# The Origin of Life

- What is life?
- History of the Earth:  The Big Bang
  - Earliest evidence of life
- Requirements for the Evolution of Life from Non-Life
  - Abiotic Synthesis of Monomers
    - A Hypothesis by Oparin and Haldane
    - The Miller and Urey Experiment
  - Anabolic Synthesis of Polymers
  - Formation of Protobionts: Chemical Isolation
  - Evolution of a Genetic Template
    - 3 Steps Toward the Evolution of the Central Dogma
- The Evolution of Complex Cells and Multicellularity
  - Autogenesis, Compartmentation, and Symbiogenesis
- The Five Kingdoms

# Reconstructing the history of life:

- The fossil record
- Experimental models and simulations
- Deductions based on existing organisms

# 15 Billion Years of History in 90 seconds:

The Big Bang (15 bya)

↓

Condensation of Solar System (5 bya)

↓

The Third Planet (4.6 bya)
Earth and Primitive Atmosphere

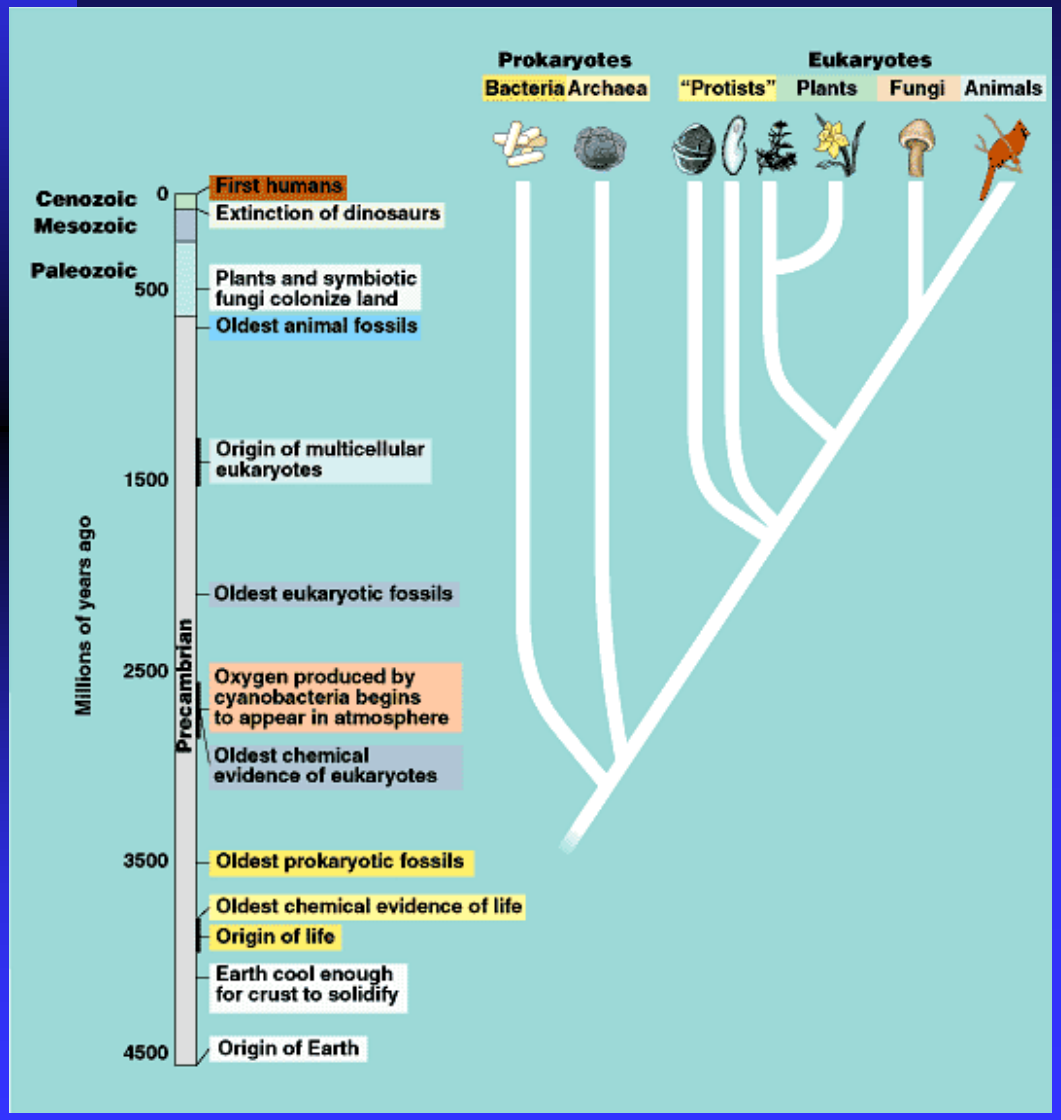
↓

Crust Solidifies (4 bya)

↓

Oceans and land masses
(solid, liquid and gas states)

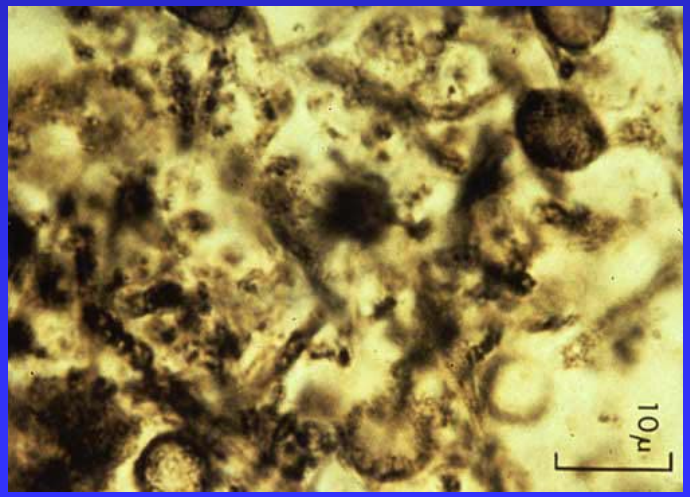
# The scale of geological time and fossil evidence:




# Compressing Geological Time: If 4.5 billion years = a single year

- Jan 1 - formation of earth
- Feb 17 - Meteor bombardment ends
- Mar 20 - Simple cells appear
- Nov 17 - Simplest animals (750 mya)
- Nov 20 - Cambrian Explosion and the Burgess Fauna (520 mya)
- Nov 28 - first land plants
- Dec 13 - Permian extinction
- Dec 21-27 - Dinosaurs present and gone
- Dec 31 8:45pm - Last ice age begins
- Dec 31 9:07pm - Early man (Homo)
- Dec 31 11:45pm - Man (Homo sapiens)

