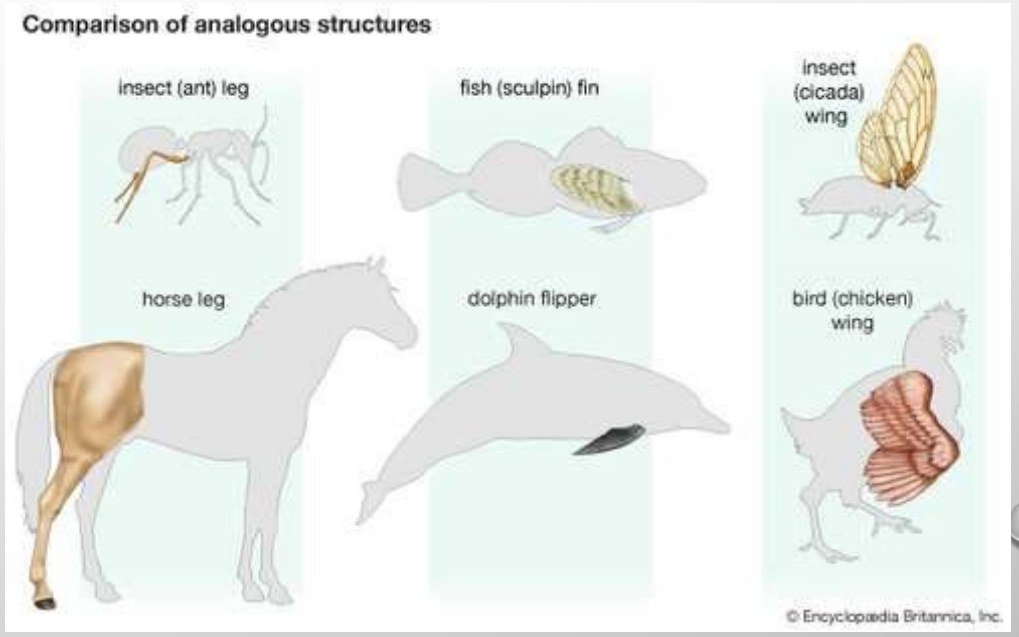


EVOLUTIONARY RELATIONSHIPS

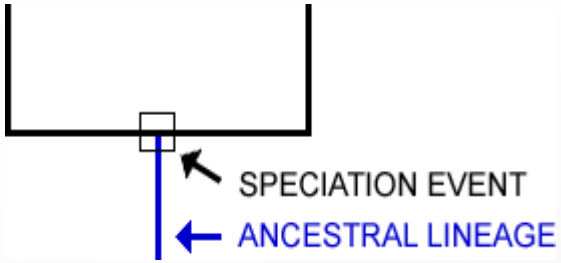
HOMOLOGOUS

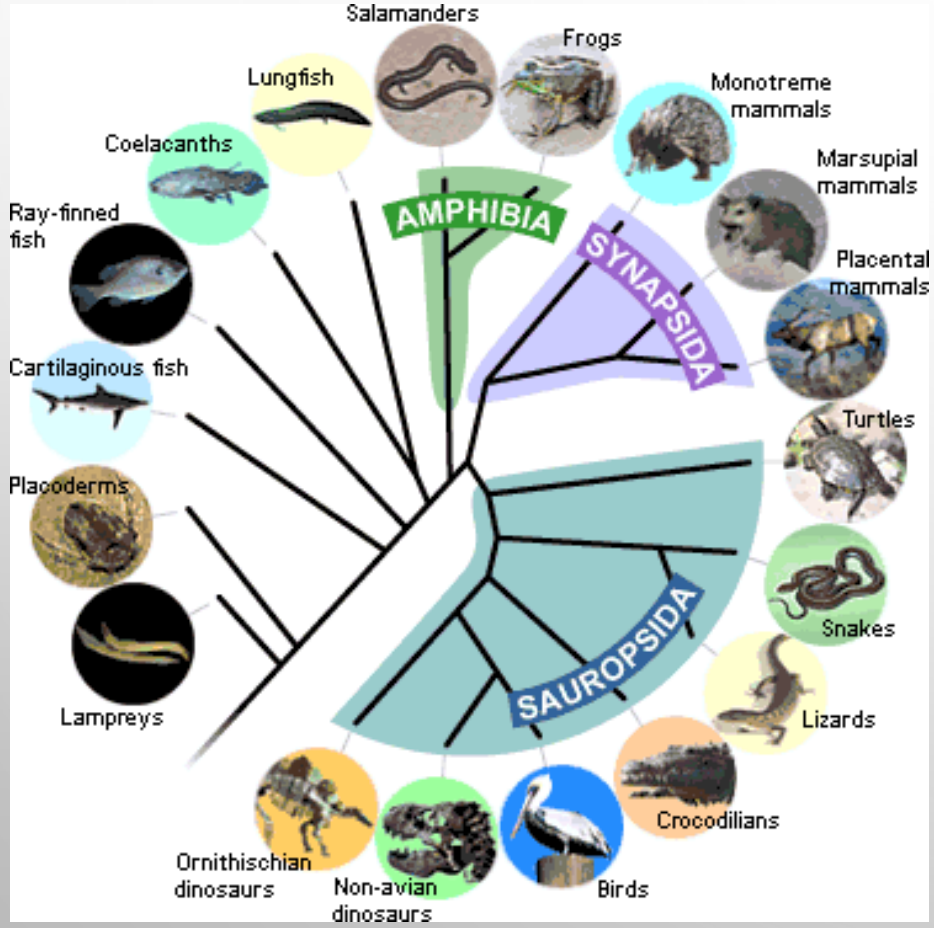


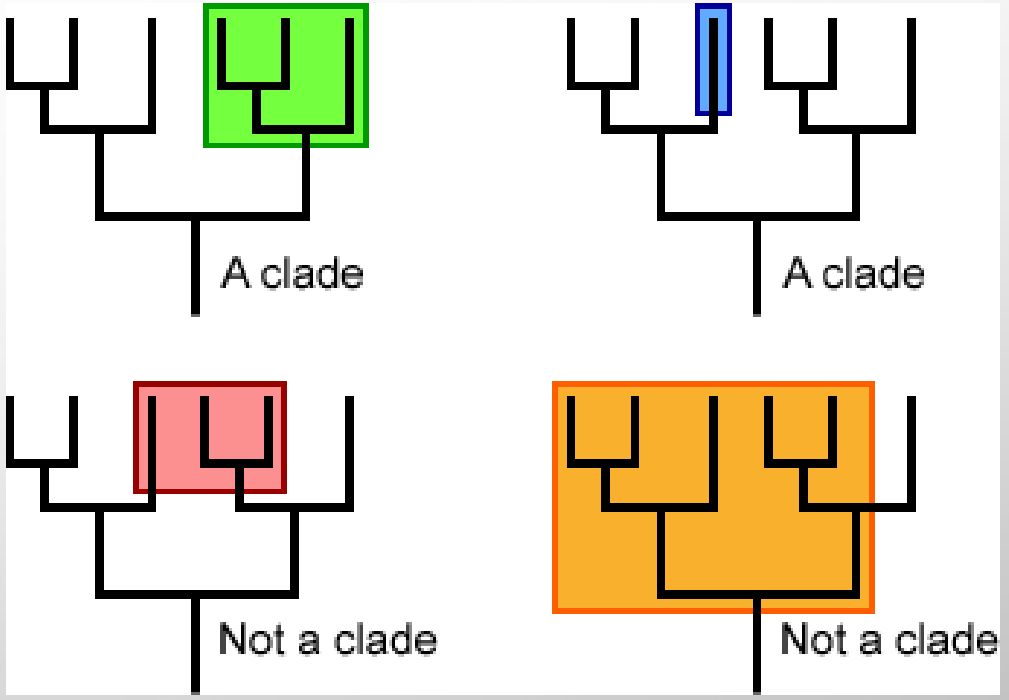
ANALOGOUS



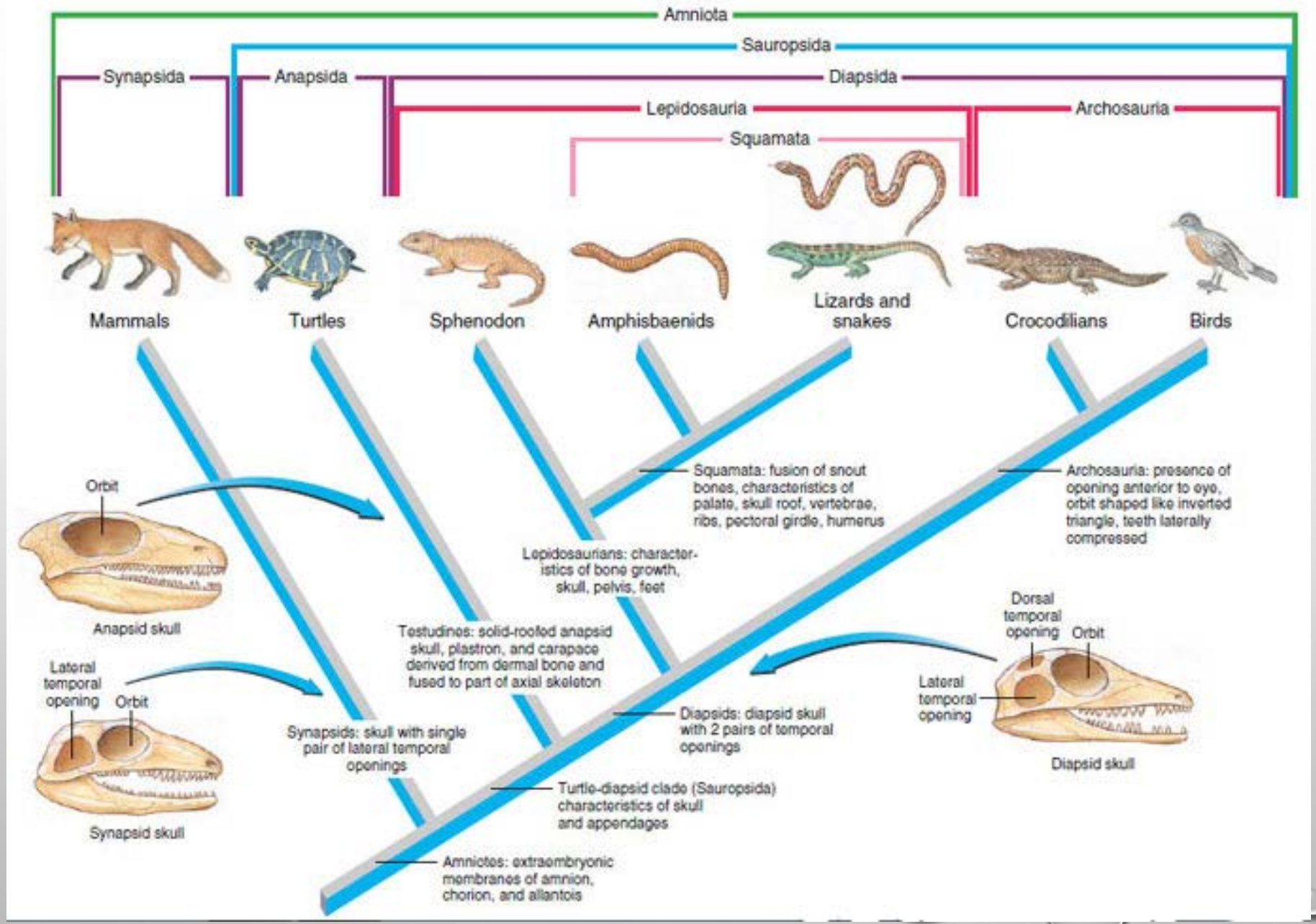
PHYLOGENIC TREE





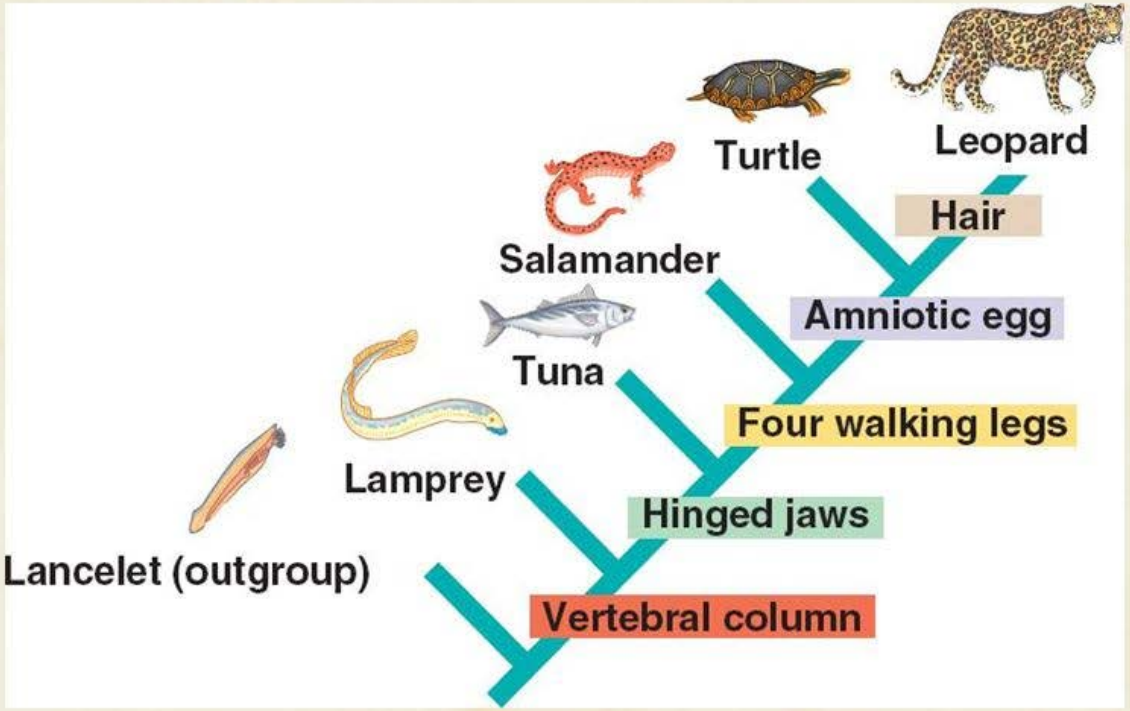


Hierarchy of ancestors → species


Amniota
Sauropsida
Synapsida
Anapsida
Diapsida
Lepidosauria
Archosauria
Squamata
Mammals
Turtles
Sphenodon
Amphisbaenids
Lizards and snakes
Crocodilians
Birds
Orbit
Anapsid skull
Lateral temporal opening
Orbit
Synapsid skull
Squamata: fusion of snout bones, characteristics of palate, skull roof, vertebrae, ribs, pectoral girdle, humerus
Archosauria: presence of opening anterior to eye, orbit shaped like inverted triangle, teeth laterally compressed
Lepidosaurians: characteristics of bone growth, skull, pelvis, feet
Testudines: solid-roofed anapsid skull, plastron, and carapace derived from dermal bone and fused to part of axial skeleton
Synapsids: skull with single pair of lateral temporal openings
Diapsids: diapsid skull with 2 pairs of temporal openings
Turtle-diapsid clade (Sauropsida) characteristics of skull and appendages
Amnictes: extraembryonic membranes of amnion, chorion, and allantois
Dorsal temporal opening
Orbit
Lateral temporal opening
Diapsid skull

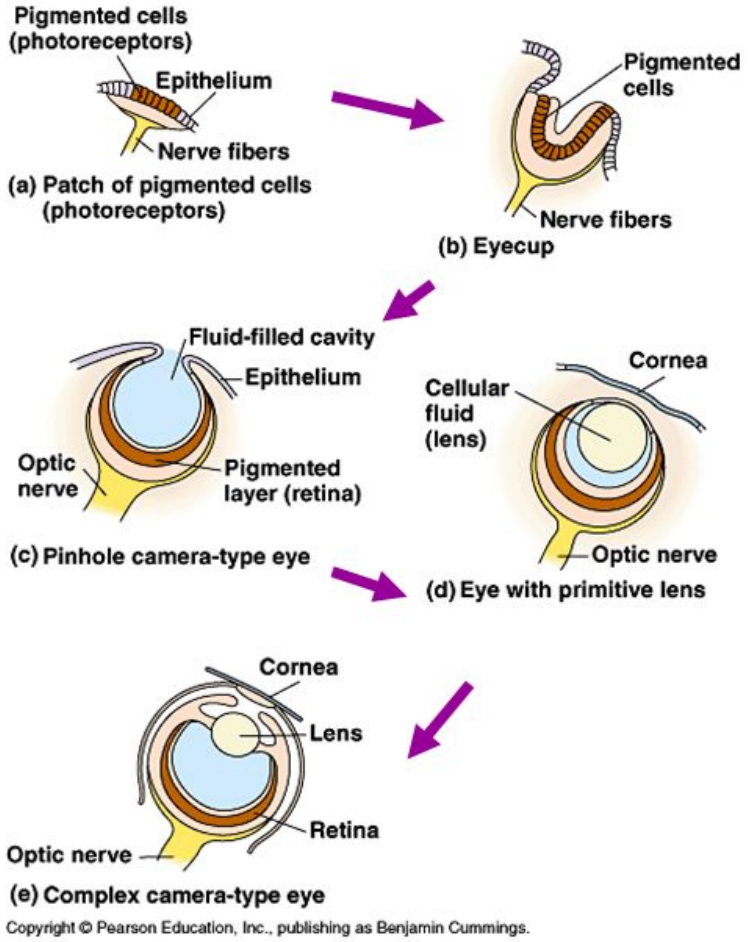
Evolutionary novelty:

a characteristic shared by one branch of the cladogram



Evolutionary Novelties

Evolutionary novelties usually arise as modifications of existing traits



LANDMARKS FOR EVOLUTIONARY NOVELTIES

ORIGIN OF MAJOR EVOLUTIONARY NOVELTIES

- **Almost all macro-evolutionary change can be attributed to the gradual modification of existing structures, e.g., changes in allometric growth patterns, and heterochronic changes in the relative timing of developmental events.**
