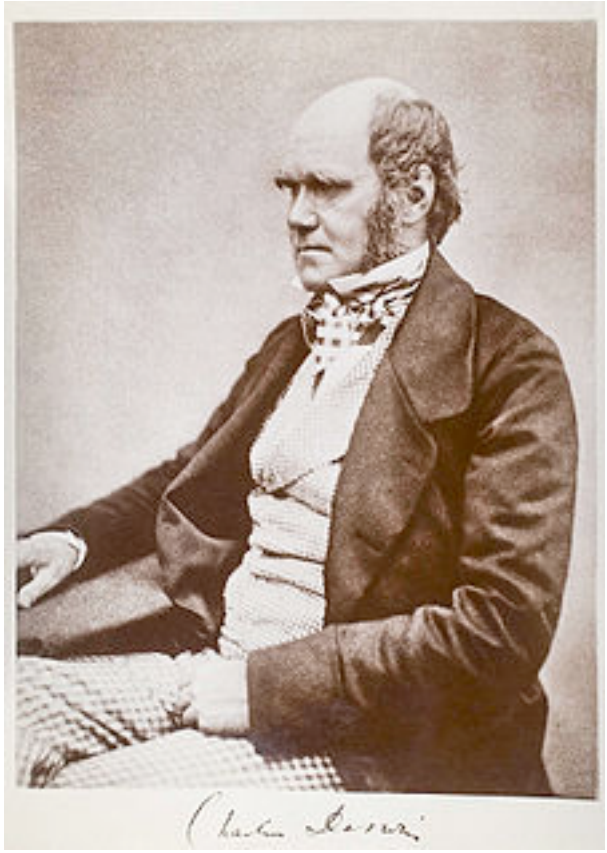
Lecture 24: Evolution at the Molecular Level

Read: 791- 801
Fig. 22.1-22.10



51 year old Charles Darwin

Just published

On the origin of Species

Born Feb 12, 1809

His theory of Evolution:

All species of life have evolved over time from common ancestors, through the process he called natural selection.[

Read page 802-803 Box

Darwinian Evolution vs. creationism/Intelligent Design

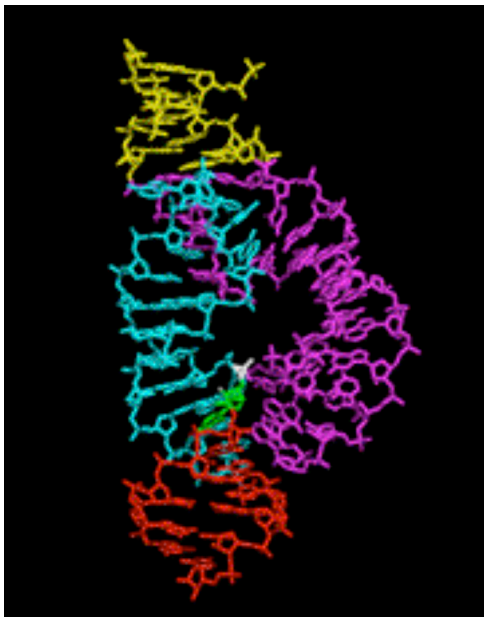
Speculations on how the first cell arose

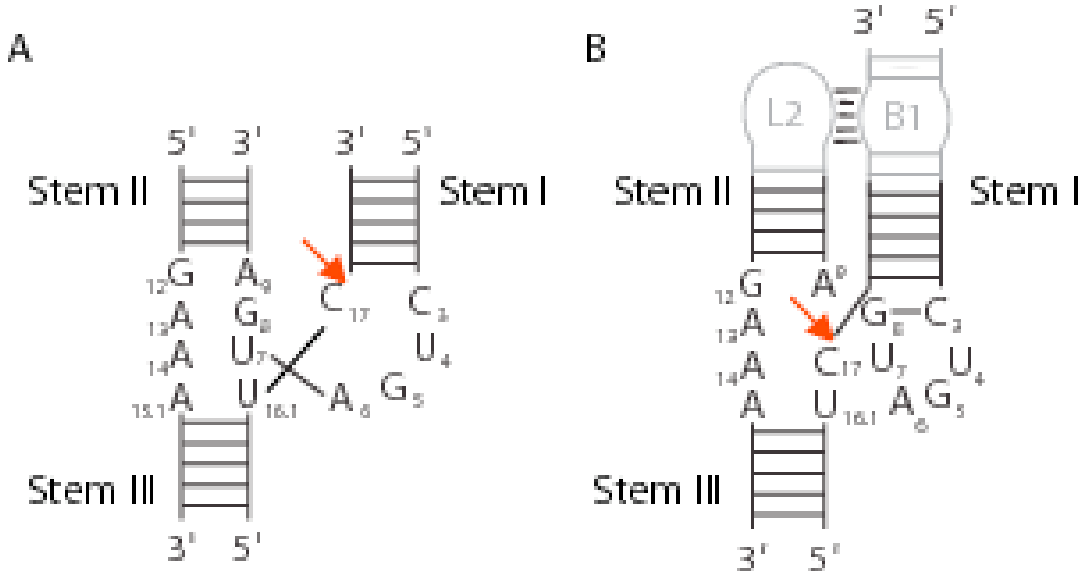
- The first step to life must have been a replicator molecule.
  - Three requirements to give rise to living cells:
    - Encode information by variation of letters in strings of a simple digital alphabet.
    - Fold in three dimensions to create molecules capable of self replication and other functions.
    - Expand the population of successful molecules through selective self-replication.