# Fossil Evidence for the Origin of Life 3.5 billion years ago:


# Requirements for Chemical and Cellular Evolution:

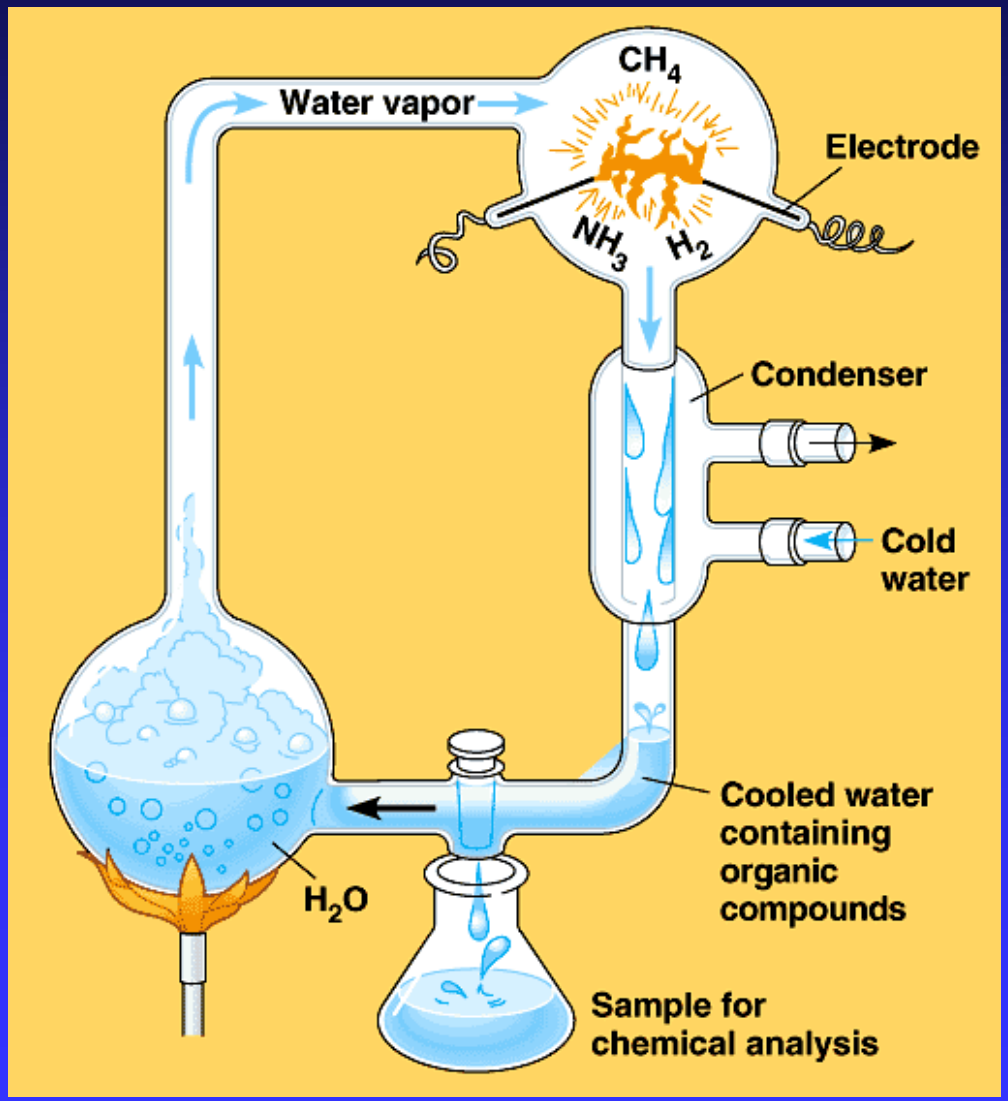
- A. Abiotic synthesis and accumulation of monomers
- B. Condensation of monomers into polymers (molecules → macromolecules)
- C. Formation of protobionts: chemically isolated systems
- D. Origin of genetic material: directive, continuity and changeable (mutable)

# Experimental Evidence for Abiotic Synthesis:

- A. Oparin and Haldane's Hypothesis (1920's):
  - Elemental requirements:CHNOPS
  - Reducing atmosphere
  - Energy sources
- B. Miller and Urey: Testing $H_o$ w/ Primitive Earth apparatus
  - $H_2O$, $H_2$, $CH_4$, $NH_3$
  - $CO_2$, CO, $N_2$

Benjamin Cummings

# The Miller-Urey Experiment: Brewing-up some "prebiotic soup"…



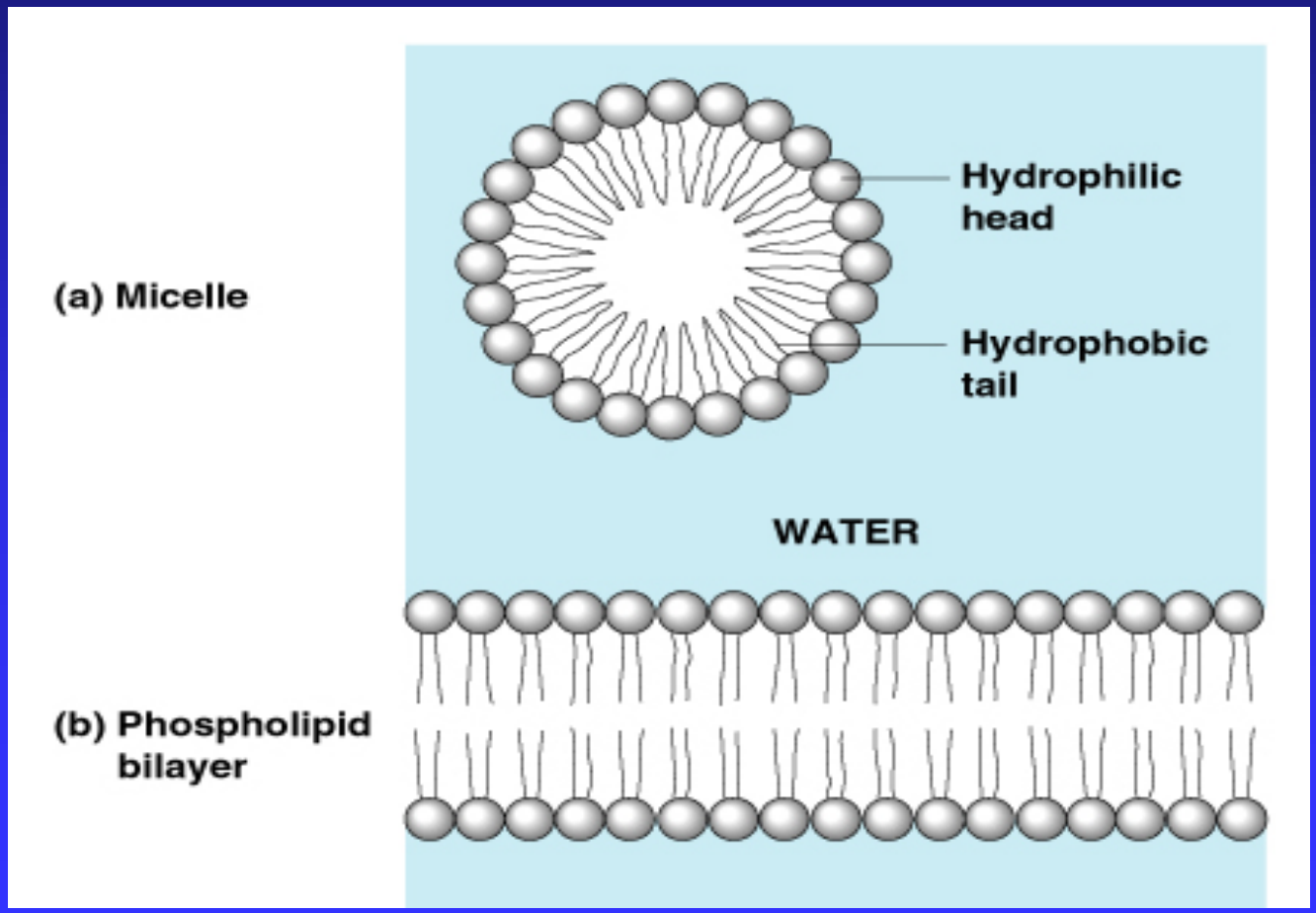
# Evidence for the production of organic polymers:

- Polymerization=dehydration synthesis


- Proteinoids formed on hot sand or clay
- The importance of clay and zinc to concentration