- **Small changes in regulatory/developmental pathways can be magnified into major changes in the phenotype.**
- **Canalized traits can be reservoirs of "hidden" genetic variation which can lead to the sudden appearance of novel phenotypes.**

Evolutionary Novelties/Landmarks of Phylum Chordata

- Development of hinged **jaws**
- **Bony (calcium phosphate) skeleton** instead of cartilaginous skeleton
- Terrestrial Adaptations
  - Internal **lungs** instead of external gills
  - Four **legs** for walking on land
  - **Amniotic egg** to avoid dehydration of embryo
  - **Endothermy** instead of ectothermy
    - Feathers or fur to maintain constant body temp.

NATURAL SELECTION

- VARIATION
- COMPETITION FOR RESOURCES
  - FOOD
  - WATER
  - MATES
- SELECTION OF FAVORABLE TRAITS
  - ALTER GENE FREQUENCIES
  - INHERITABLE
- ADAPTATION
  - SURVIVAL
  - REPRODUCTION
  - FITNESS

8.10 When three simple conditions are satisfied, evolution by natural selection occurs.

1. There must be variation for the particular trait within a population.
2. That variation must be inheritable.
3. Individuals with one version of the trait must produce more offspring than those with a different version of the trait.

EXTINCTION EVENTS

- VOLCANIC ERUPTIONS
- METEORITE
- ENVIRONMENTAL DESTRUCTION

- RESULTS
  - NEW HABITAT
  - DIFFERENT COMPETITION
  - DIVERGENT EVOLUTION

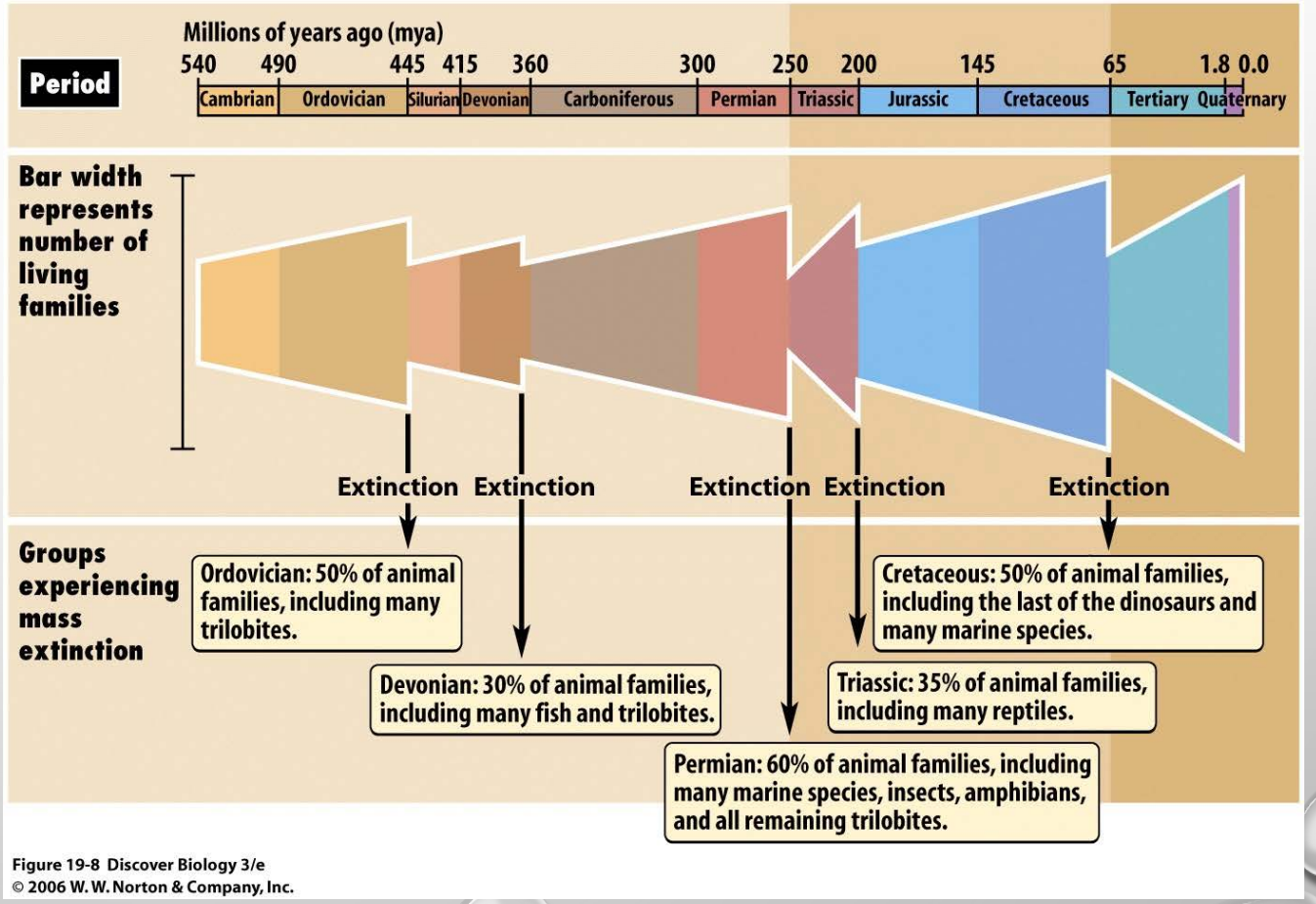


Figure 19-8 Discover Biology 3/e

Theories and Hypotheses

Diverse Branching

LAW OF ADAPTIVE RADIATION

An isolated region, if large and sufficiently varied in its topography, soil, climate and vegetation, will give rise to a diversified fauna from primitive types. Branches will spring off in all directions to take advantage of every possible opportunity of securing food."

