

Tree of Life: Prokaryotes and Eukaryotes

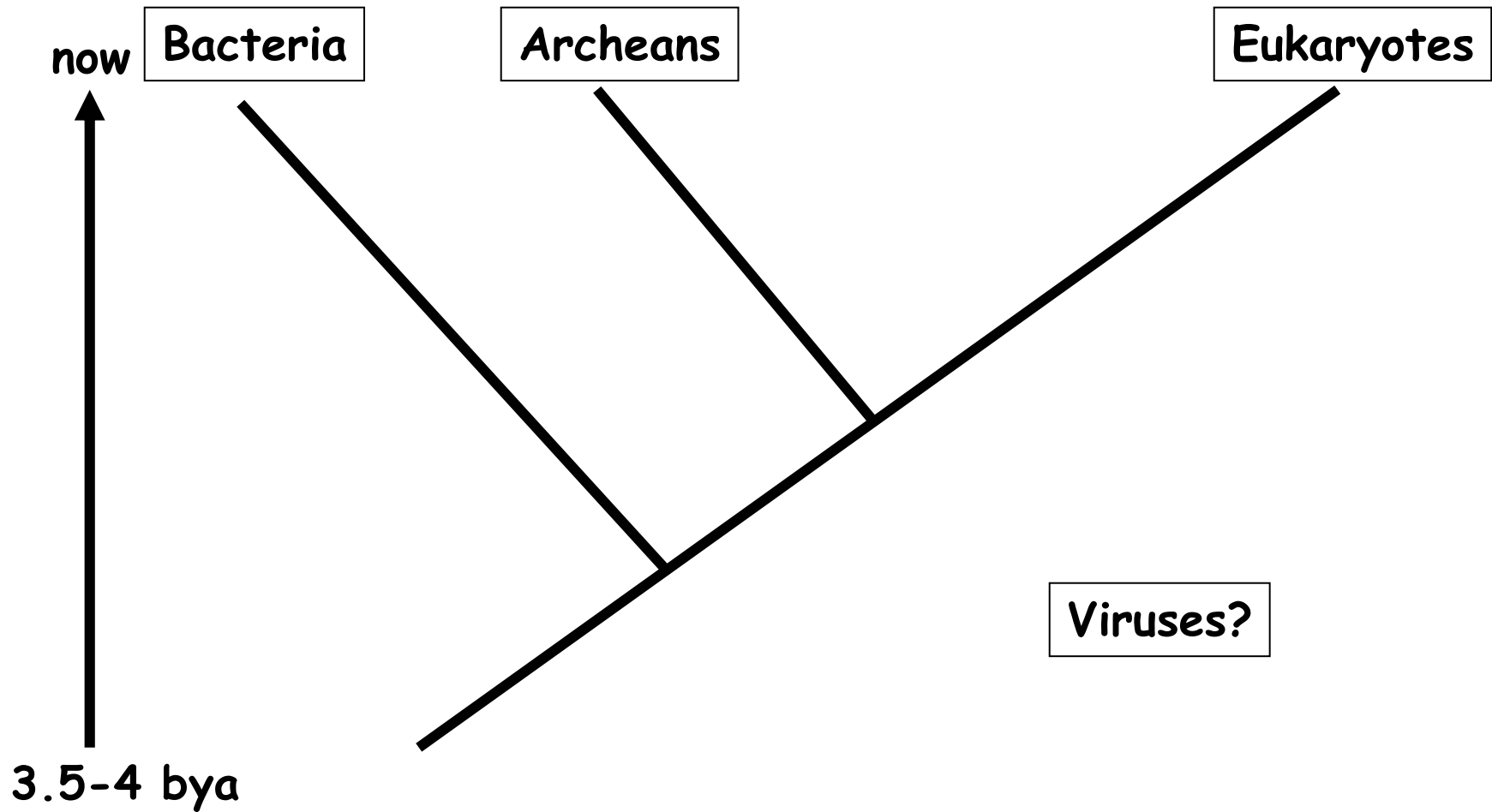
Biology/Env S 304

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Tree of Life: The Big Picture

- The deepest divisions of life are very old
- The ancestors of all current diversity were single-celled and prokaryotic
- Prokaryotes had evolved by 3.5 billion years ago and ruled the planet for about 2 billion years
- Eukaryotes appeared about 1.25 billion years ago

Tree of Life: The Big Picture



Tree of Life: The Big Picture

Prokaryotes vs. Eukaryotes

Bacteria
Archeans
(Archaea,
Archaeobacteria)

Protistans
(Protoctists)
Fungi
Animals
Plants

Viruses?

