- Chapter 25

  Early Earth and The Origin of Life

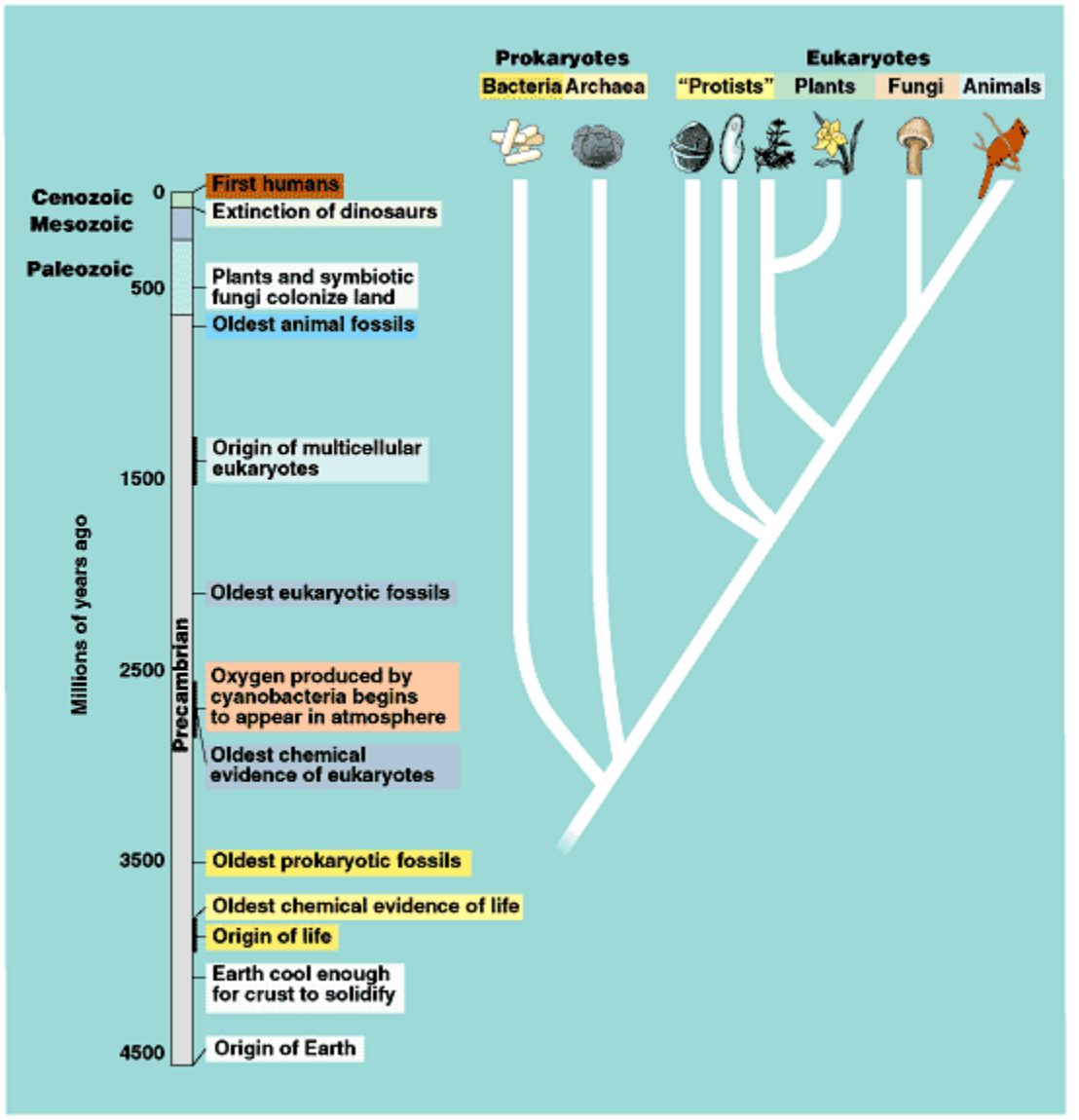
Essential Knowledge

- 1.A.4 – Biological evolution is supported by scientific evidence from many disciplines, including mathematics
- 1.B.1 – Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today
- 1.C.1 – Speciation and extinction have occurred throughout the Earth's history

Essential Knowledge

- 1.D.1 – There are several hypotheses about the natural origin of life on Earth, each with supporting scientific evidence
- 1.D.2 – Scientific evidence from many different disciplines supports models of the origin of life
- 4.B.3 – Interactions between and within populations influence patterns of species distribution and abundance