The original replicator may have been RNA.

- 1980s Thomas Cech – RNA can catalyze chemical reactions and carry genetic information
  - Ribozymes – RNA molecules that act as enzymes
- Earliest RNAs
  - Probably had coding region for polymerase separated by noncoding regions of background noise
  - Evolutionary pressure to cut, splice, and synthesize RNA molecules
- No record exits of the intermediates between the RNA world and organized complexity of cell.

Hammerhead ribozymes

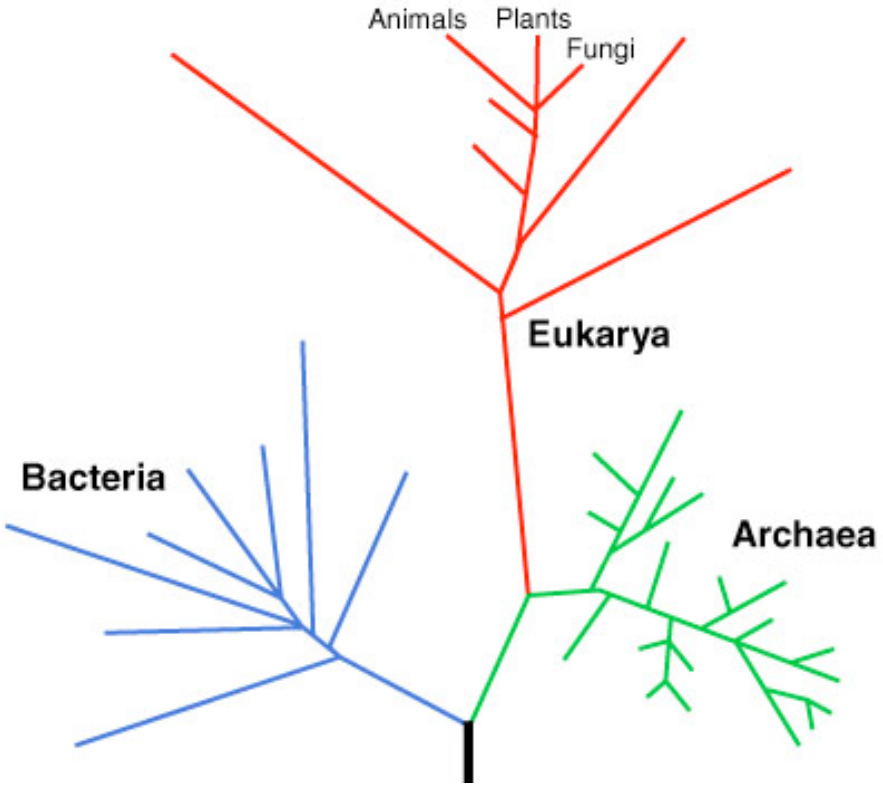




Secondary structures and sequences of the minimal (A) and full-length (B) hammerhead ribozymes. Conserved and invariant nucleotides are shown explicitly. Watson-Crick base-paired helical stems are represented as ladder-like drawings. The red arrow depicts the cleavage site, 3' to C17, on each construct.