Prokaryotes

- One-celled, no compartments within the cell (no nucleus)
- Genetic material in a single, circular chromosome
- Therefore only 1 copy of each gene per bacterium
- A typical bacterium has 1,000-2,000 genes

Eukaryotes

- One-celled or many-celled, with compartments (e.g., a nucleus is present)
- Genetic material in two to many linear, separate chromosomes in the nucleus
- Normally two copies of each gene present in an individual in part of the life cycle
- A eukaryote has about 50,000 genes on average
- Much less metabolic diversity

Tree of Life: Microorganisms

Microorganisms are microscopic in size; include all prokaryotes (bacteria, archeans) and the single-celled eukaryotes (most protistans, some fungi, and some plants) as well as viruses.

TOL: Viruses

- Debate over whether viruses are living organisms or not
- Some argue that they are pieces of genomes and therefore non-living biological entities
- Others argue that viruses are degenerate lineages of bacteria living as obligate parasites

TOL: Viruses

- But viruses are functional biological units (protein coat + genetic material)
- They:
 - Have genetic material
 - Replicate (but not independently)
 - Evolve
 - Occupy specific ecological niches
 - Exhibit variability

TOL: Viruses

**Ca. 5,500 species formally
recognized**

Est. 500,000 species exist

So only 1% are known

TOL: Prokaryotes

- Two lineages: Bacteria and Archaea
- Both are ancient
- Most primitive members of each group are thermophiles (heat-lovers) suggesting that the common ancestor was also thermophilic
- Differ mainly in membrane and cell wall structure, genes controlling protein manufacture

TOL: Prokaryotes

- Great metabolic diversity
- Extremely important ecologically then and now
- Responsible for the formation of the early atmosphere on Earth
- Now control many key steps in nutrient cycles (e.g., nitrogen cycle)

TOL: Prokaryotes

- About 10,000 “species” recognized and named
- Estimated to be anywhere from 400,000 to 3,000,000 species
- Still no widely accepted species concept
- “It’s a prokaryote world.” (Stephen J. Gould)

TOL: Prokaryotes (examples)

Bacteria

Cyanobacteria (blue-green algae)

Purple Bacteria

Nitrogen-fixing bacteria

Actinomycetes

various groups of disease-causing bacteria

Archeans (Archaea)

Thermophiles (heat-lovers)

Halophiles (salt-lovers)

TOL: Bacteria

- Widespread
- Exhibit a wide variety of metabolisms
- Important as producers, decomposers, disease-causing organisms and in nutrient cycling (e.g., nitrogen fixation)
- May form symbiotic relationships (e.g., *E. coli*; lichens)

TOL: Archeans

- Typically found in many extreme environments
- More widespread than previously thought
- Includes extreme thermophiles (hot springs), methanogens (anaerobes), and halophiles (very salty habitats)
- *Thermus aquaticus* is the source of Taq polymerase used in PCR

TOL: Eukaryotes

- First appeared about 1.25 billion years ago
- Probably arose several times through independent endosymbiotic events
- Earliest lineages are all microbial
- Almost all exhibit sexual reproduction
- Vast majority of known biodiversity is eukaryotic but we know some groups a lot better than others

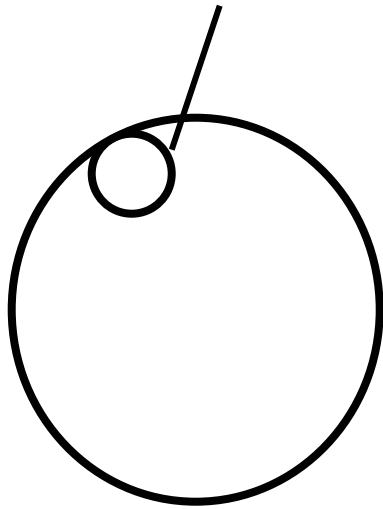
TOL: Eukaryotes

Two main hypotheses explain the evolution of the nucleus:

- Infolding of cell membrane in a prokaryote to enclose the genetic material
- Capture of another prokaryote (endosymbiosis)