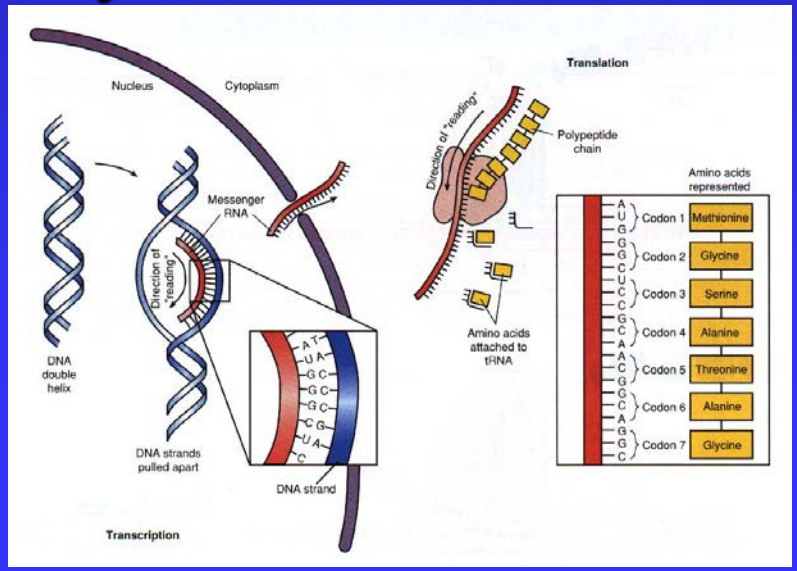
# Chemical Isolation: Protobionts

- David Deamer: The spontaneous formation of liposomes from phospholipids



# Evolution of Genetic Material

- A. Three functional requirements reviewed
- B. The Central Dogma: DNA → RNA → Protein
- C. Stepwise evolution of a complex process
  - RNA-based genome and catalysis
  - RNA-directed protein synthesis
  - DNA-RNA-protein



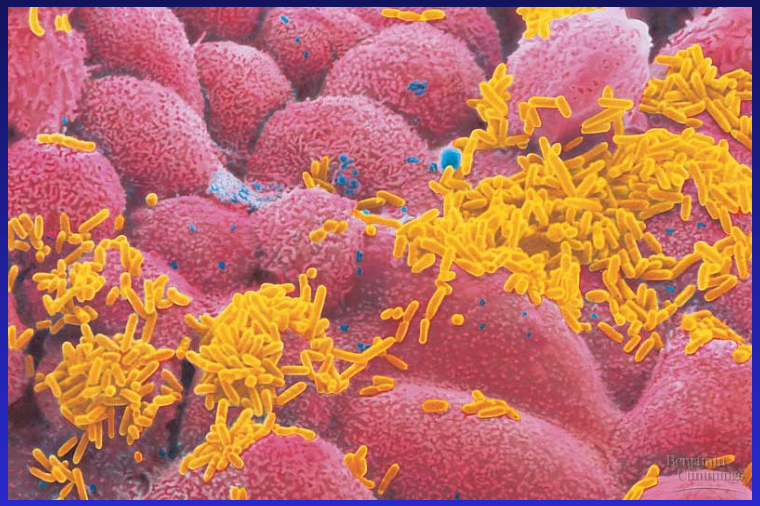
# Kingdom Monera

- Kingdom Monera includes the bacteria and cyanobacteria.
- Very simple cells.
- Called prokaryotes or prokaryotic.
- Have no nucleus or complex organelles.
- Most closely resemble the earliest ancestral cells from 3.7 BYA
- Ecologically and clinically important.

*E. coli*

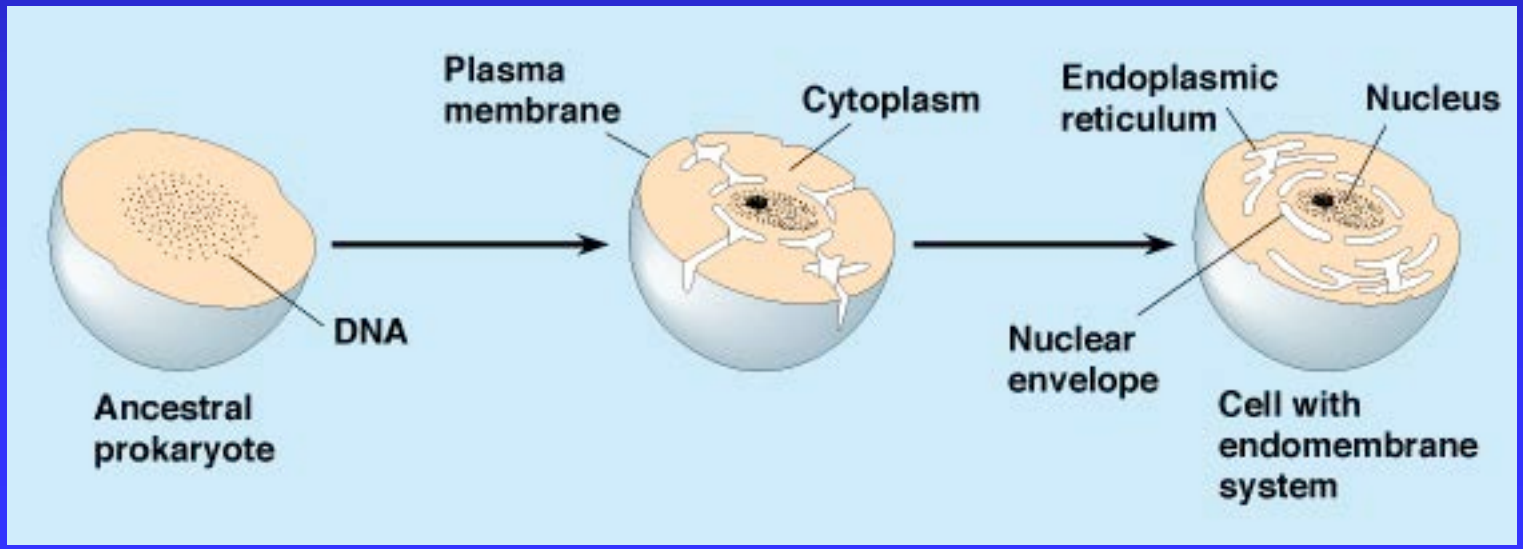
# Ecological Importance Bacteria and Cyanobacteria

- Nutrient Cycling:
  - Decomposers
  - Carbon fixation
  - Nitrogen fixation
  - Others
- Symbioses:
  - Mutualistic: +/+
  - Commensalistic: +/o
  - Parasitic: +/-
- How is natural selection driving evolutionary change among these early prokaryotes?
  - NS acting on genes
  - Mutations
  - Free exchange genes b/w individuals