Osborn(1902)

CAUSES OF ADAPTIVE RADIATION

1. Entry into an adaptive zone by :-
   - Evolution of a key innovation
   - Invasion into a new habitat
   - Extinction of competition

(Simpson)

2. Ecological Opportunity

(Dolph Schlutler,2002)

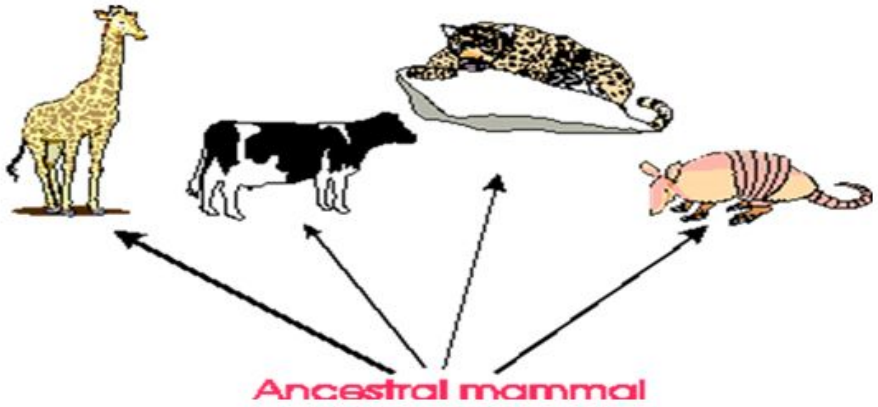
2. Mass extinction

Types:

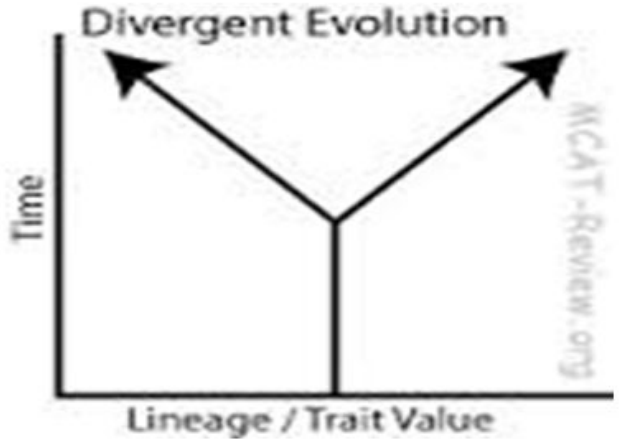
- Worldwide
- Regional

Divergent Evolution=Adaptive Radiation

- One species give rise to many species
- More alike to less alike
- Also known as adaptive radiation.
- Examples: - Darwin's Finches.
  - Brown bears and polar bears



Draw this diagram in notes



Worldwide Adaptive Radiations

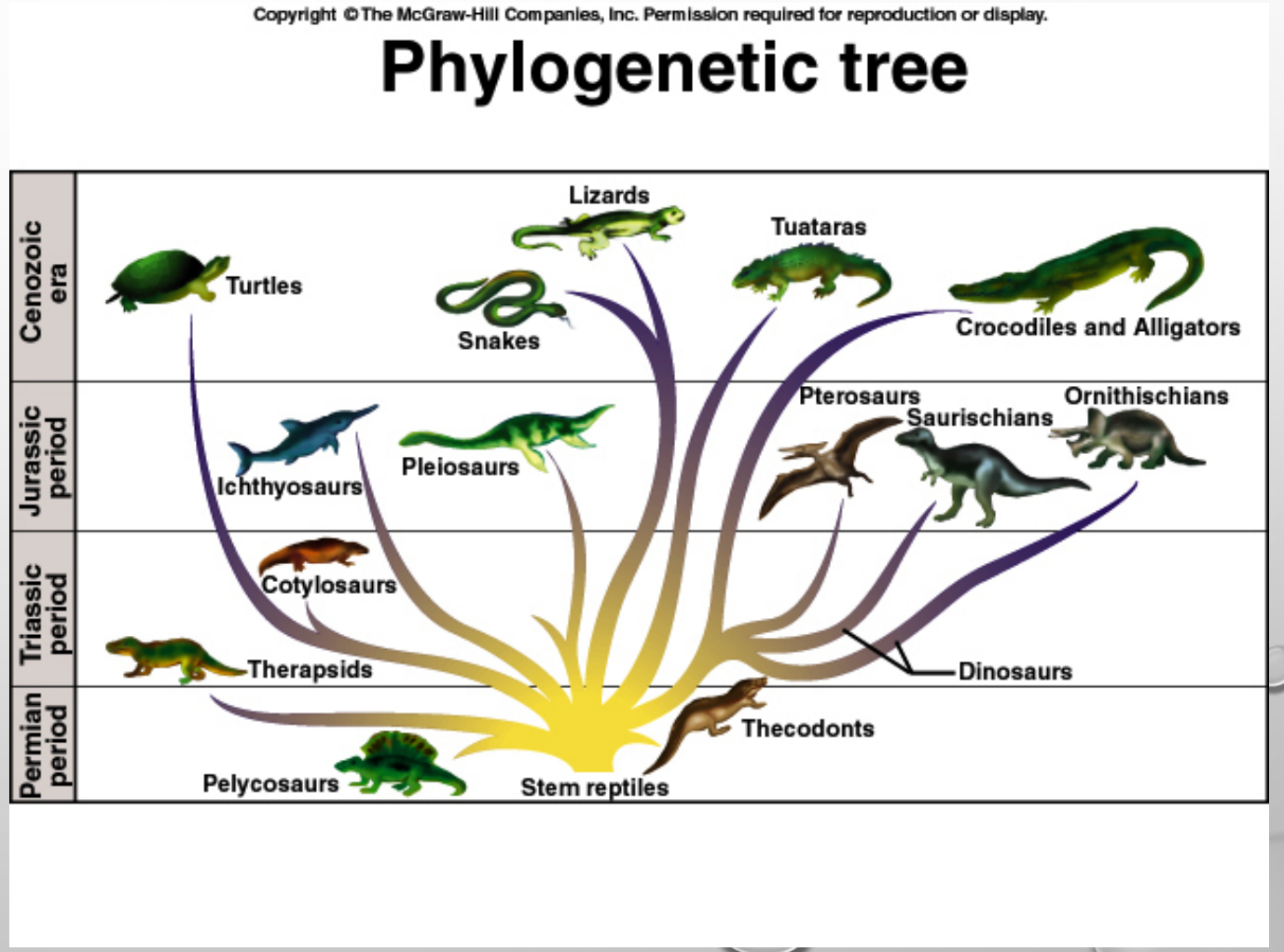
- Mammals underwent an adaptive radiation after the extinction of terrestrial dinosaurs
- The disappearance of dinosaurs (except birds) allowed for the expansion of mammals in diversity and size
- Other notable radiations include photosynthetic prokaryotes, large predators in the Cambrian, land plants, insects, and tetrapods

The Cenozoic: Paleogene Period

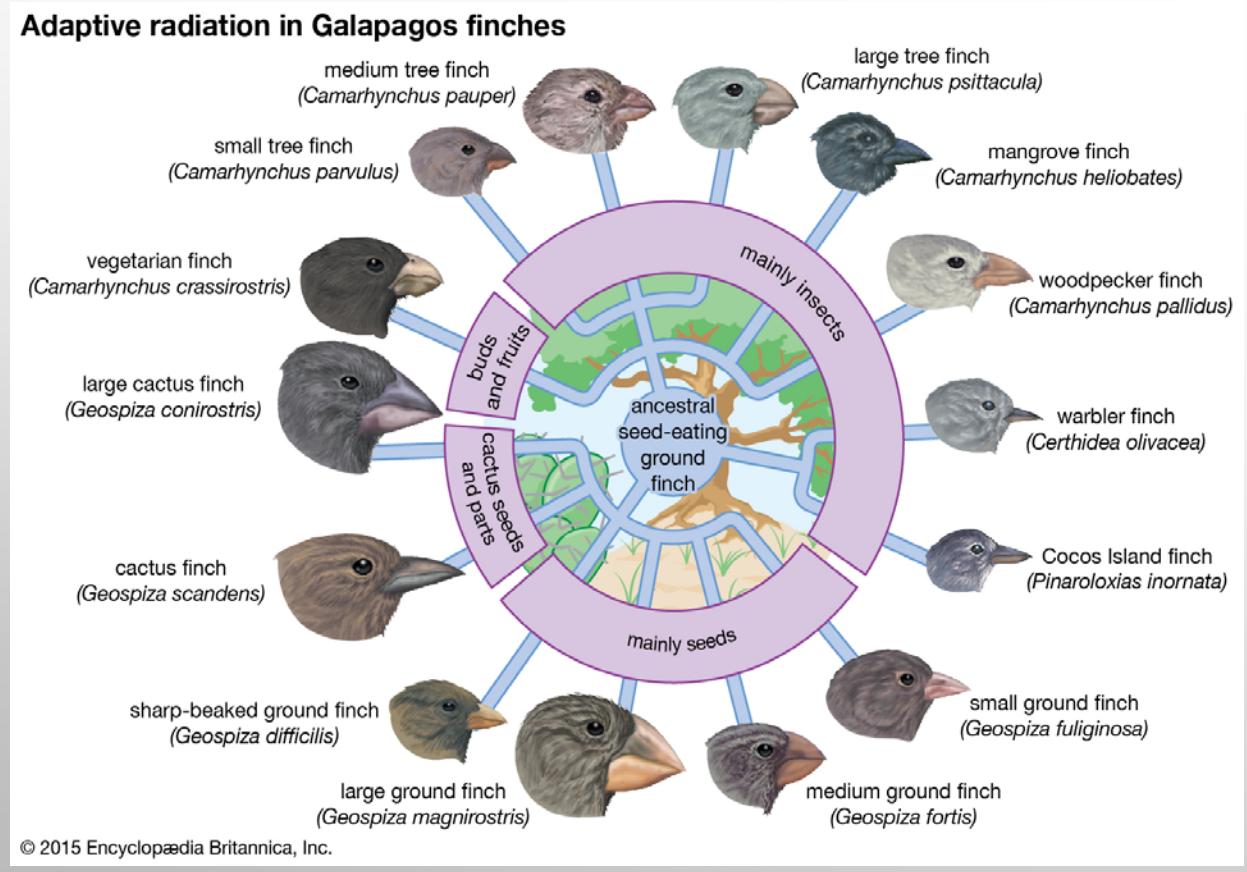
- Mammalian adaptive radiation to fill angiosperm niches
- **Paleocene** wet & warm
- **Eocene** wetter & warmer
  - Tropical forests
  - SA isolated from NA & Europe = new species
  - Primates (prosimians) highly successful & diverse
  - First anthropoids appear
- **Oligocene** getting colder & drier, more seasonal variation
  - Mostly modern continent positions
  - SA still separate
  - Cold water currents cooling earth but Africa & SA tropical forests
  - Monkeys prosper, first hominoids appear