Evolution of living organisms

- Intermediate stages of evolution from a single cell to complex multicellular organisms exist in the fossil record and in living fossils that surround us.
- Single-celled organisms without a membrane-bound nucleus emerged first.
  - Planet earth coalesced 4.5 billion years ago.
  - Oceans covered earth 4.2 billion years ago.
  - Fossil cells 3.5 billion years ago near North Pole



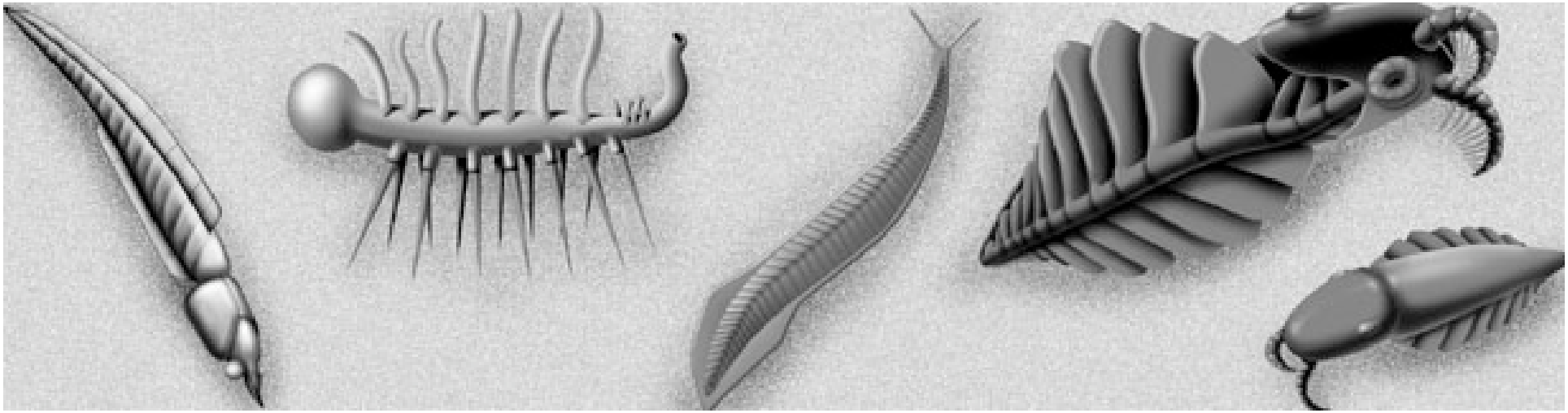
- Earliest cells evolved into three kingdoms of living organisms.
  - Archaea and bacteria now contain no introns.
  - Introns late evolutionary elaboration

Fig. 22.3b

- More complex cells and multicellular organisms appeared > 2 billion years after cellular evolution.
  - 1.4 bya – eukarya
    - Single cells invaded other cells.
    - Compartmentalization of cells interior into organelles
  - 1 bya – single-celled ancestors of plants and animals diverged
  - 600-900 mya first primitive multicellular organisms
  - 570 mya explosive appearance of multicellular organisms, both plants and animals

- Burgess shale of southeastern British Columbia
  - Mud slide that trapped a wide variety of organisms in a shallow Cambrian sea
  - Many fossils in excellent form
  - Organisms arose within 20-50 million years of one another – punctuated equilibrium.
  - Basic body plans of contemporary organisms emerged during the metazoan explosion.

Basic body plans of some Burgess shale organisms



Many species resulting from metazoan explosion have disappeared.