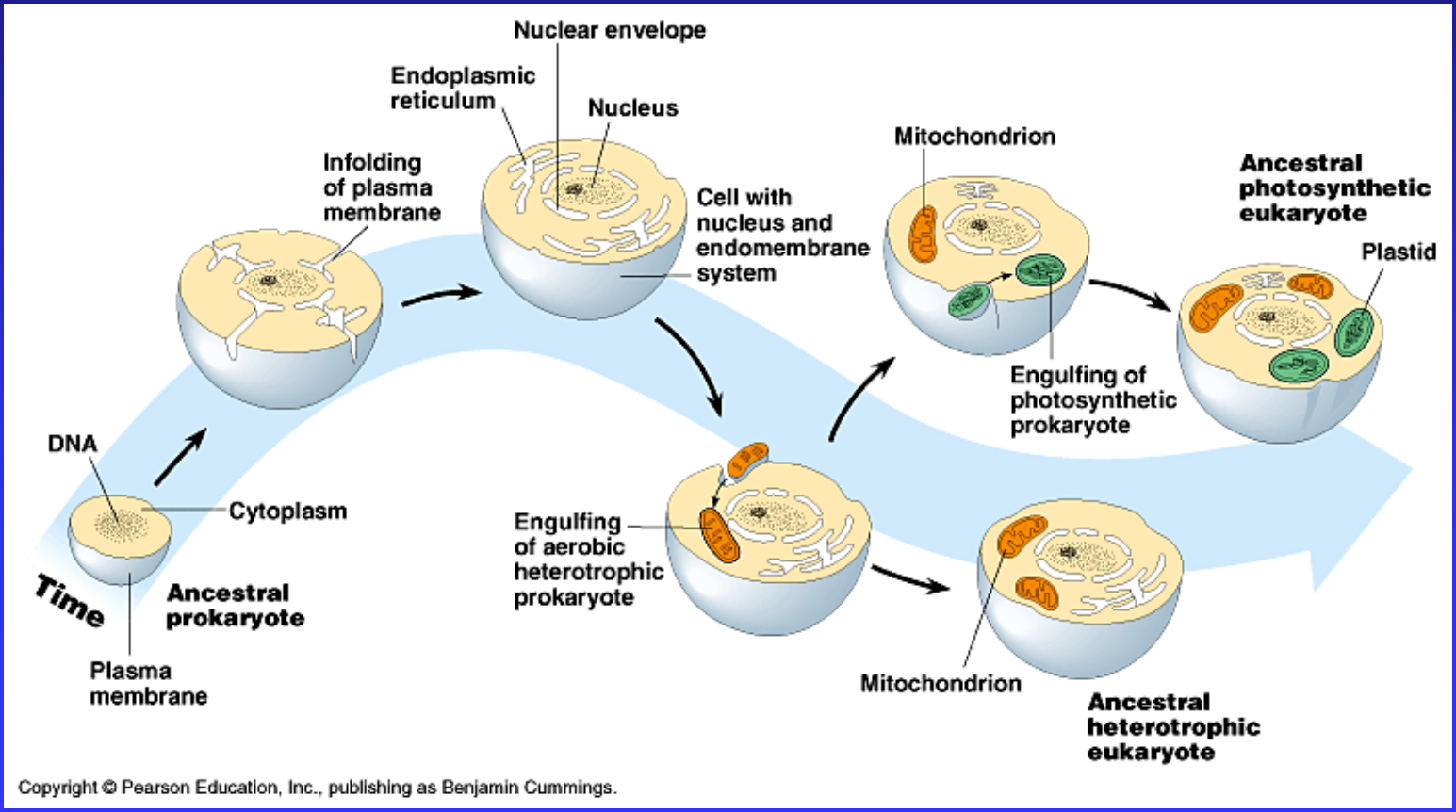
# The Evolution of Structural and Genomic Complexity: Eukaryotes and Compartmentalized Cell Structure

- Part 1 - The Autogenesis Theory
  - 1. Compartmentalization w/ regional specialization
  - 2. Increased membrane surface area



# Evolution of Eukaryotes and Compartmentalized Cell Structure: Part 2 - The Endosymbiotic Theory

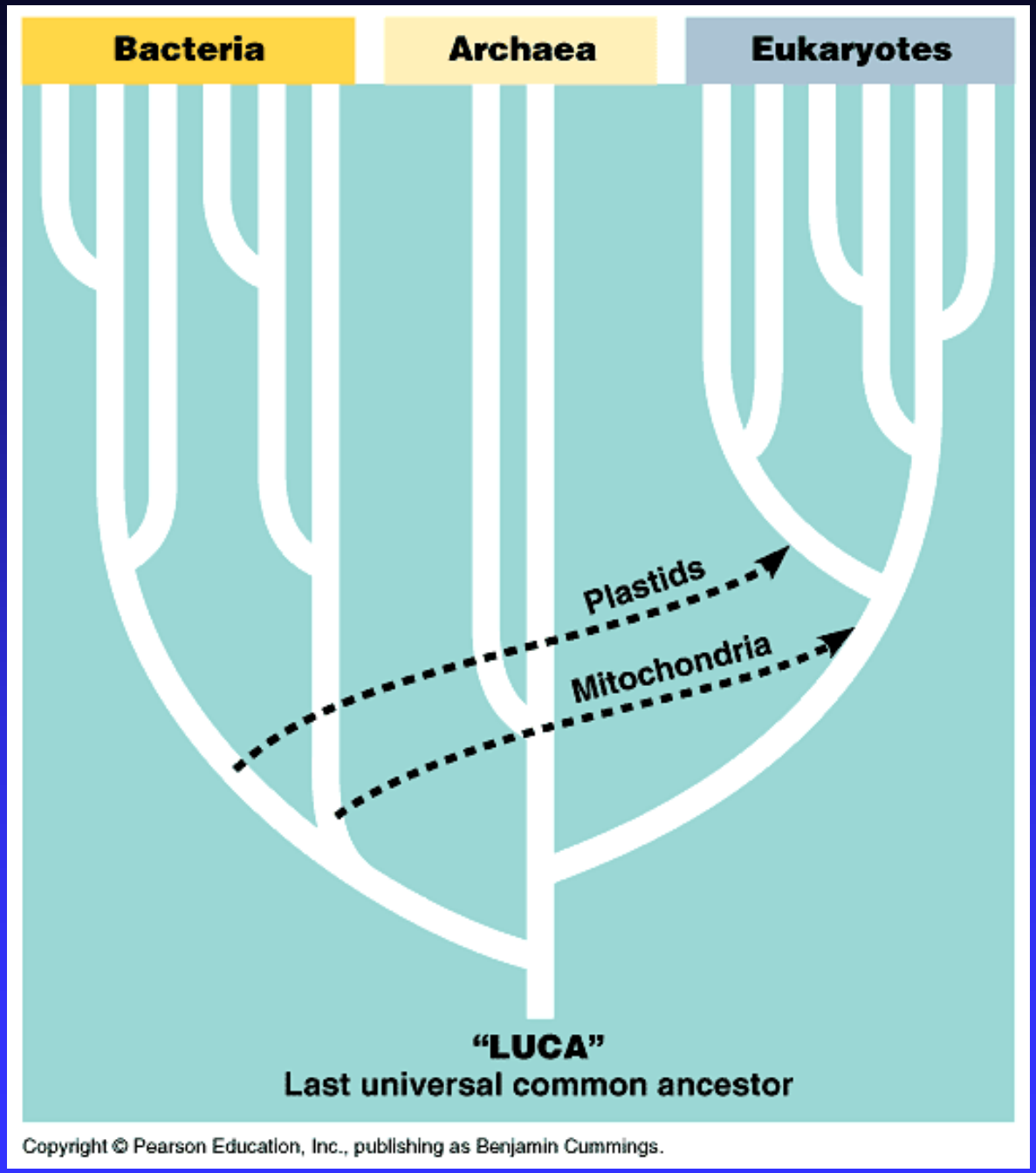
1. Parasites or prey are internalized
2. Mutualistic relationship develops



# Evidence for Endosymbiotic Theory:

- 1. size
- 2. homology to prokaryotic plasma membranes
- 3. replication: binary fission, not *de novo* synthesis
- 4. DNA structure: circular loop and packing
- 5. complete "intracellular" protein synthesizing machinery
- 6. ribosomal structure, sequence and Abx sensitivity