WORLDWIDE (GENERALIZED) ADAPTIVE RADIATION

- REPTILES
  - PALEOZOIC
    - CARBONIFEROUS
    - PERMIAN
  - MESOZOIC
    - TRIASSIC
    - JURASSIC
    - CRETACEOUS



REGIONAL (SPECIALIZED) ADAPTIVE RADIATION



Regional Adaptive Radiations

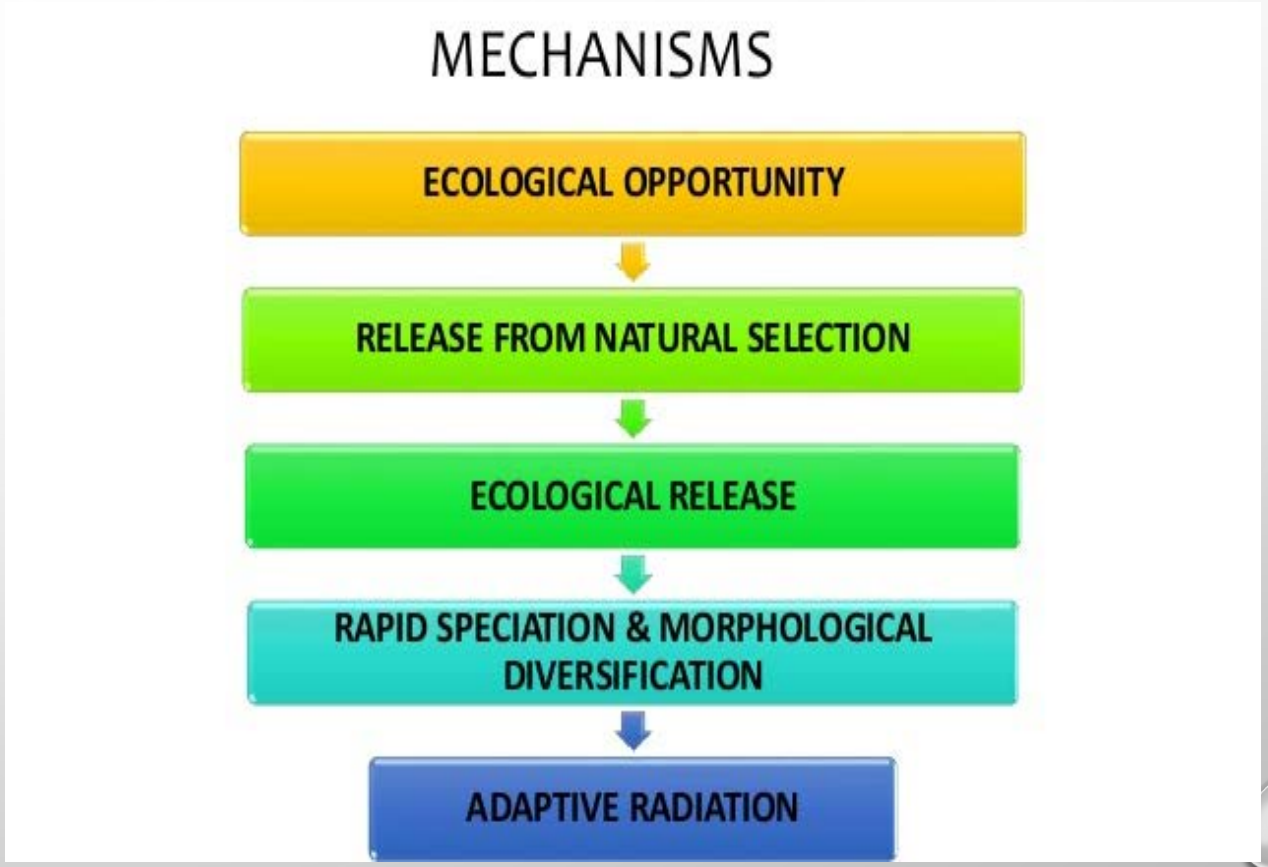
- Adaptive radiations can occur when organisms colonize new environments with little competition
- The Hawaiian Islands are one of the world's great showcases of adaptive radiation

HAWAIIAN HONEYCREEPERS

BIODIVERSITY

ADAPTIVE RADIATION SUMMARY

- EVOLUTIONARY DIVERGENCE
- ECOLOGICAL NICHES
  - NEW OR DISTINCT AREAS
  - EXTINCTION → NEW OPPORTUNITIES
  - CHANGE IN COMPETITION
- SPECIES ADAPTATION → EVOLUTION
- INNOVATION → DIFFERENT FORMS
  - GAIN
  - LOSS
- AREAS
  - WORLDWIDE
  - REGIONAL



ADAPTIVE CHANGES: GENES

Concept 25.5: Major changes in body form can result from changes in the sequences and regulation of developmental genes

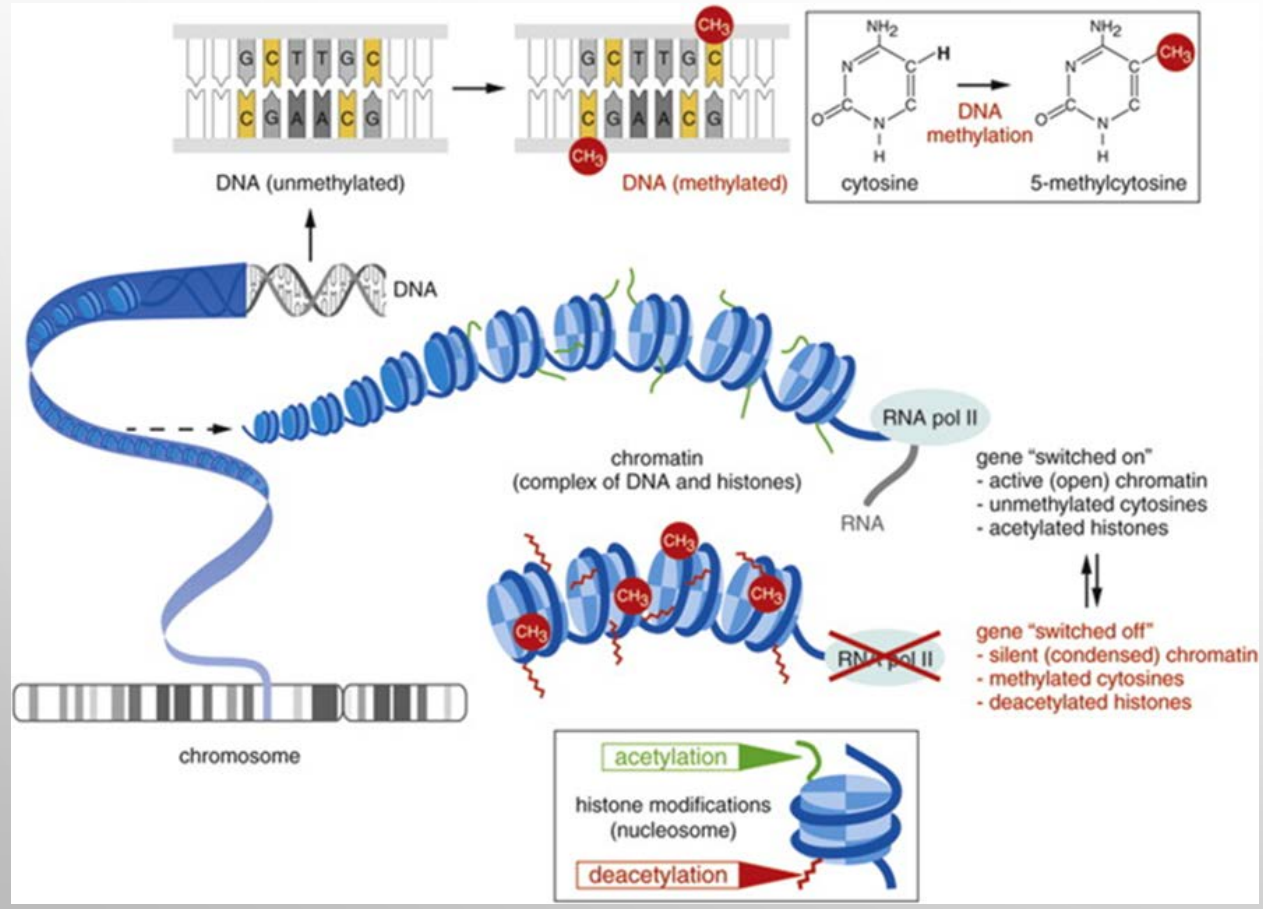
How can we understand life's diversity?

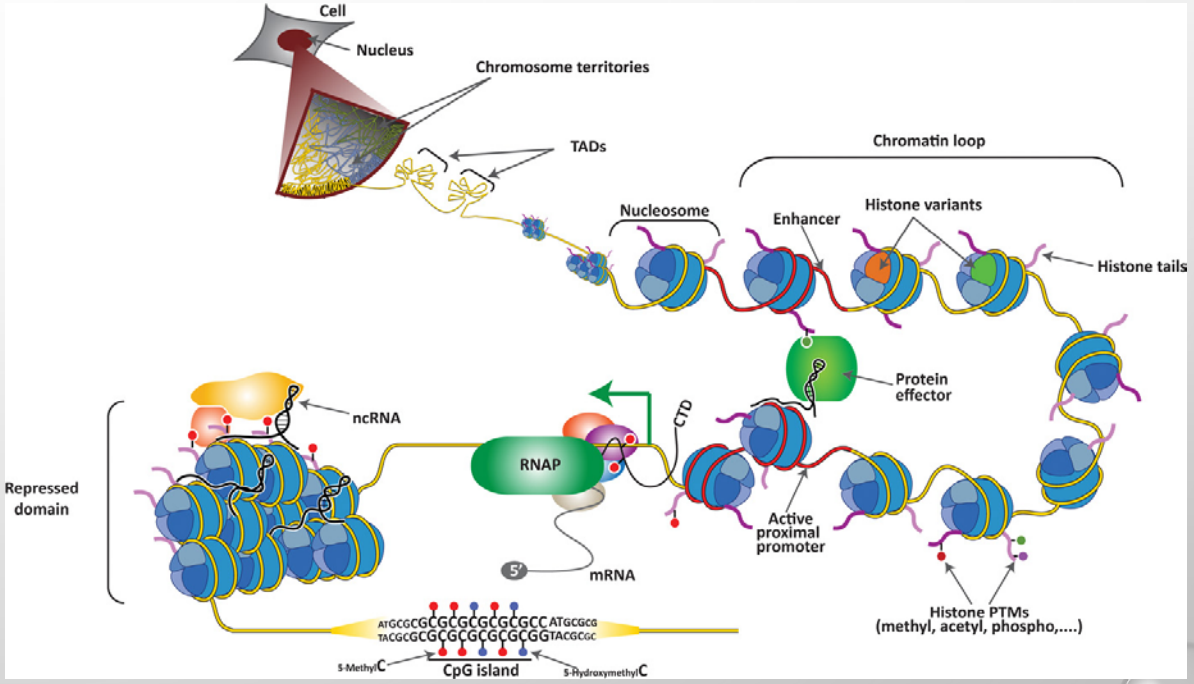
1. Fossils – evidence of past biodiversity
2. Continental drift, mass extinction, adaptive radiation – environmental changes influence biodiversity
3. ***Genetic Change – changes in DNA sequences and regulation modify bodies/cells***

Changes in Gene Regulation

- Changes in morphology likely result from changes in the regulation of developmental genes rather than changes in the sequence of developmental genes
  - For example, threespine sticklebacks in lakes have fewer spines than their marine relatives
  - The gene sequence remains the same, but the regulation of gene expression is different in the two groups of fish

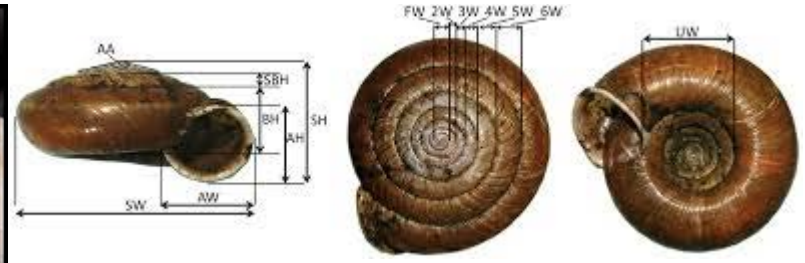
REGULATION OF GENE TRANSCRIPTION





25.5 Major changes in body form can result from changes in sequences and regulation of developmental genes

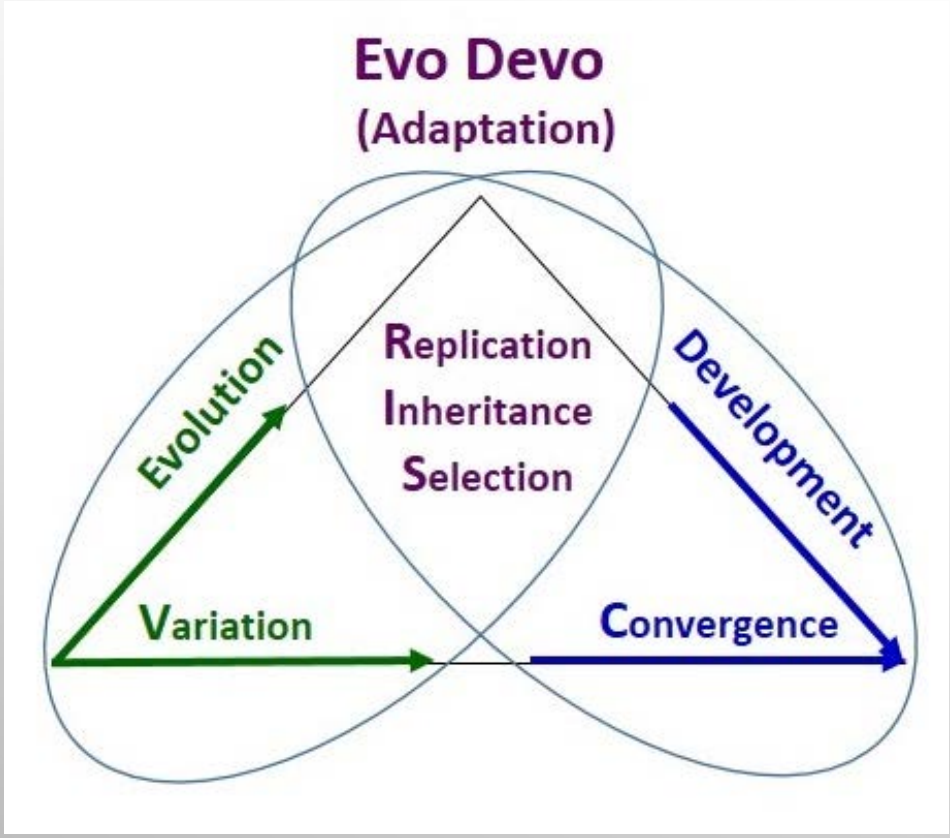
- Small genetic changes can cause major morphological differences between species