Fig. 22.4

Evolution of humans

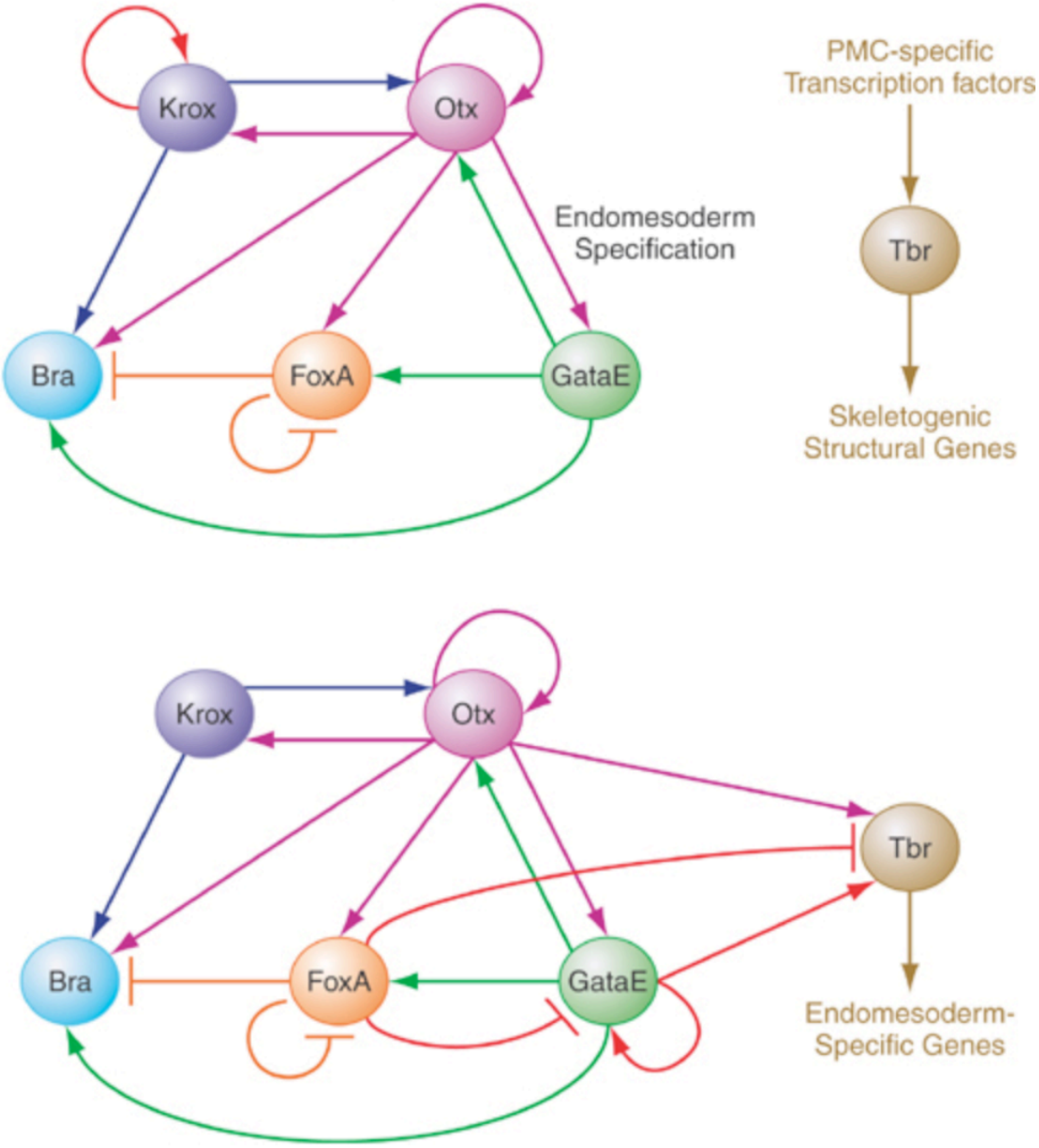
- 35 mya – primates
- 6 mya – humans diverged from chimpanzees

Fig. 22.5

Evolution of Humans

- Human and chimpanzee genomes 99% similar
- Karyotypes almost same
- No significant difference in gene function
- Divergence may be due to a few thousand isolated genetic changes not yet identified.
- Probably **regulatory sequences**

© Marc Chamberlain/SeaPics.com.



DNA alterations form basis of genomic evolution

- Mutations arise in several ways.
  - Replacement of individual nucleotides
    - Synonymous (silent) – no effect on amino acid encoded
    - Nonsynonymous – change in amino acid encoded
      - Conserved amino-acid changes – one acidic amino acid to another
      - Nonconserved amino acid changes – charged amino acid to noncharged amino acid
  - Insertions
  - Deletions
  - Order and type of transcription factor binding sites in promoter
- Mutations may be deleterious, neutral, or favorable.

Effect of mutations on population

- Neutral mutations are unaffected by agents of selection.
- Deleterious mutations will disappear from a population by selection against the allele.
- Rare mutations increase fitness.

An increase in genome size correlates with evolution of complexity.

- Genomes grow in size through repeated duplications.
  - Some duplications result from transposition.
  - Other duplications arise from unequal crossing over.