Traditional hypothesis for how the three domains of life are related

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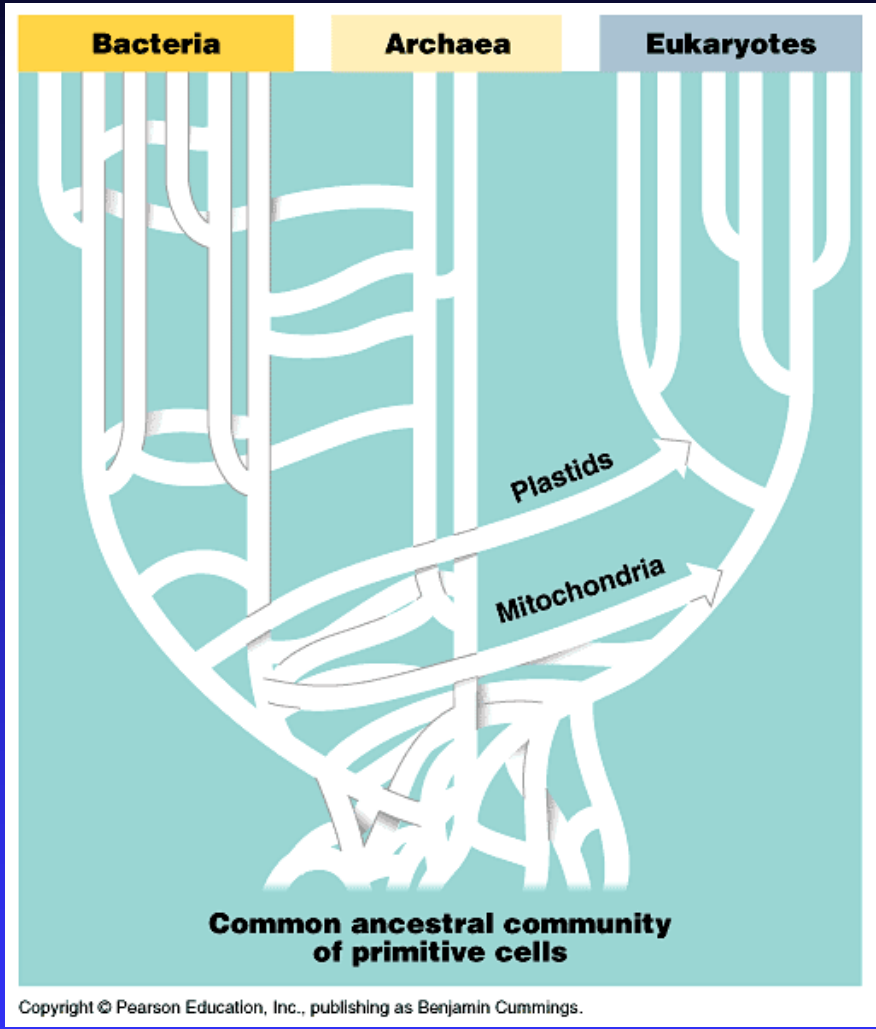
An alternative hypothesis for how the three domains of life are related



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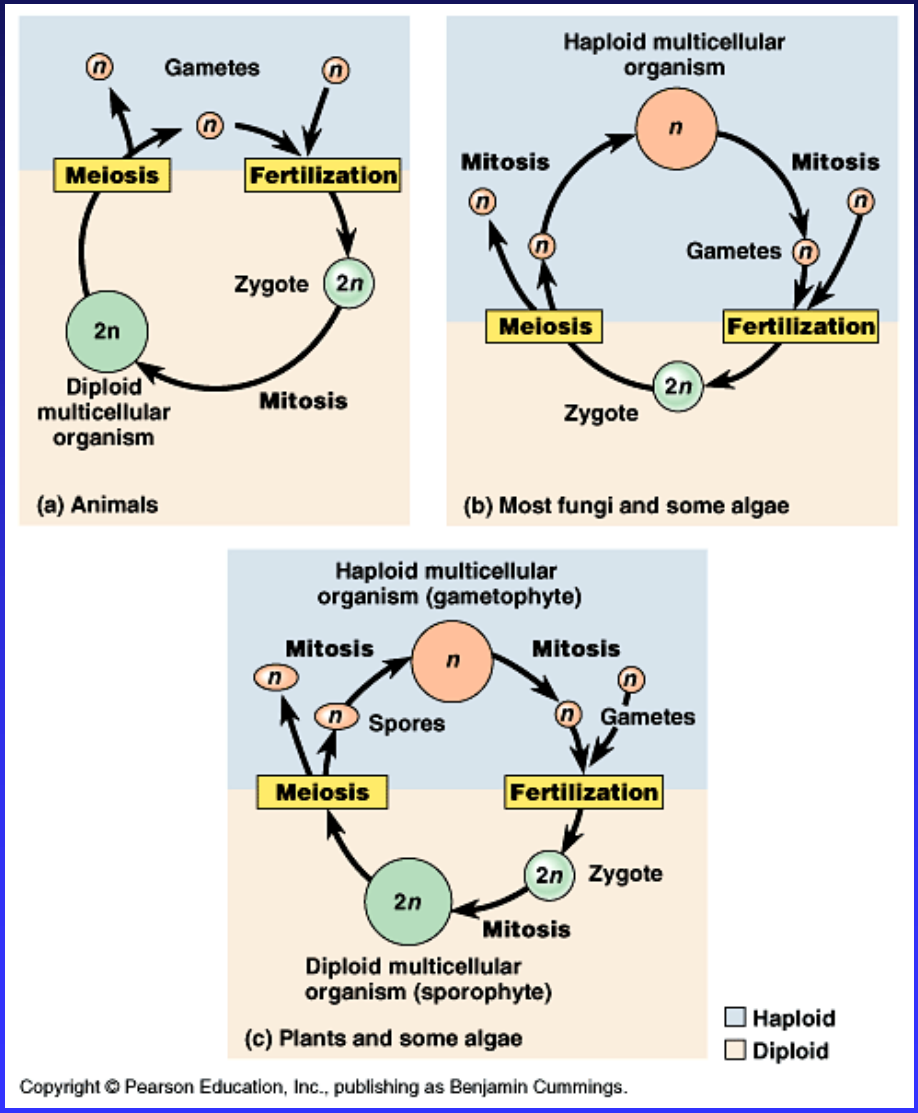
**Consider the concepts of "Horizontal evolution" and "symbiogenesis".**