Genes of Speciation

EX: Japanese *Euhadra* snails, the direction of shell spiral affects mating and is controlled by a single gene

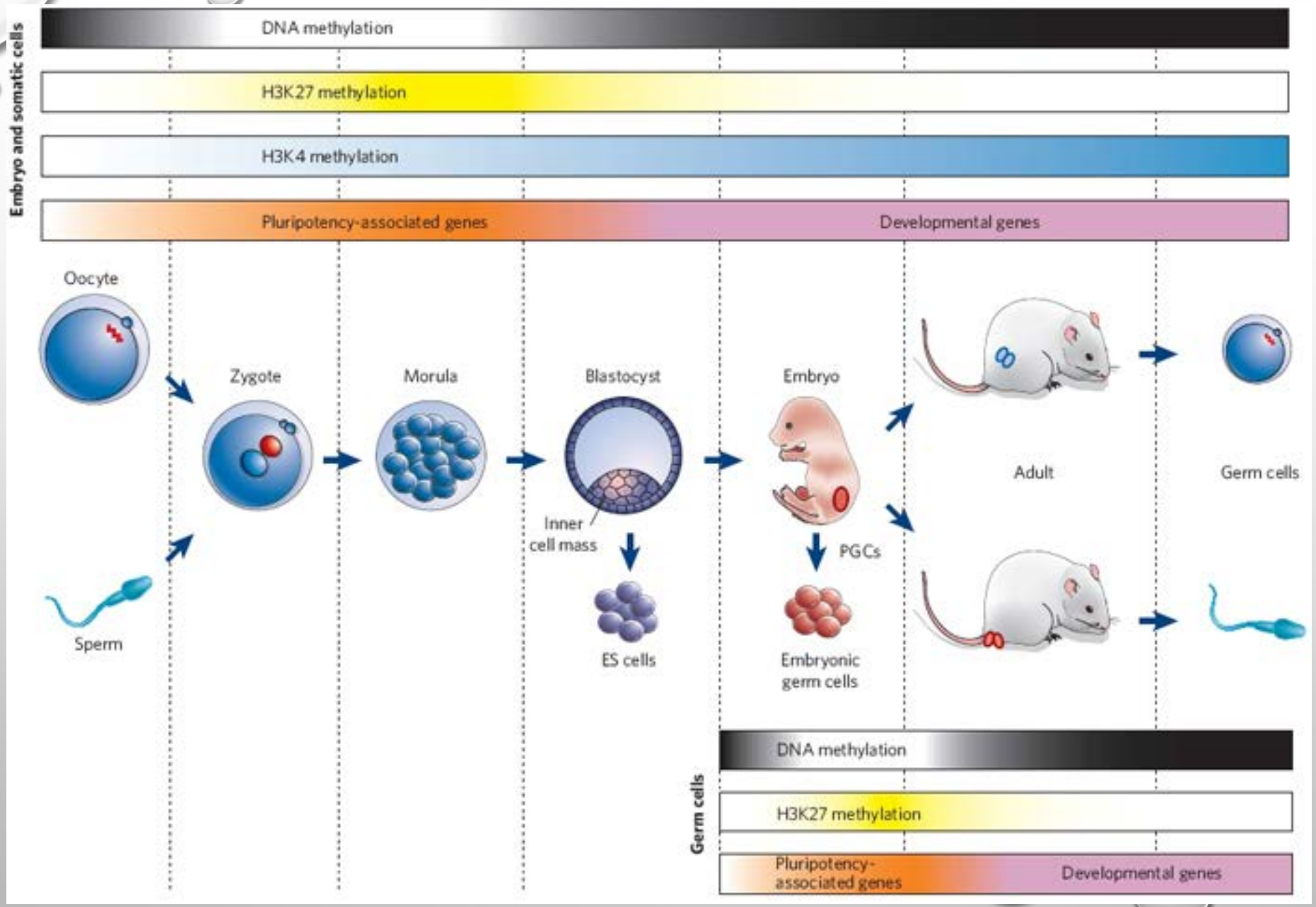
EVO-DEVO



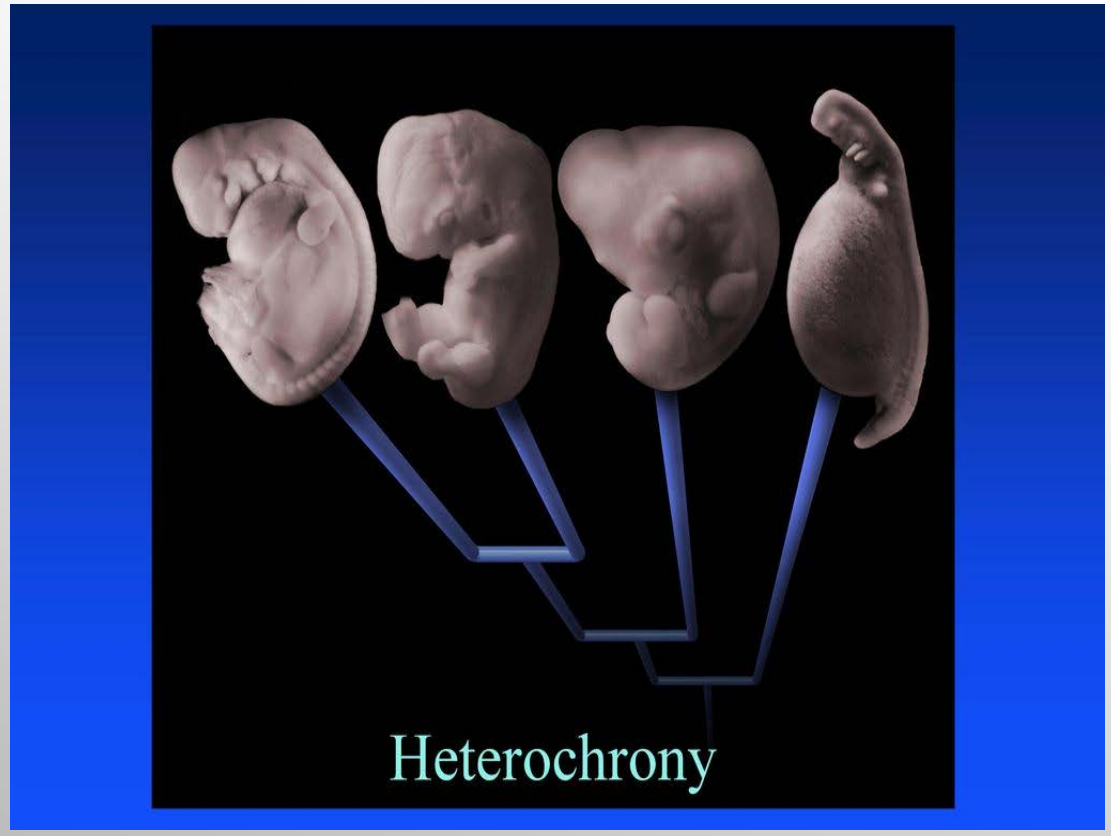
Evo-Devo: Evolutionary Developmental Biology

- Compares the development of different organisms to understand:
  - Ancestral relationships between organisms
  - Developmental mechanisms that bring about evolutionary change
- Involves the discovery of genes that control development, and how their roles vary in different species

27


Embryo and somatic cells
DNA methylation
H3K27 methylation
H3K4 methylation
Pluripotency-associated genes
Developmental genes
Oocyte
Zygote
Morula
Blastocyst
Embryo
Adult
Germ cells
Inner cell mass
PGCs
Sperm
ES cells
Embryonic germ cells
Germ cells
DNA methylation
H3K27 methylation
Pluripotency-associated genes
Developmental genes

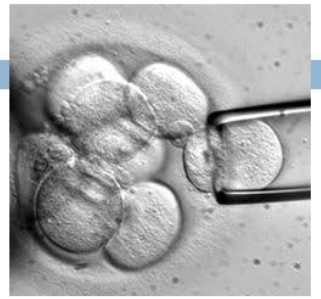
DEVELOPMENTAL GENES

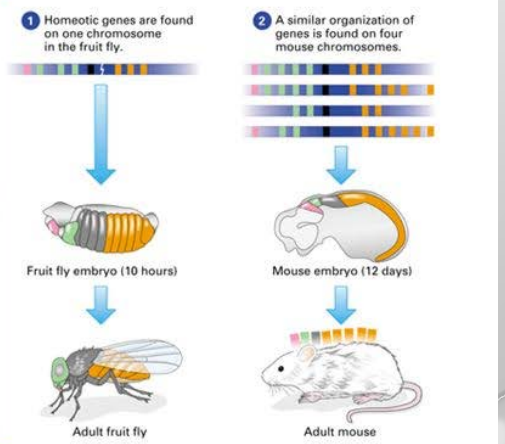


Developmental Timing

13.5 Stem Cells and Homeotic Genes

- **Stem cells** – cells (early in development) that remain undifferentiated and have the potential to be any type of cell.
- **Homeotic Genes** – genes that control development of specific locations in organisms.

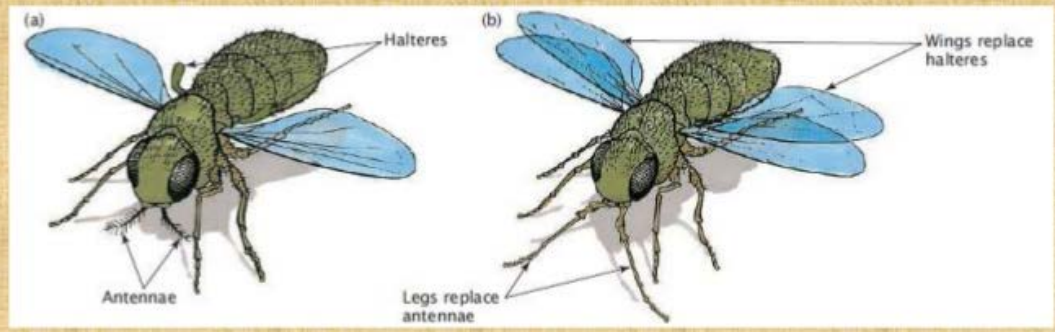




HOMEOTIC GENES

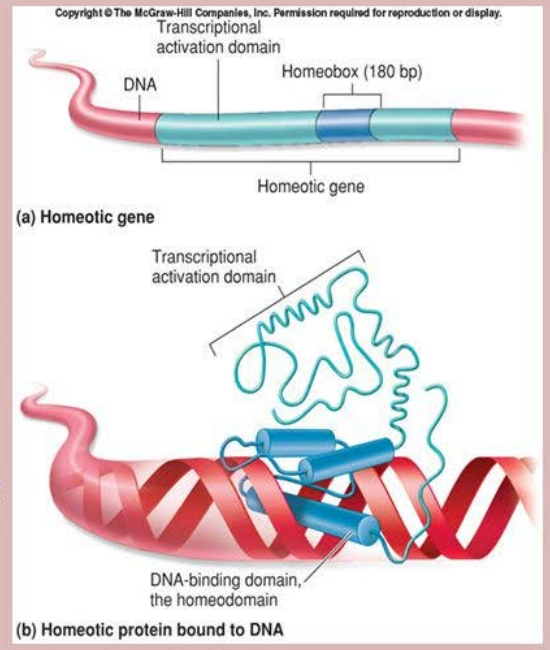
Homeotic Genes

- "Master genes" that control embryonic development in insects and vertebrates.
- A malfunctioning homeotic gene in flies may result in wings, legs, antennae and halteres being absent, or appearing in places that they should not.