Early History of Life



Early History of Life

- **Solar system = 12 billion years ago (bya)**
- **Earth = 4.6 bya**
- **Life = 33.5 bya**
- **Prokaryotes dominated Earth = 3.5 to 2.0 bya**
  - ***Stromatolites = hold the first living fossil***

- **Oxygen accumulation = 2.7 bya**
  - *photosynthetic cyanobacteria = created oxygen in the atmosphere*
- **Eukaryotic life = 2.1 bya**
- **Multicellular eukaryotes = 1.2 bya**
- **Land colonization = 500 million years ago (mya)**
- **Animal diversity with the Cambrian explosion = 543 mya**

The 4 Stage Origin of Life Hypothesis:

1) Abiotic synthesis of organic monomers

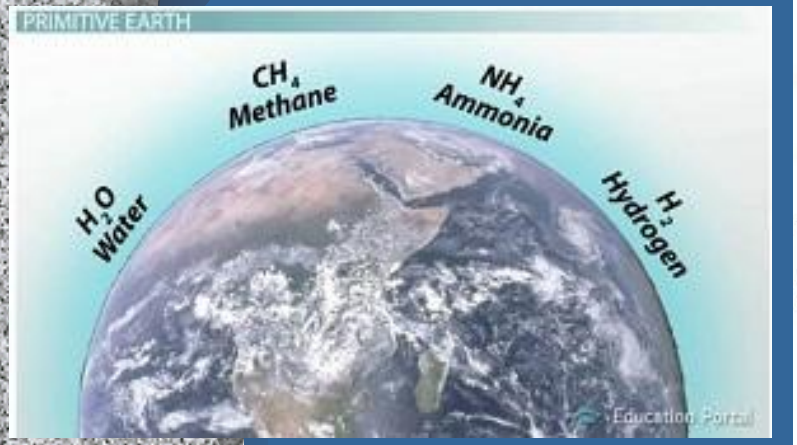
2) Polymer formation

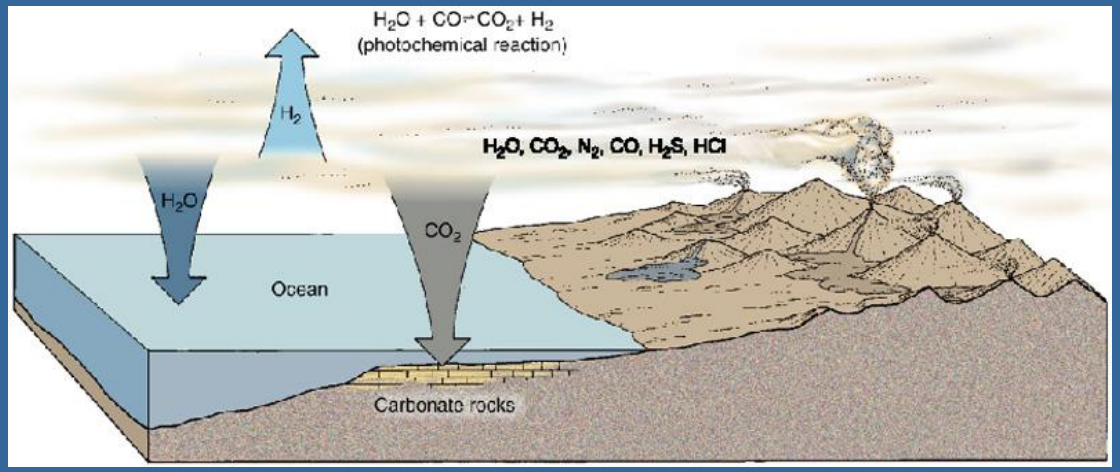
3) Molecule packaging (“protobionts”) – membrane containing droplets

4) Origin of self-replicating molecules

Origin of Life

- Primitive Earth provided inorganic precursors from which organic molecules could have been synthesized
  - This is due to the presence of available free energy and the absence of a significant quantity of oxygen in the atmosphere





Early Atmosphere

- The Precambrian atmosphere was composed mainly of nitrogen and carbon dioxide. Also had some methane and ammonia
- Volcanoes released water vapor, carbon monoxide, and even more nitrogen and carbon dioxide
- But no free oxygen was present

Origin of Life

- This early atmosphere provided molecules that served as monomers or building blocks for the formation of more complex molecules, including amino acids and nucleotides