# Sexual Reproduction: A rapid and continuous source of genetic variation that accelerates adaptability and change

Gametic Life Cycle

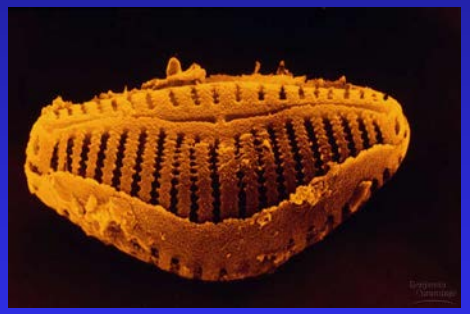



Zygotic Life Cycle

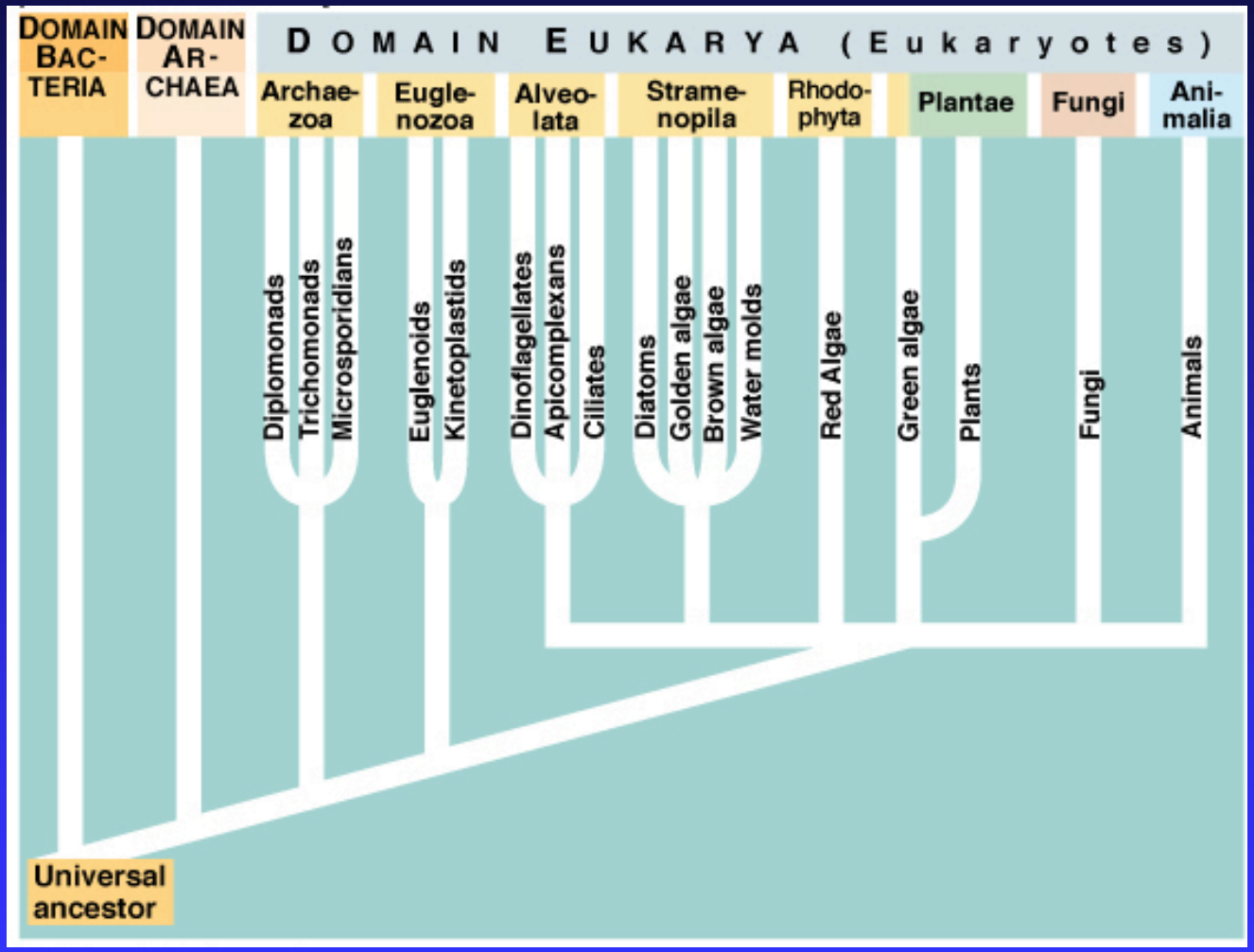
Sporic: The Alternation of Generations

# “Kingdom Protista” (aka, K. Fruit Salad)

- Eukaryotic single celled and colonial organisms
- 100,000 living species, 35,000 fossilized members
- Autotrophic, heterotrophic mixotrophic
- Ancestors to metazoans: plants, fungi, animals
- Low specialization, high complexity
- The origins of Eukaryotic complexity: Two trends allowed the eukarya to arise from the eubacteria
  - Compartmentalized cell structure
  - Increased genomic size
    - Nuclear lineage and symbiogenesis



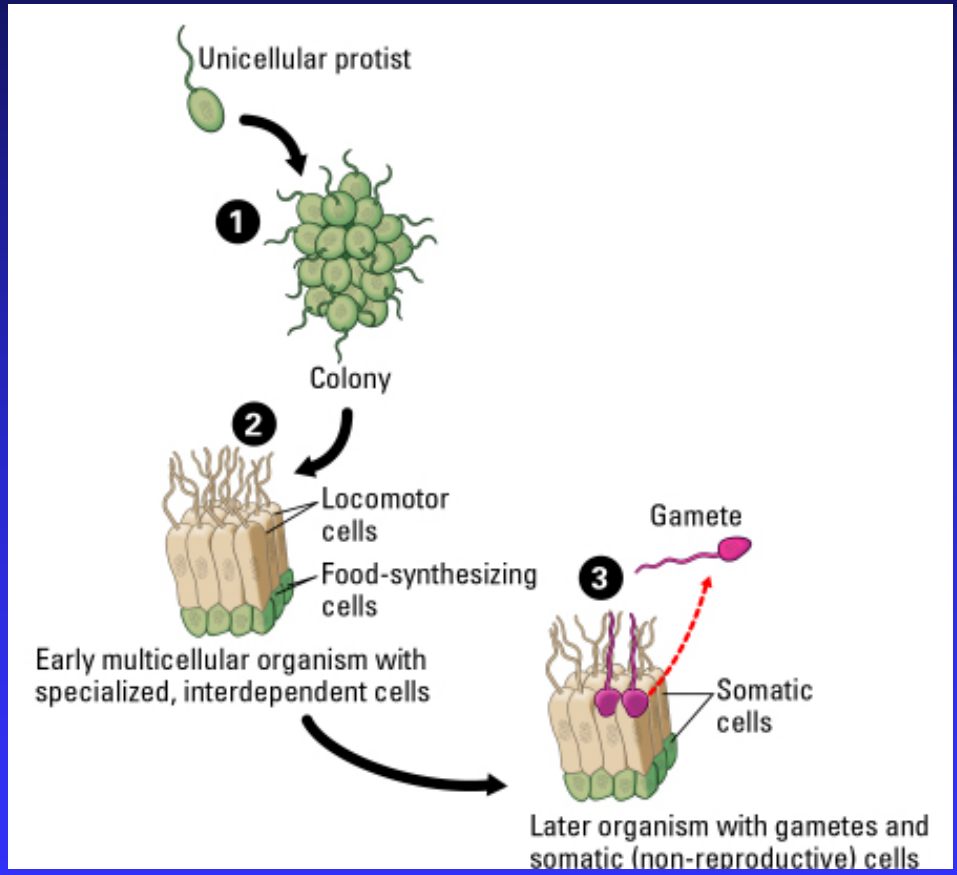
# Protistans are NOT monophyletic




Note: These groups only represent a sample of protist diversity; many other lineages are not shown on the tree.

# The Evolution of "Multicellularity" Among Autotrophs and Heterotrophs:

- Cellular specialization
  - Somatic and gametic cells
- Division of labor
- Interdependence
- Intercellular coordination



# Kingdom Plantae- Eukaryotic

- Eukaryotic and multicellular
- Photosynthetic autotrophs
- Cellulose cell walls
- Terrestrial and aquatic environments
- Base of food chain on land

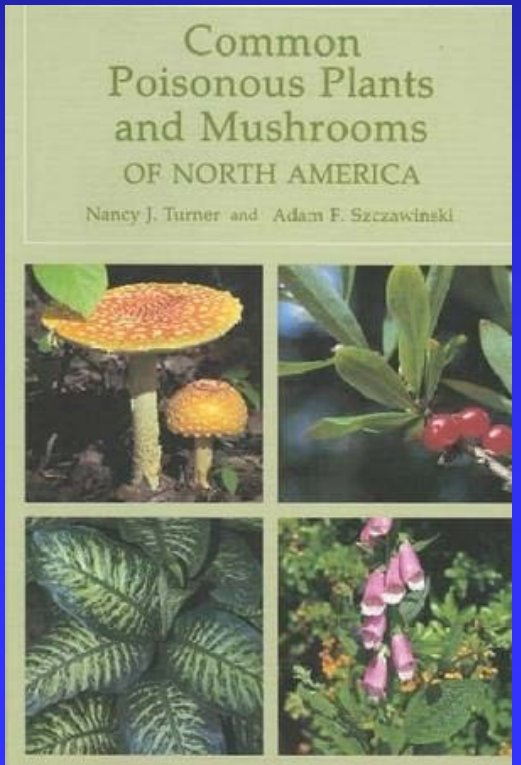
# Kingdom Fungi-

- Eukaryotic and multicellular
- Absorptive  heterotrophs
- Cell walls of chitin
- Yeast, molds, lichens, mycorrhizae
- Heterotrophic, mainly terrestrial. Some microscopic.
- Cytoplasmic continuity, a different brand of multicellularity
- Important in decomposition