Discovery: Edward B Lewis

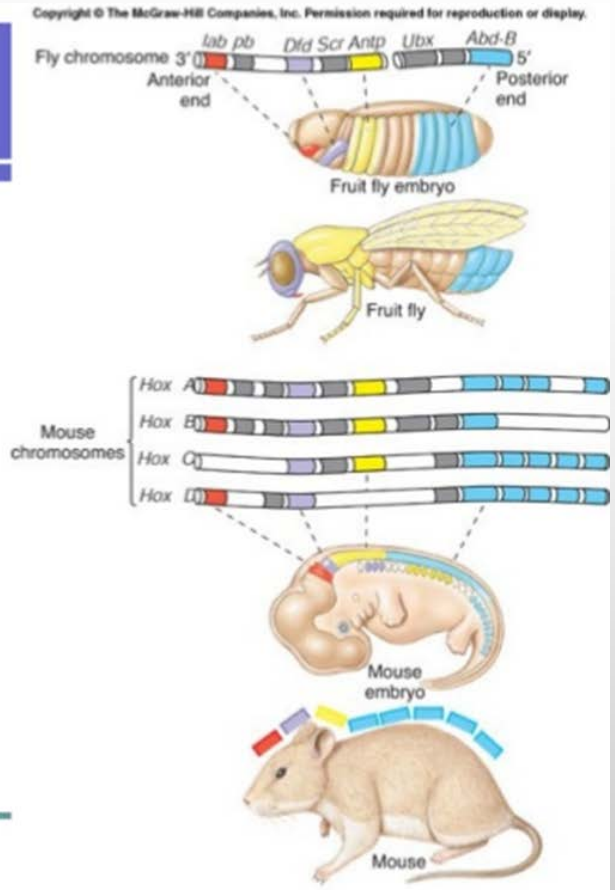
- Homeotic genes encode homeotic proteins that function as transcription factors which switch on other genes
- The Homeobox is a coding sequence within homeotic genes which contains 180 base-pair sequences, codes for 60 amino acid polypeptide
  - Encodes *homeodomain* for DNA binding
  - -- Promoter

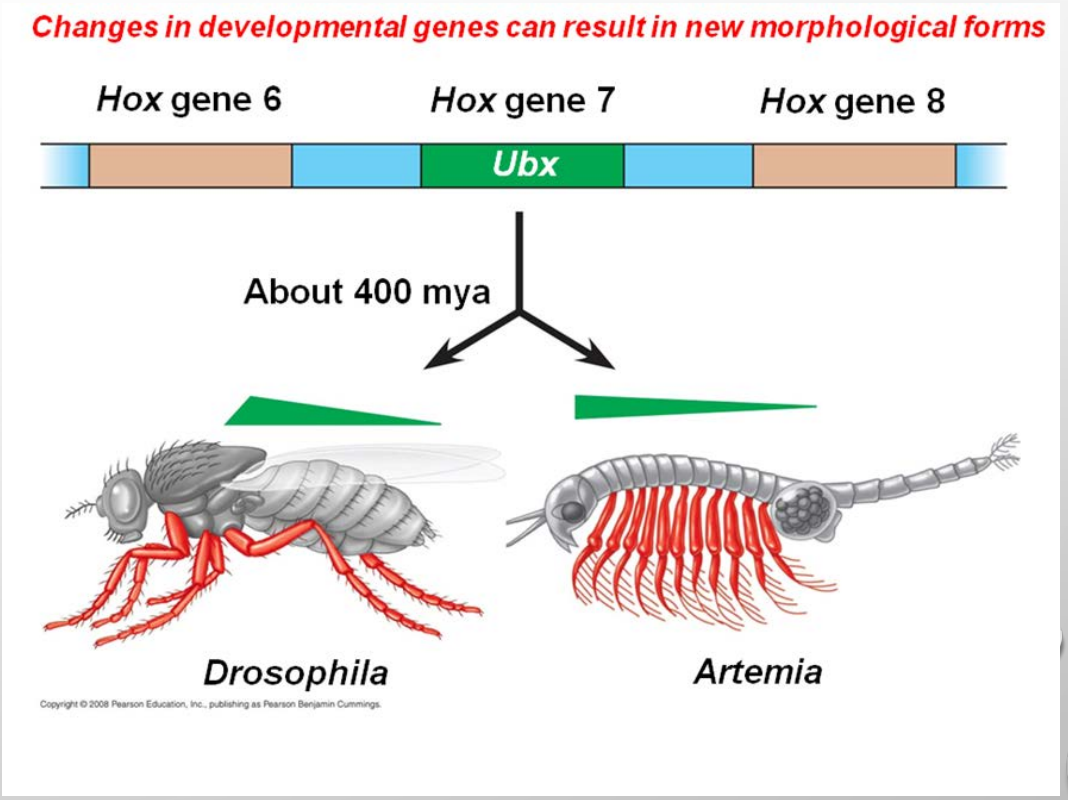


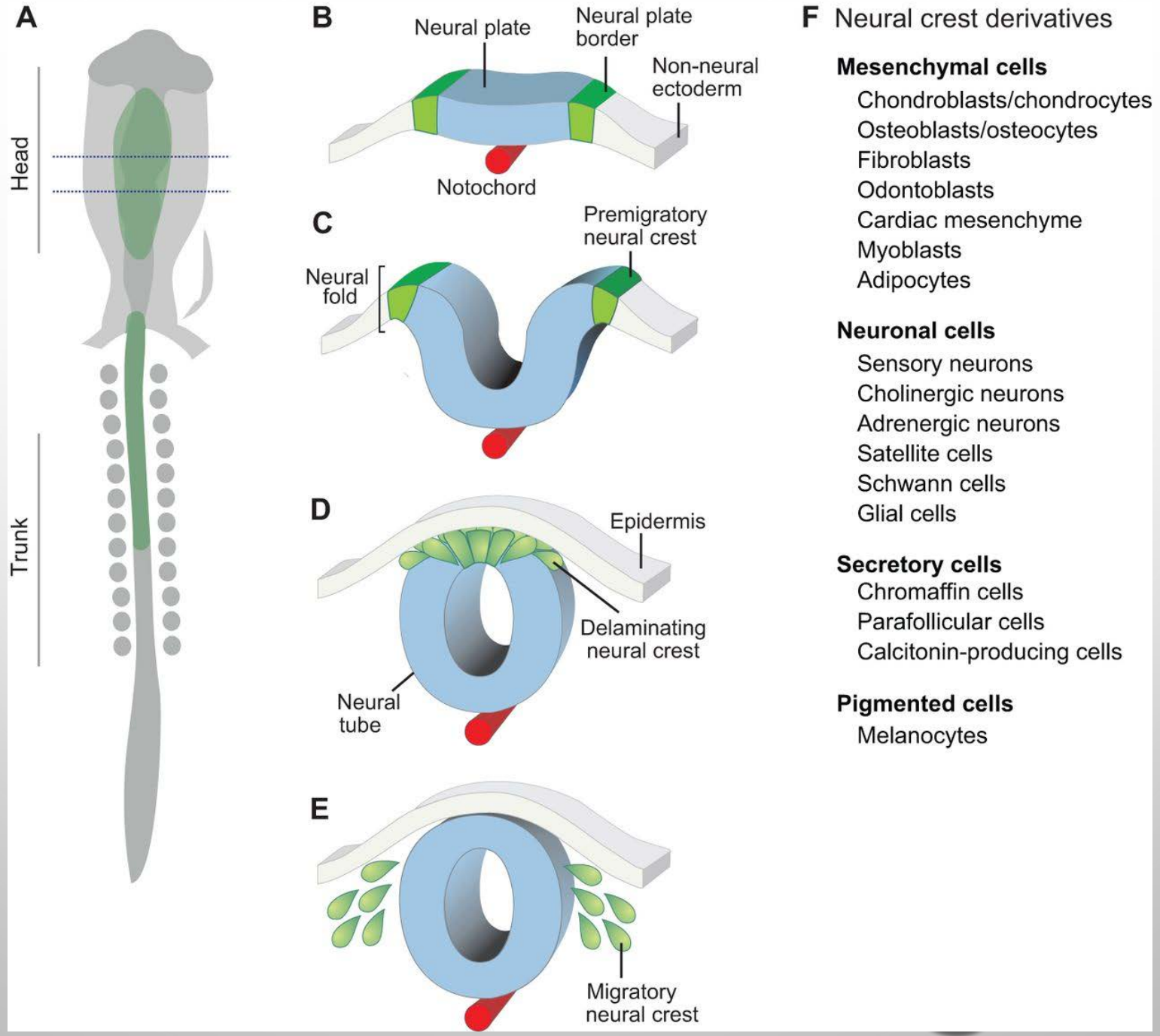
HOMEOBOX: HOX GENES

Hox Genes

- ***Hox* genes** control the subdivision of embryos into regions of different developmental fates along the anteroposterior axis.
  - Homologous in diverse organisms.
- These are master genes that control expression of subordinate genes.






A
Head
Trunk
B
Neural plate
Neural plate border
Non-neural ectoderm
Notochord
C
Premigratory neural crest
Neural fold
D
Epidermis
Delaminating neural crest
Neural tube
E
Migratory neural crest
F Neural crest derivatives
Mesenchymal cells
Chondroblasts/chondrocytes
Osteoblasts/osteocytes
Fibroblasts
Odontoblasts
Cardiac mesenchyme
Myoblasts
Adipocytes
Neuronal cells
Sensory neurons
Cholinergic neurons
Adrenergic neurons
Satellite cells
Schwann cells
Glial cells
Secretory cells
Chromaffin cells
Parafollicular cells
Calcitonin-producing cells
Pigmented cells
Melanocytes

Major changes in body form result from changes in the sequences and regulation of developmental genes

- Studying genetic mechanisms of change can provide insight into large-scale evolutionary change.
- Genes that program development control the rate, timing, and spatial pattern of changes in an organism's form as it develops into an adult.
- ***Heterochrony*** *is an evolutionary change in the rate or timing of developmental events*.
- It can have a significant impact on body shape.
- The contrasting shapes of human and chimpanzee skulls are the result of small changes in relative growth rates.

What is heterochrony?

- heterochrony = (evolutionary) change in developmental timing
- two main types (not necessarily independent):
  - sequence heterochrony: change in time of appearance of a structure
  - allometric heterochrony: changes in growth rate