Basic structure of a gene

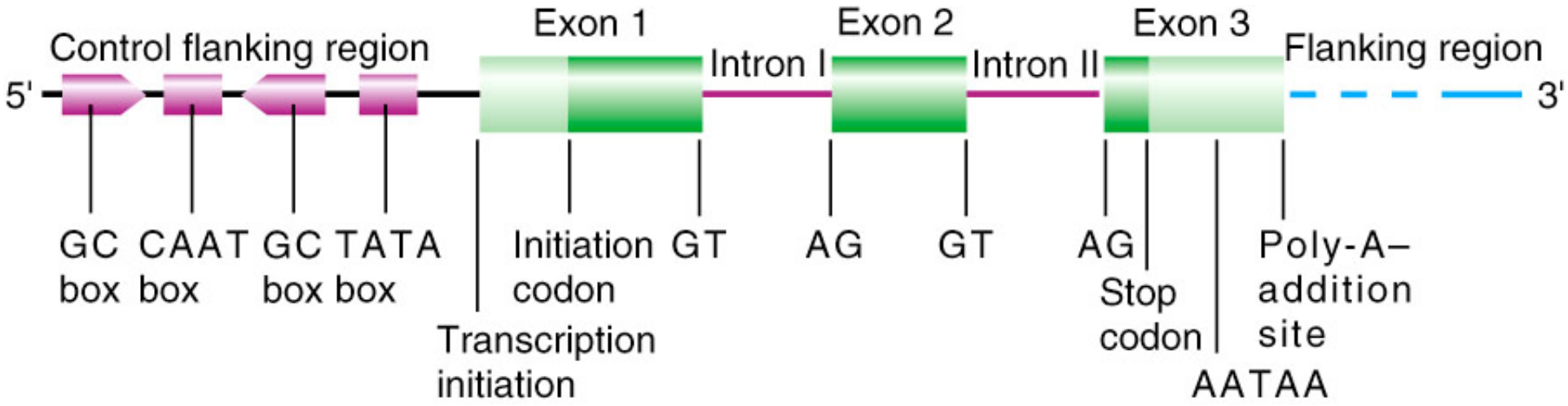


Fig. 22.12

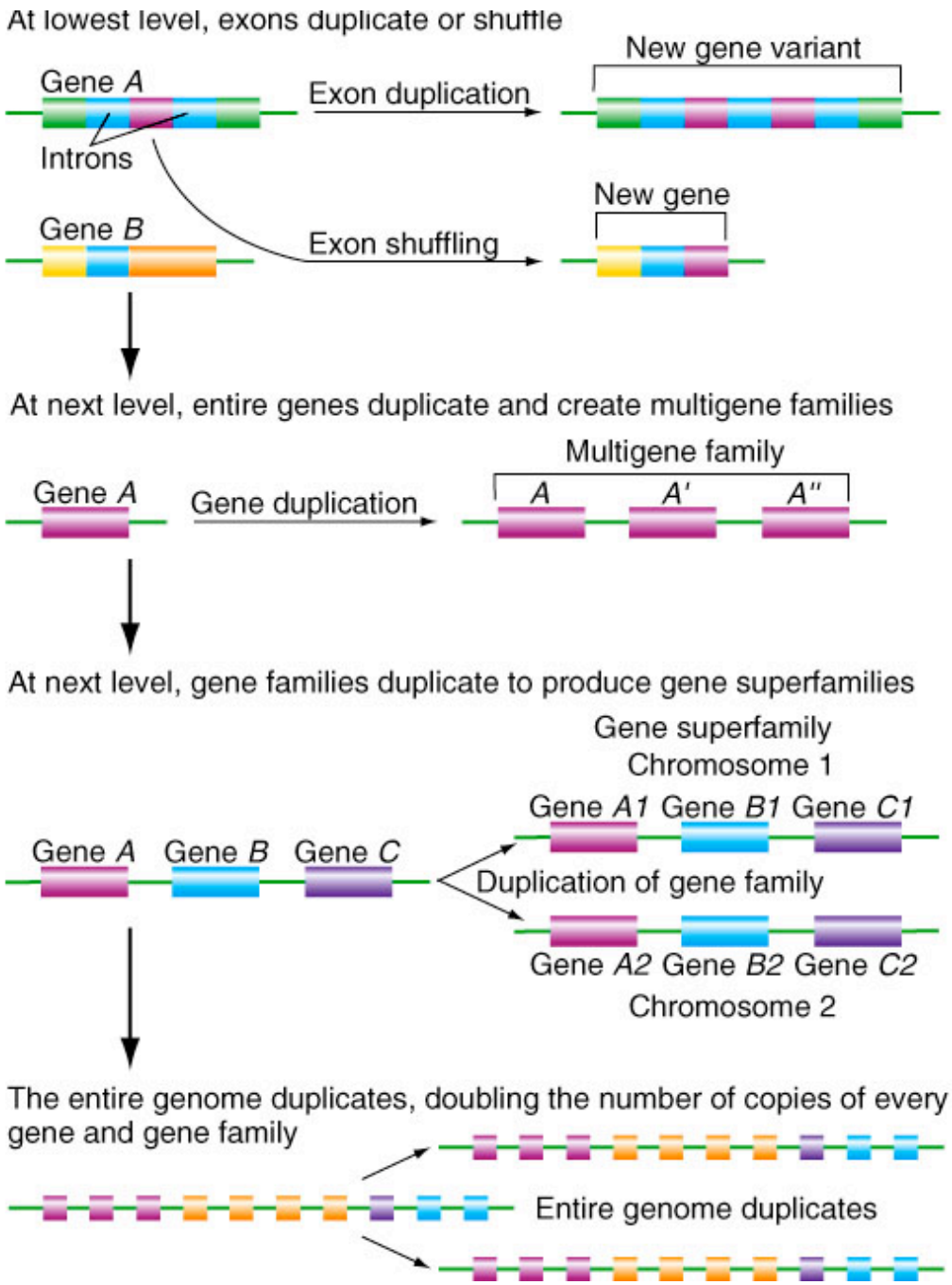
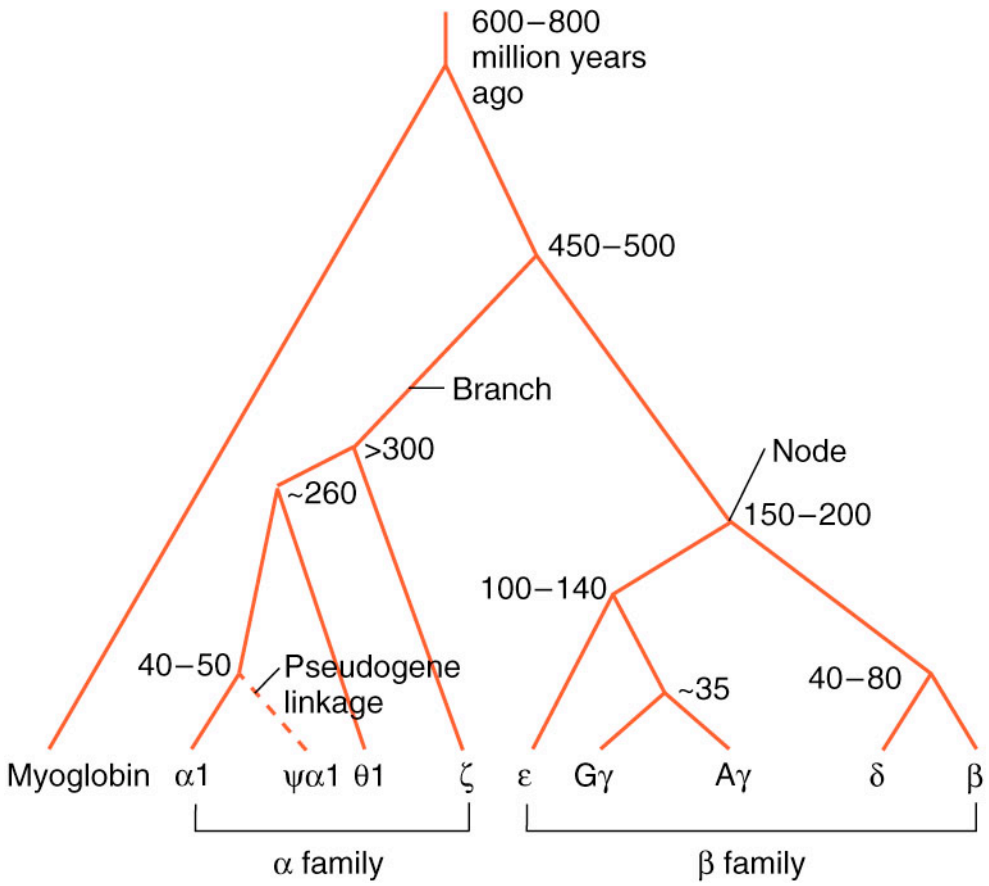


Fig. 22.11

- Genome size increases through duplication of exons, genes, gene families and entire genomes

Molecular archaeology based on understanding of gene diversification and selection



Phylogenetic trees – illustrate relatedness of homologous genes or proteins

- Nodes – taxonomic units such as species, populations, individuals, or genes
- Branches – length suggests amount of time elapsed based on molecular change

Fig. 22.10

Synthetic Biology
(You Tube)