Fungus eating a cd

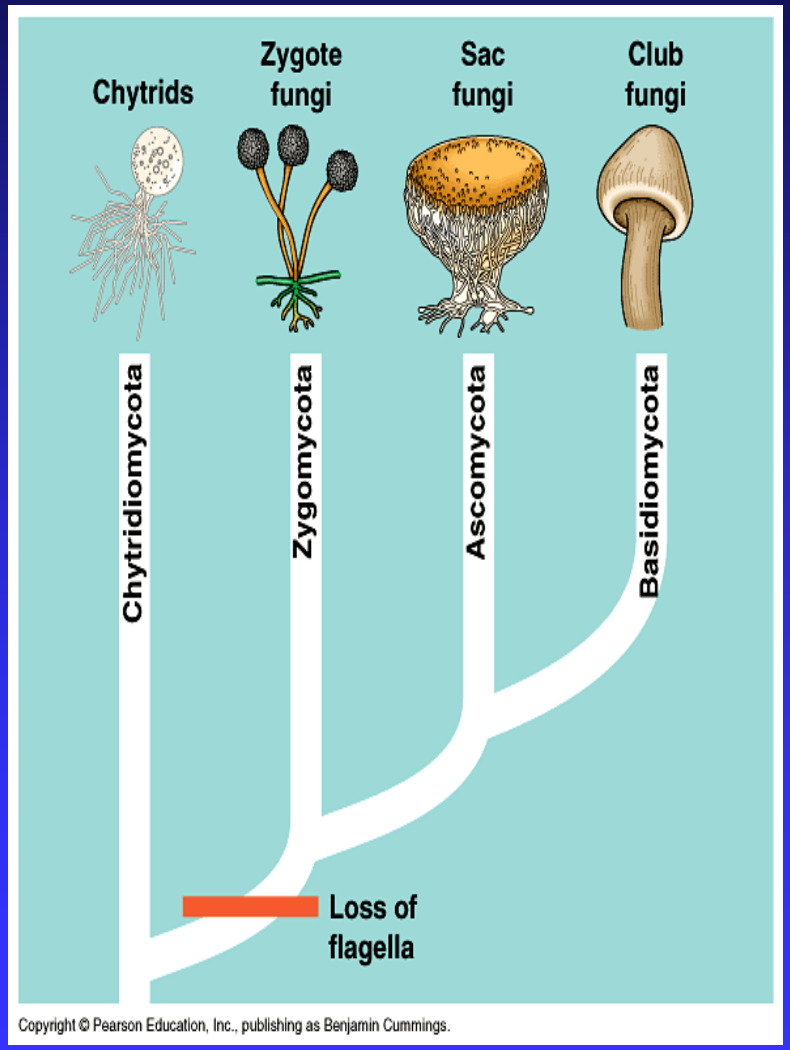
# You want mushrooms on that veggie pizza?

- Cell wall composition?
- Free flowing cytoplasm?
- Autotrophic or heterotrophic?
- Flagella?
- Gametes?
- Males and females?



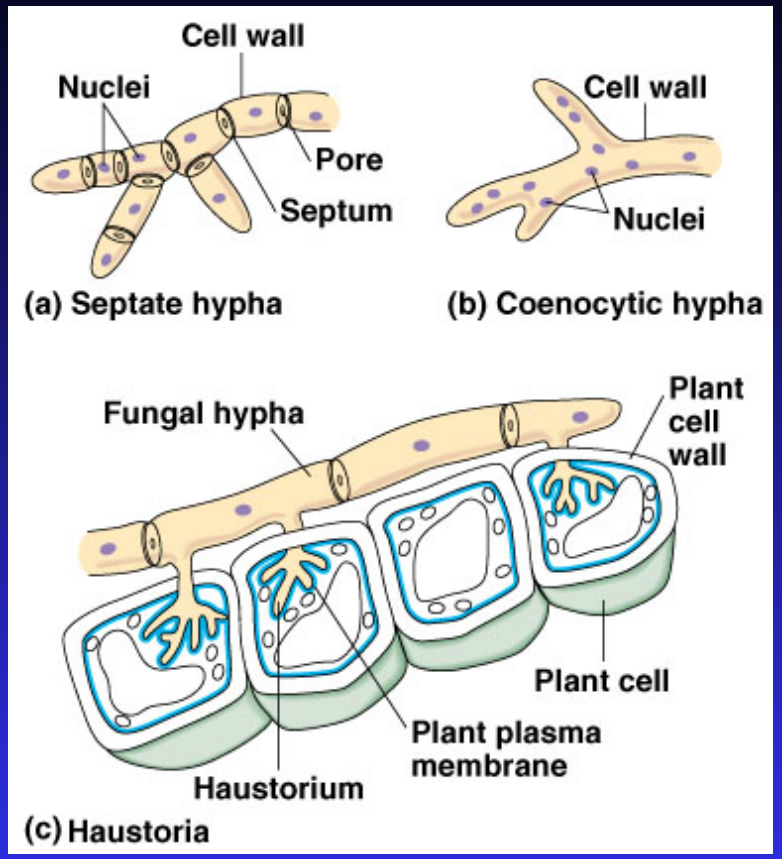
# Evolutionary Origin of K. Fungi

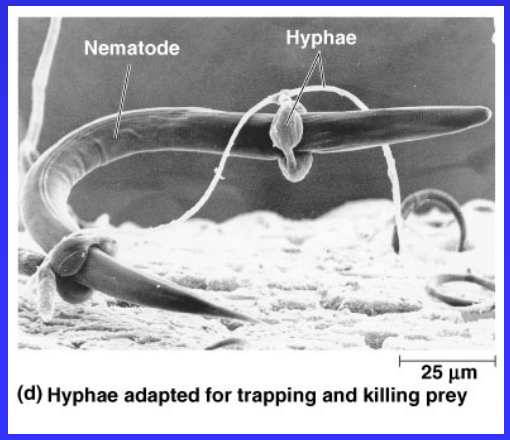
- Heterotrophs with monophyletic origin
- Co-evolution with plants to terrestrial habitats
- Cell wall prohibits phagotropic link with protozoans
- 3 patterns of metabolism:
  - 1/3 mutualists
  - 1/3 decomposers
  - 1/3 parasites