Heterochrony

evolutionary change in the rate or timing of development

Peramorphosis

derived type of heterochrony

child Paedomorphosis

adult stage resembles juvenile stage

Neotony

adult stage resembles juvenile stage by decrease in rate of development

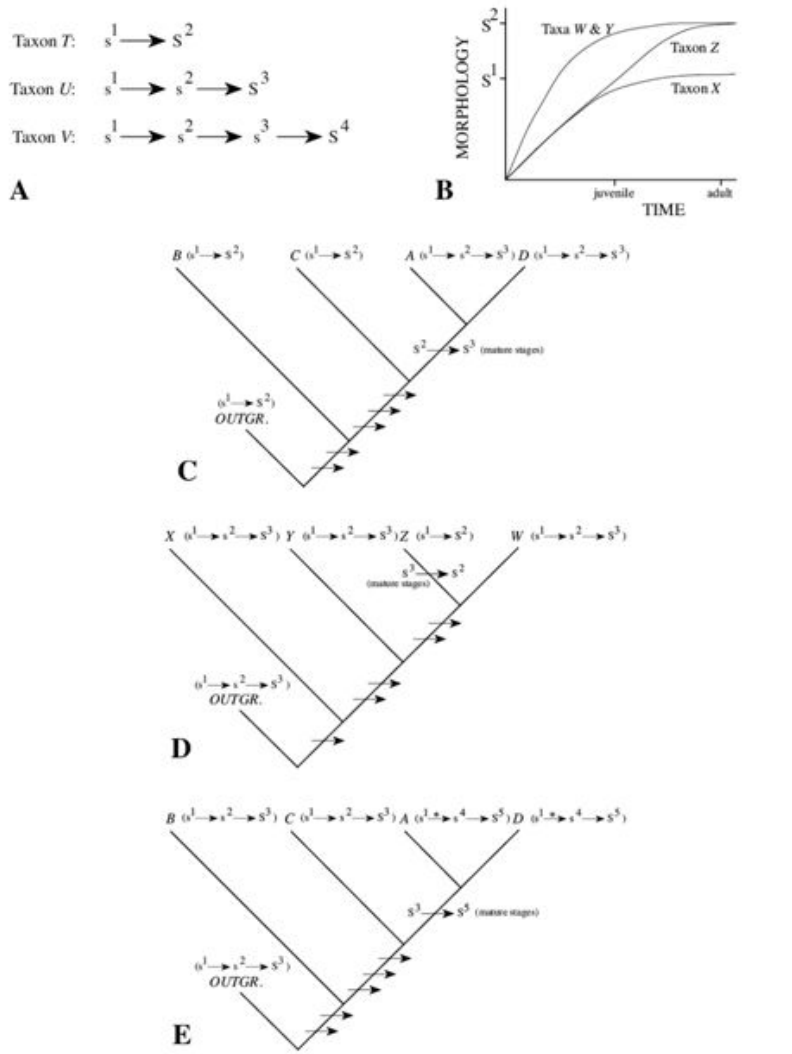
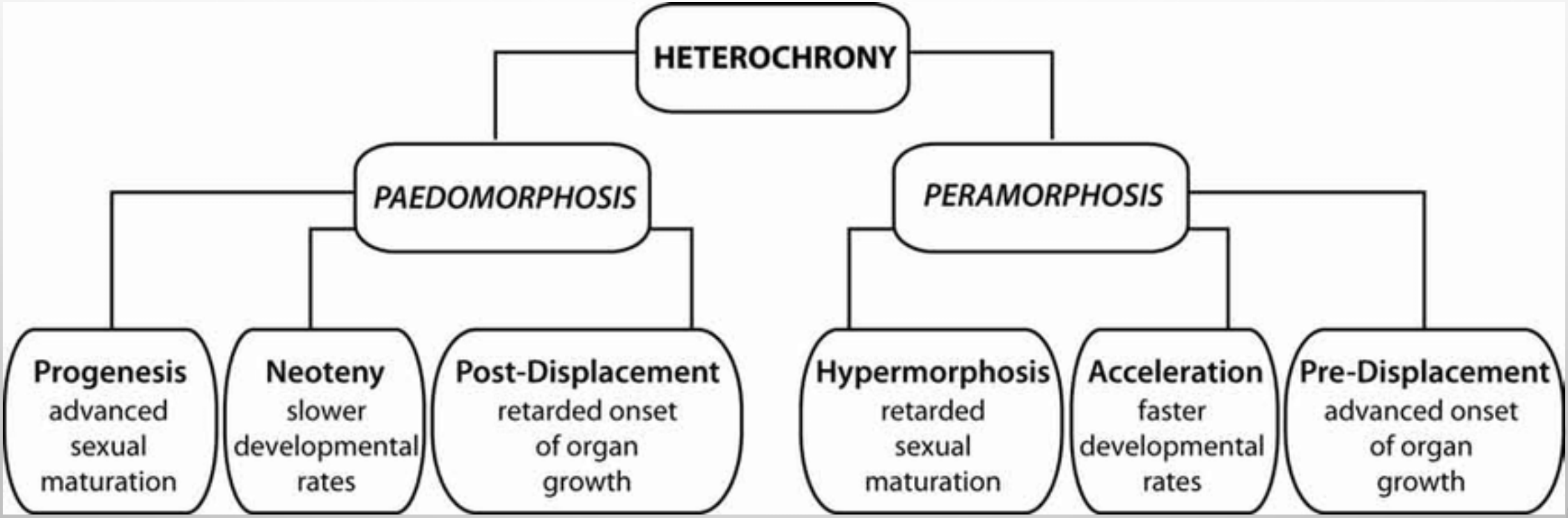


Figure 2.23 **A.** Representation of an ontogenetic sequence, a change from one discrete stage to another in various taxa. **B.** Ontogenetic trajectories of various taxa. Note juvenile and adult stages. **C–E.** Cladograms, with ontogenetic data (in parentheses next to taxa) and character state changes of mature structures (along lineage internodes). Note that "s" represents a juvenile developmental stage; "S" is a mature, adult feature. See text for further explanation.

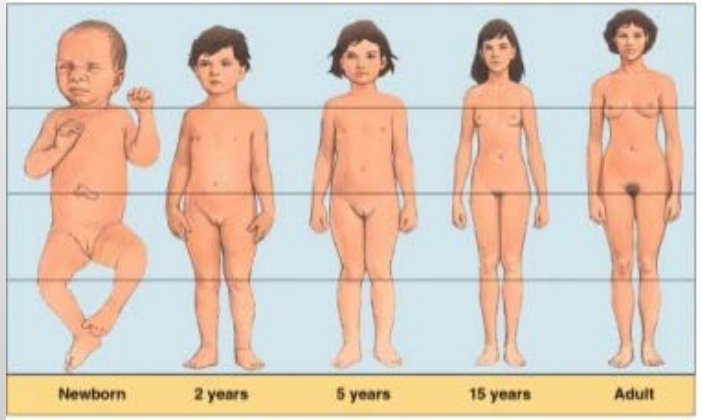
HETEROCHRONY: EVOLUTION OF DEVELOPMENT



PATTERNS IN DEVELOPMENTAL EVOLUTION

Heterochrony

http://www.bio.miami.edu/dana/dox/heterochrony.html



Allometric Growth
Differential growth in organs and body parts

Paedomorphy
Retention of juvenile structures

B. Developmental Trends in Morphological Patterns

3. Heterochrony

evolutionary change due to a change in the timing of developmental events...two classic examples are:

Peramorphosis - delayed maturity; reproduction at a disproportionately large size

Peramorphosis

BRANCHING EVOLUTIONARY TRENDS

INTERACTIONS BETWEEN ORGANISM & ENVIRONMENT

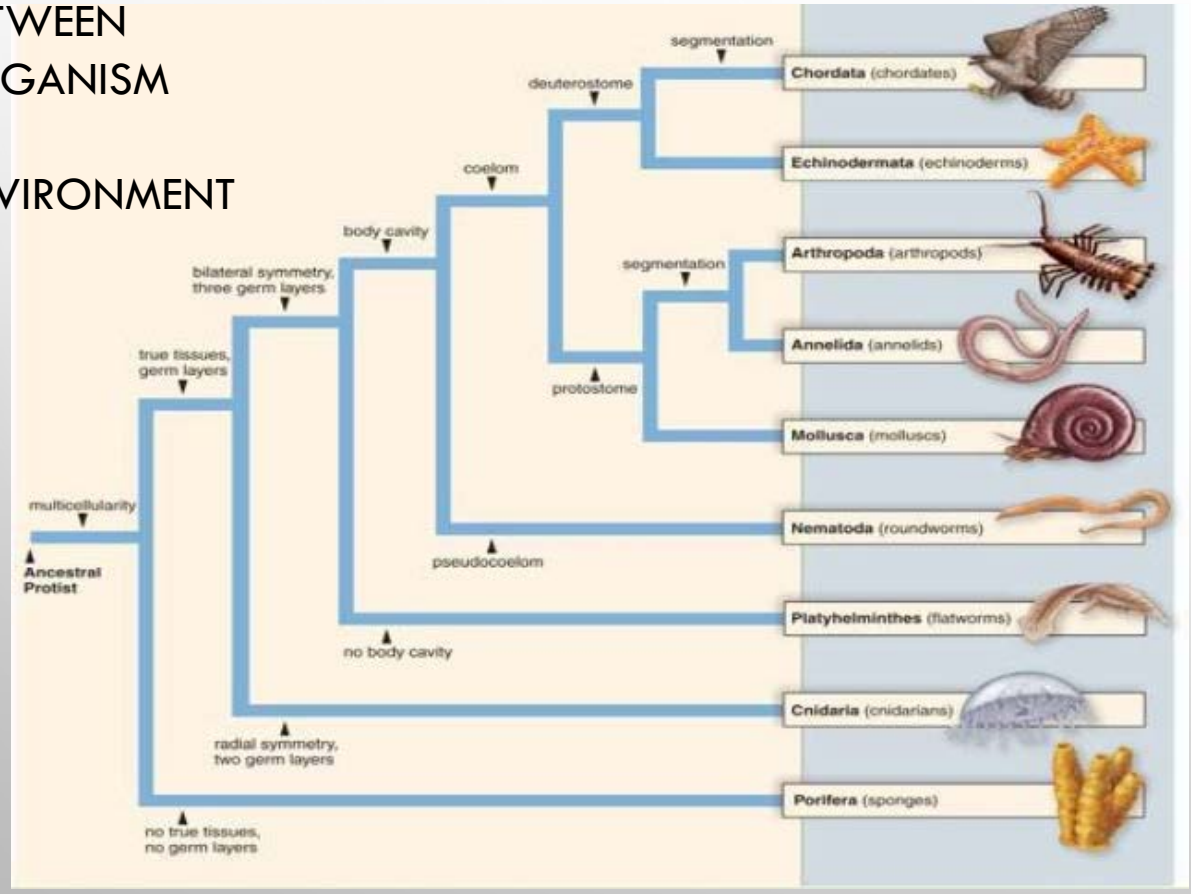
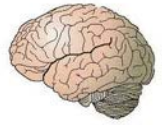
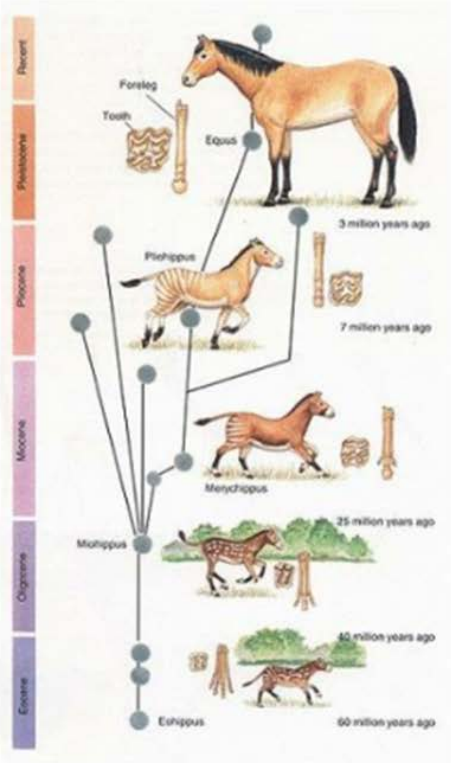


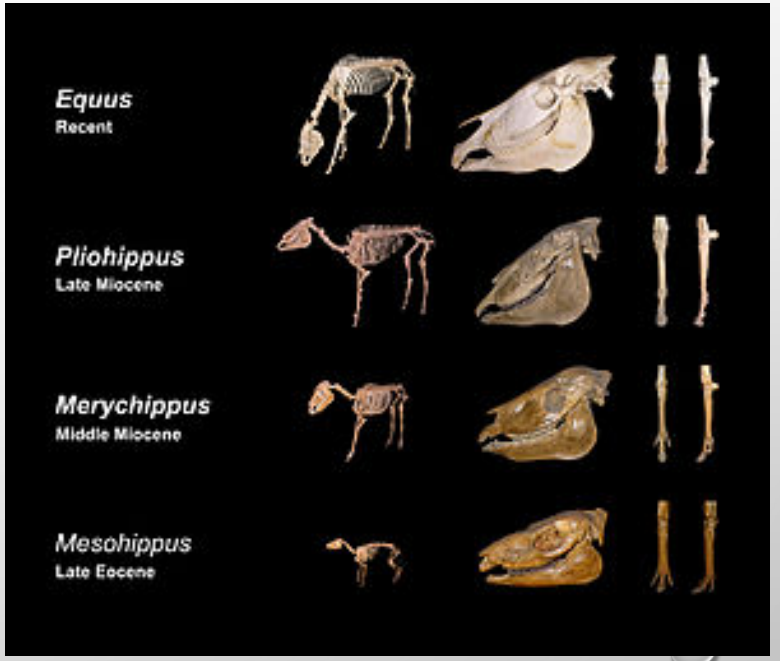
TABLE 10.2 Trends from Late Australopithecine to Early *Homo*

	LATE AUSTRALOPITHECINE	→	EARLY *HOMO*
Brain		Increase in size	
Face		Reduction in size	
Teeth		Reduction in size	

Macroevolution

- Macroevolution: major patterns and changes among living organisms over long periods of time.
- The evidence comes from 2 main sources: fossils and comparisons between living organisms.