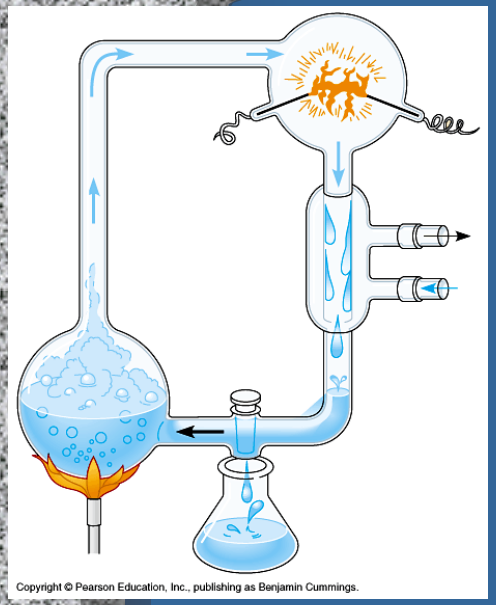
Origin of Life

- The joining of these monomers produced polymers with the ability to replicate, store and transfer information
- These complex reaction sets could have occurred in solutions (organic soup model) or as reactions on solid reactive surfaces

Organic Monomer/Polymer Synthesis

- ***Oparin /Haldane*** **hypothesis (1920s):**
  - **primitive earth: volcanic vapors (reducing atmosphere which means electron-adding) with lightening & UV radiation**
  - **This will enhance complex molecule formation (no O_2)**
  - **Haldane coined the phrase "primitive soup" because he suggested the oceans were a solution of organic molecules from which life arose**

- ***Miller/Urey*** **experiment (1953):**
  - **Water, hydrogen, methane, ammonia, all 20 amino acids, nitrogen bases, & ATP formed, but not organic molecules**
  - **Evidence suggests that that the atmosphere was probably not reducing or oxidizing (electron-removing)**
    - **Possible that just areas around volcanic openings were reducing in order to create molecules**