TOL: Eukaryotes

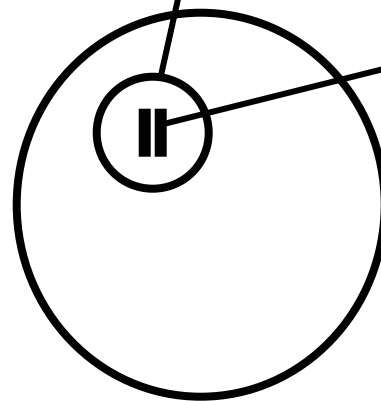
circular chromosome



prokaryotic cell



nucleus



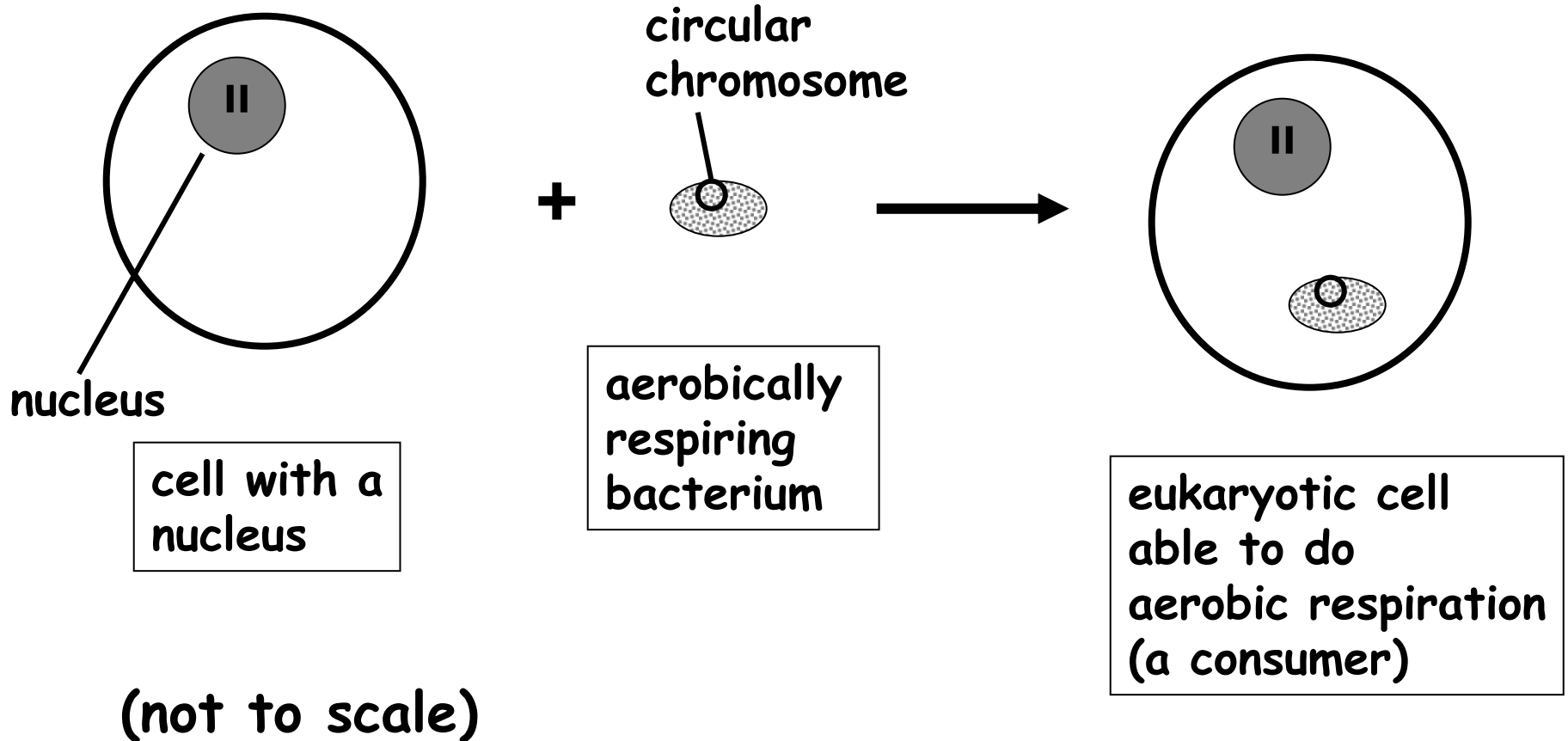
linear
chromosomes

proto-eukaryotic cell

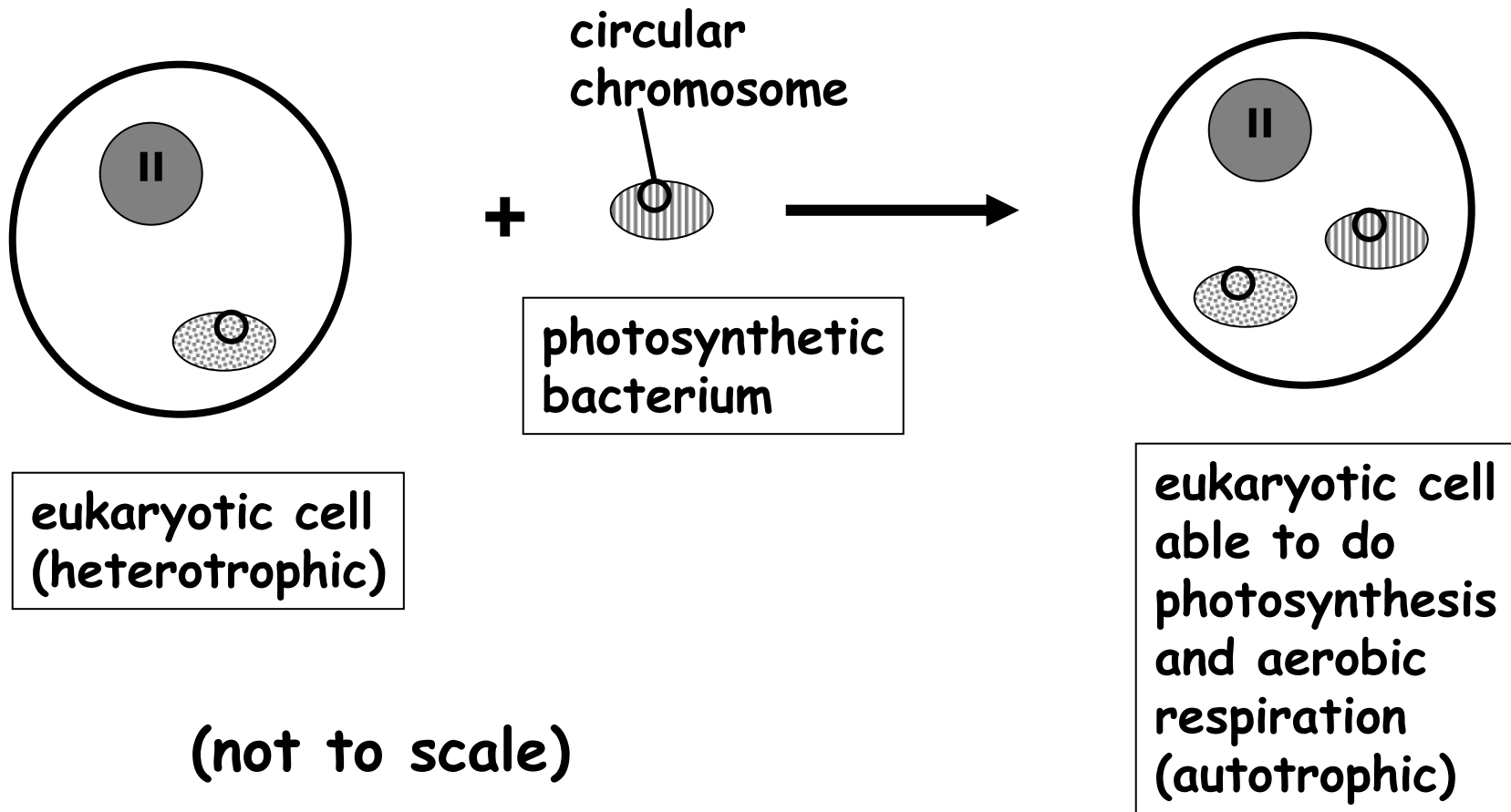
TOL: Endosymbiosis

- Endosymbiosis = capture or lasting association of a prokaryote within a cell
- Capture of a prokaryote able to do aerobic respiration → mitochondria
- Capture of a prokaryote able to do photosynthesis → chloroplasts

TOL: Endosymbiosis



TOL: Endosymbiosis



TOL: Endosymbiosis

- Mitochondria and chloroplasts have their own genetic material (just like their bacterial ancestors) and they can replicate (eukaryote cells normally have multiple mitochondria and chloroplasts)
- Endosymbiosis leading to mitochondria may have happened only once, but it happened a number of times leading to chloroplasts
- Lineages have also lost their chloroplasts

TOL: Eukaryotes

- 1) Protistans (protocists)
- 2) Plants
- 3) Fungi
- 4) Animals