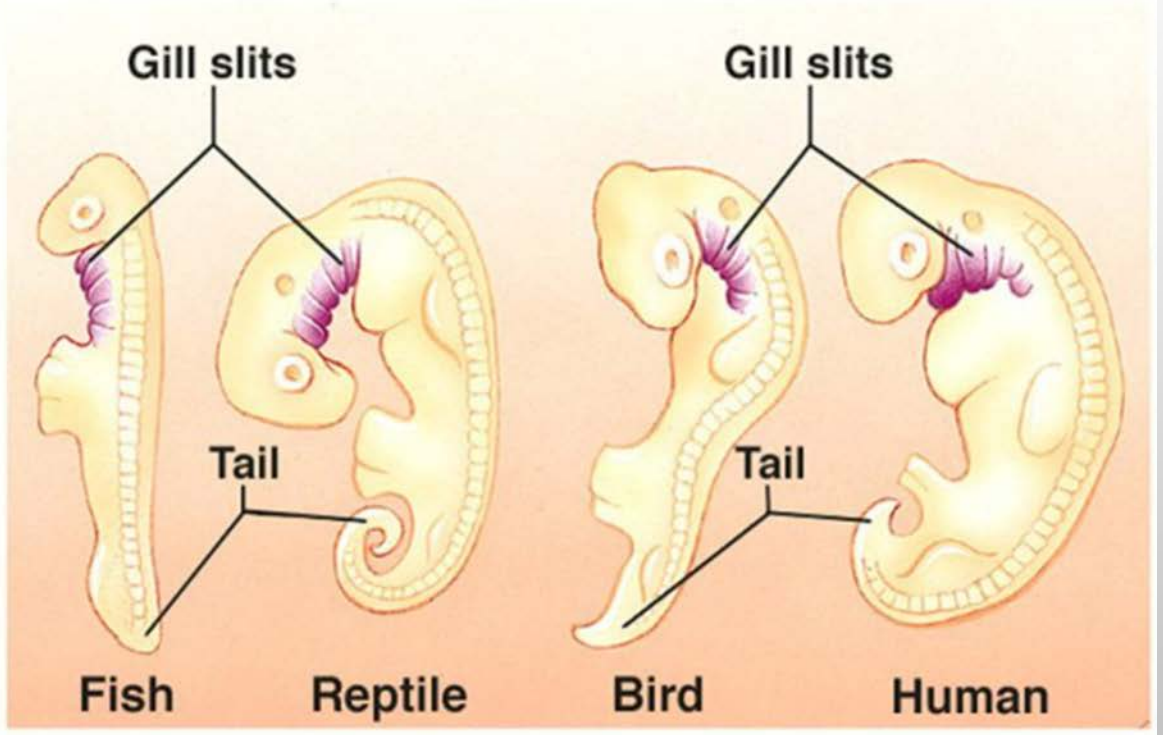
Evidence for macroevolution

Fossils

DNA

Comparative anatomy

Embryos retrace evolution as they develop



Patterns of Macroevolution

Convergent Evolution

- The word *converge* means "to come together". This pattern of macroevolution happens with distinctly different species become more similar in structure and function. Usually, this type of macroevolution is seen in different species that live in similar environments. The species are still different from one another, but they often fill the same niche in their local area.

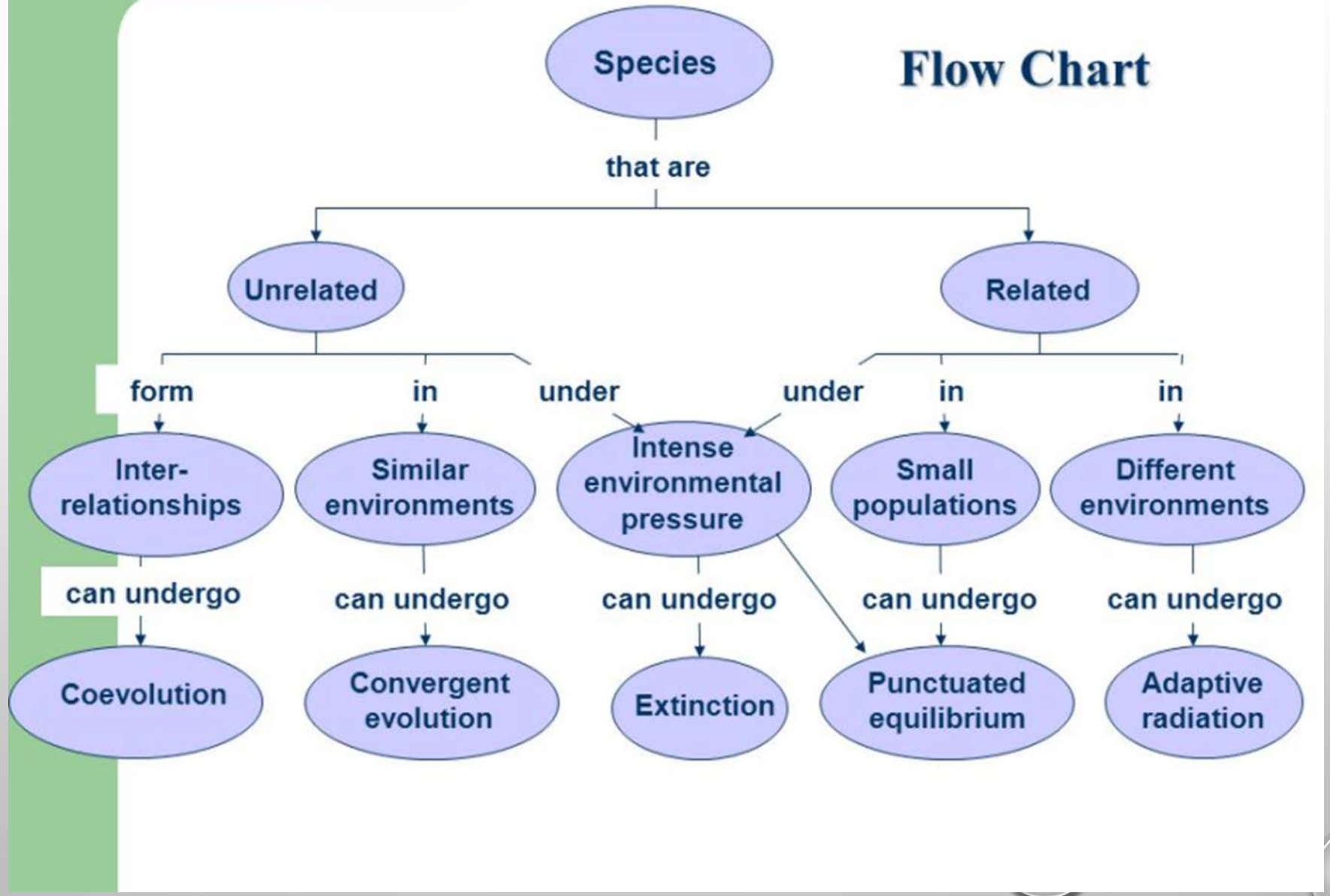
Divergent Evolution

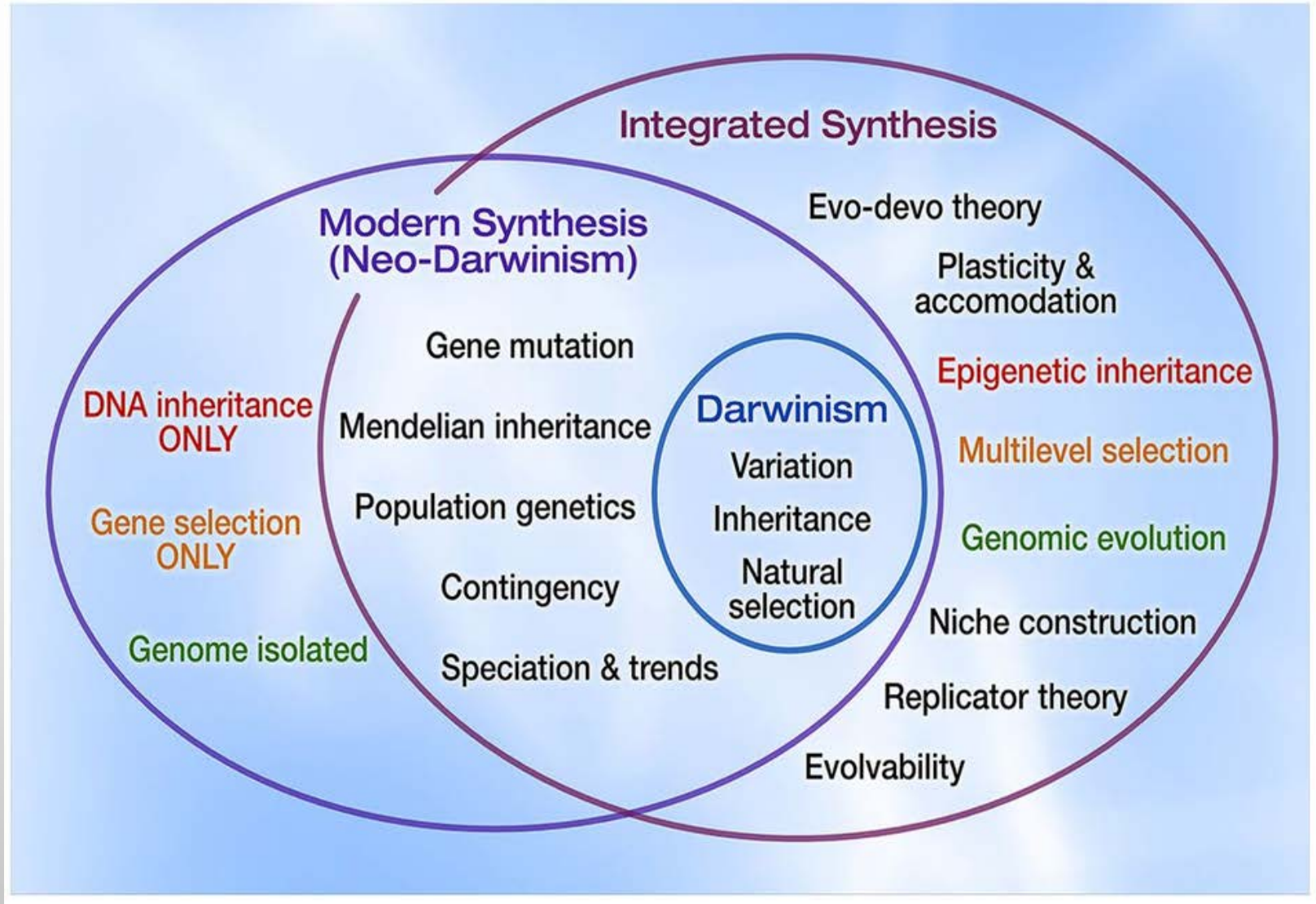
- Nearly the opposite of convergent evolution is divergent evolution. The term *diverge* means "to split apart". Also called adaptive radiation, this pattern is the typical example of speciation. One lineage breaks into two or more separate lines that each give rise to even more species over time. Divergent evolution is caused by changes in the environment or migration to new areas. It happens particularly quickly if there are few species already living in the new area. New species will emerge to fill the available niches.

Coevolution

- All living things are affected by the other living organisms around them that share their environment. Many have close, symbiotic relationships. The species in these relationships tend to cause each other to evolve. If one of the species changes, then the other will also change in response so the relationship can continue.

Patterns of Macroevolution




Integrated Synthesis
Modern Synthesis
(Neo-Darwinism)
Darwinism
Evo-devo theory
Plasticity &
accomodation
Epigenetic inheritance
Multilevel selection
Genomic evolution
Niche construction
Replicator theory
Evolvability
Gene mutation
Mendelian inheritance
Population genetics
Contingency
Speciation & trends
Variation
Inheritance
Natural
selection
DNA inheritance
ONLY
Gene selection
ONLY
Genome isolated

QUESTIONS?