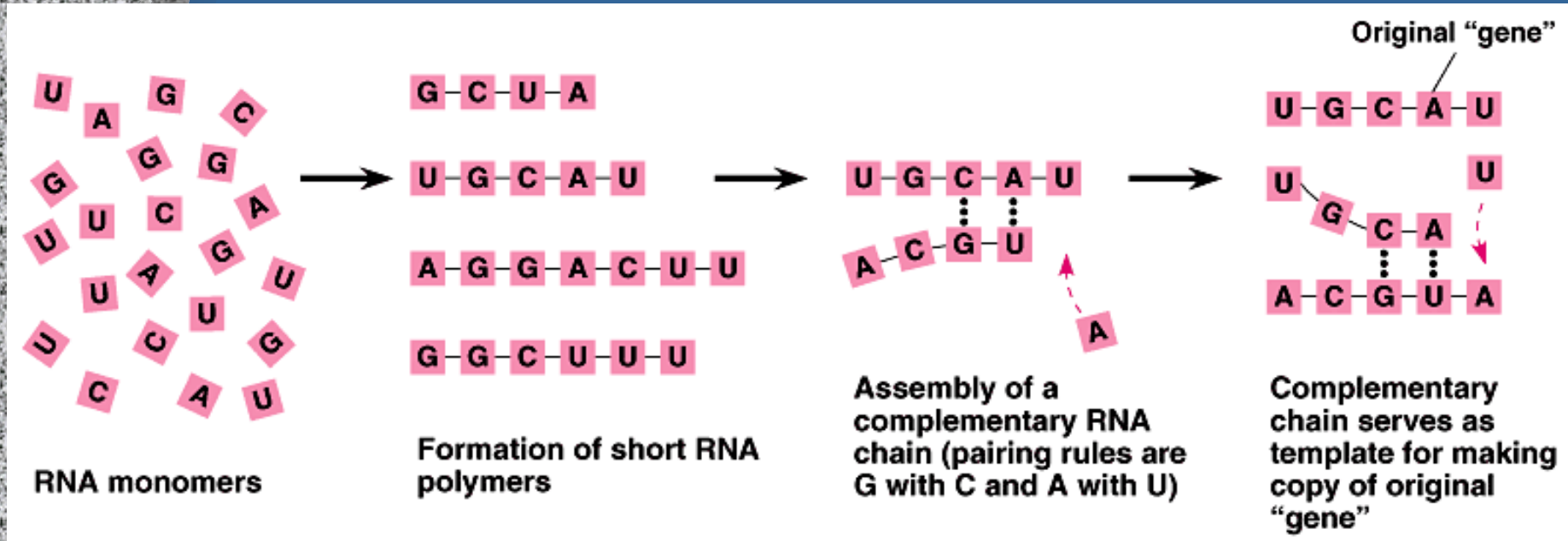


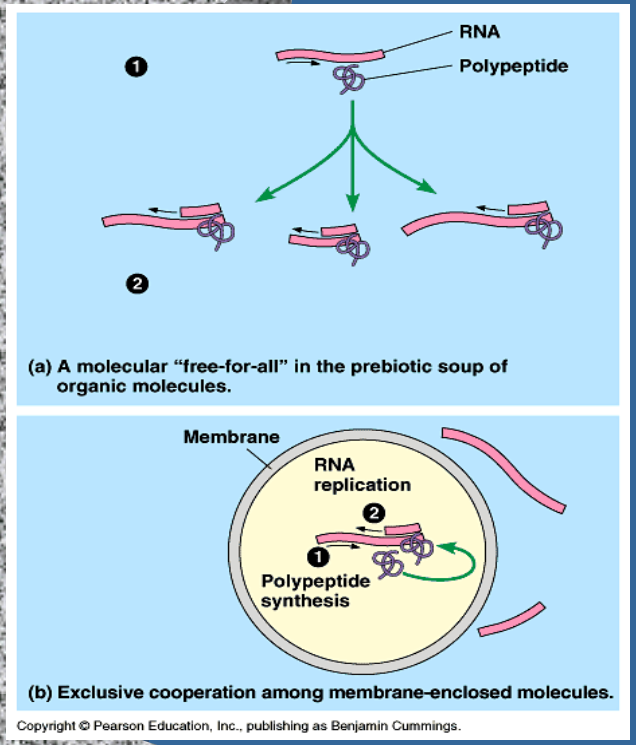
- ***Fox*** **experiment (1959):**
  - **Suggested that proteinoid formation (abiotic polypeptide spheres) occurs from organic monomers dripped on hot sand, clay or rock**
  - **Hot, dry conditions are needed followed by being dissolved in water**

- ***Oparin*** **also proposed that:**
  - **coacervates (spherical droplet of assorted macromolecules) and then protobionts (abiotic aggregate of macromolecules surrounded by a membrane) formed surrounded by a shell of H_2O molecules**

Abiotic Genetic Replication

- **The RNA World hypothesis proposes that RNA could have been the earliest genetic material (1986)**
  - **First genetic material = self-replicating RNA**





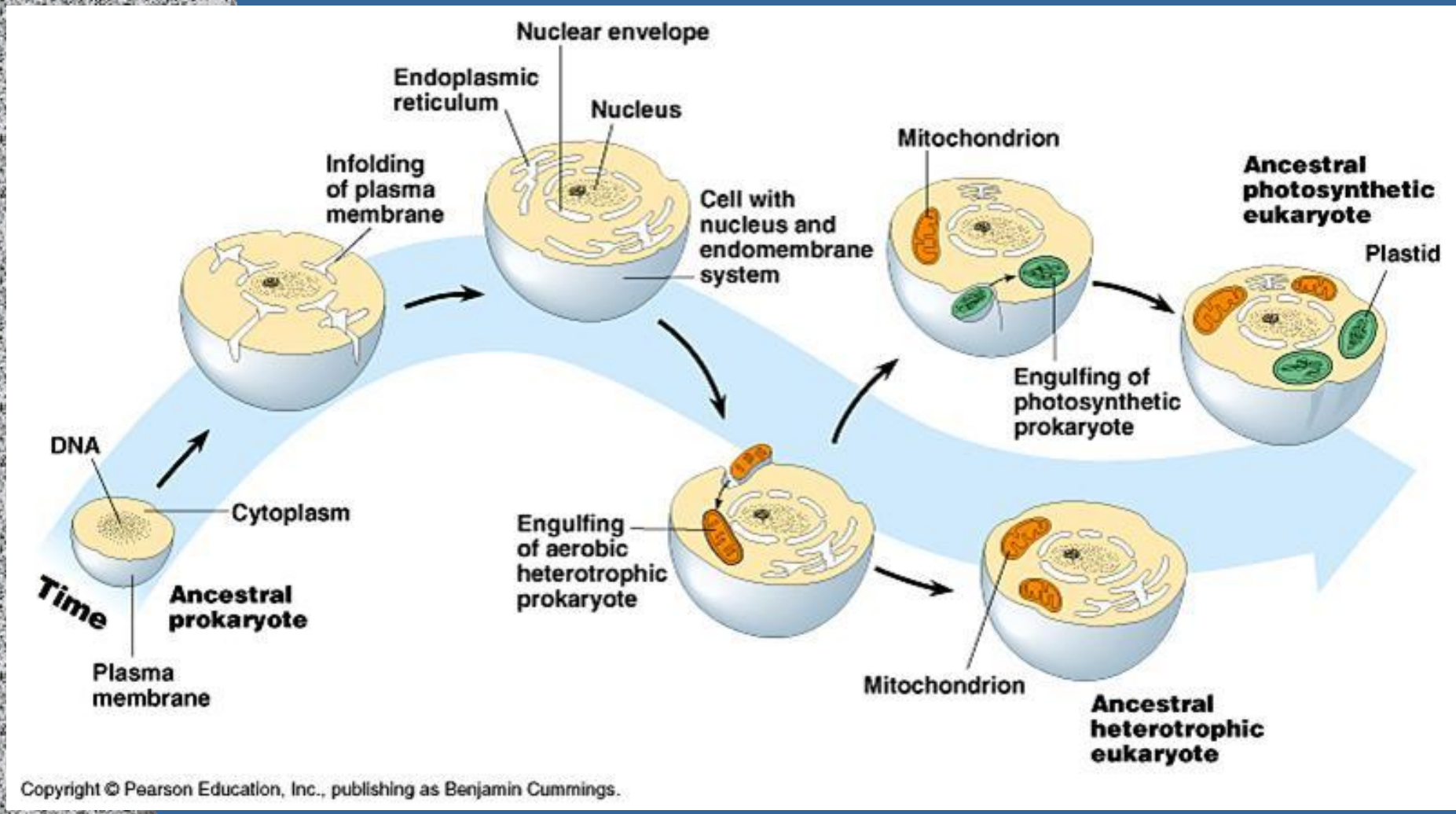
- Abiotic production of ribonucleotides
- Ribozymes = short sequence of RNA that act as a catalyst (enzyme)
- Formation of short polypeptides occurred
- RNA to DNA template?

First Organisms

- Prokaryotes were the first organisms on Earth and cyanobacteria is the oldest known fossil
- Stromatolites are rock-like buildups of mats of bacteria.
  - Photosynthetic cyanobacteria began adding oxygen to the atmosphere by taking in carbon dioxide to produce food
  - Today, cyanobacteria are still around and also contribute to converting atmospheric nitrogen into a form plants can use (nitrogen cycle)

Endosymbiotic Theory

- The theory proposes that mitochondria and plastids (chloroplasts) were once free living prokaryotes that were engulfed by another prokaryotic cell and developed into a symbiotic relationship within the cell
  - This is the connection between prokaryotic cells and unicellular eukaryotic cells



Endosymbiotic Theory Evidence

- Both organelles have enzymes and transport systems homologous to living prokaryotes
- Both replicate by a splitting process similar to prokaryotes
- Both contain a single, circular DNA molecule
- Both have ribosomes that can translate their DNA into proteins

Evidence

- Scientists determine information about the origin of species using:
  - Relative dating = order of rock strata determines relative age
  - Radiometric dating = decay of radioactive isotopes determines the exact age
    - Half-life

Evidence

- Molecular and genetic evidence from extant and extinct organisms indicates that all organisms on Earth share a common ancestral origin of life
  - Molecular building blocks are common to all life
  - Common genetic code

Rise and Fall of Species

- Continental drift = movement of continents have altered habitats and promotes speciation
- Adaptive radiation = periods of evolutionary change in which groups of organisms begin to fill different ecological niches

Rise and Fall of Species

- Mass extinctions = loss of large number of species, which can drastically alter an ecological community

- Species extinction rates are rapid at times of ecological stress
  - Ex: 5 major extinctions through the geologic time scale has drastically reduced the number of species on Earth
  - Ecology Ex: Human impact on ecosystems can lead to species extinction rates increasing

Changes in Body Form

- Evolutionary novelty = when structures had one role originally, but have gradually acquired a different role
  - Feather in birds – first for thermoregulation, now for flight
- Heterochrony = evolutionary change in the rate or timing of developmental events
  - Small changes in the embryo can have big impacts on the adult form
- Homeotic genes = master regulatory genes that determine location and organization of body parts