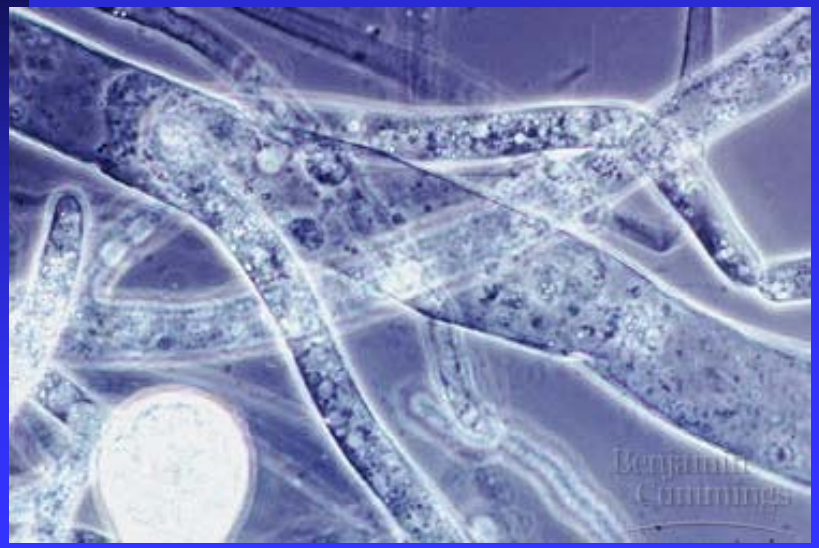
# The Vegetative Structure of Fungi

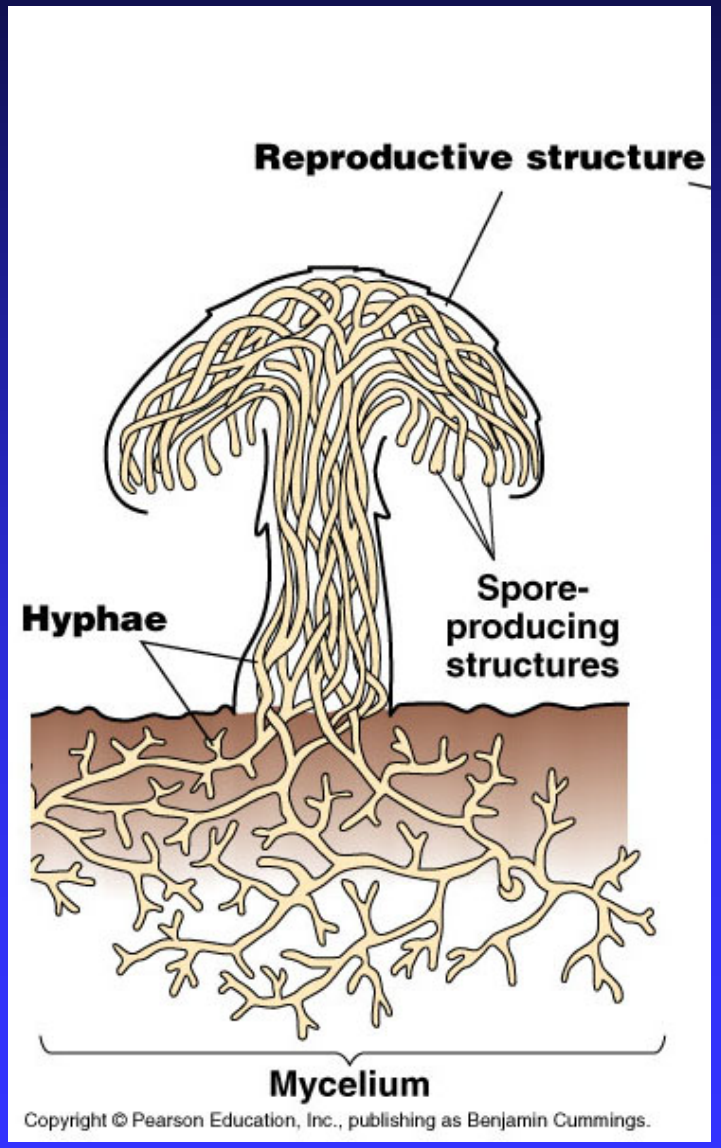
- Hyphae: microscopic filaments
- High SA
- Septate or coenocytic
- Continuous cytoplasm
- Low complexity, no tissues
- High growth potential
- Grow together as mycelia
- Surface growth



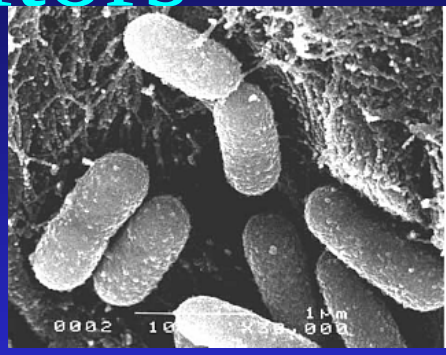
# Septate hyphae (above) and nonseptate hyphae (below)





# Fungi vs. Bacteria: Comparing the adaptations and niches of two competitors

- Fungi prefer lower pH
- Most fungi are aerobic and grow on surfaces
- Both absorptive heterotrophs
- Most fungi are resistant to osmotic pressure
  - High salt or high sugar
- Fungi capable of growth on dry, low moisture environments
- Fungi can digest unique nutrient sources, metabolic specialists
- May be polymorphic: single- and mulitcellular forms
- Role of antibiotics



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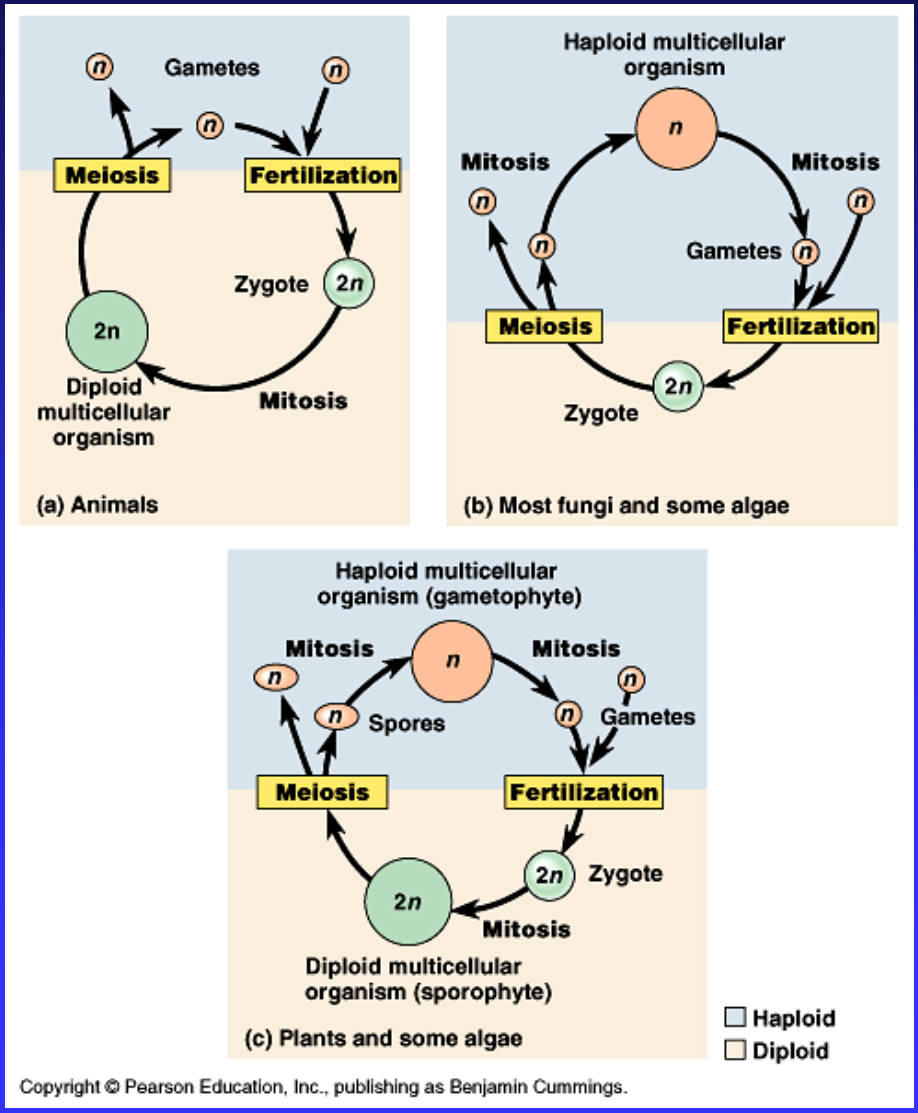
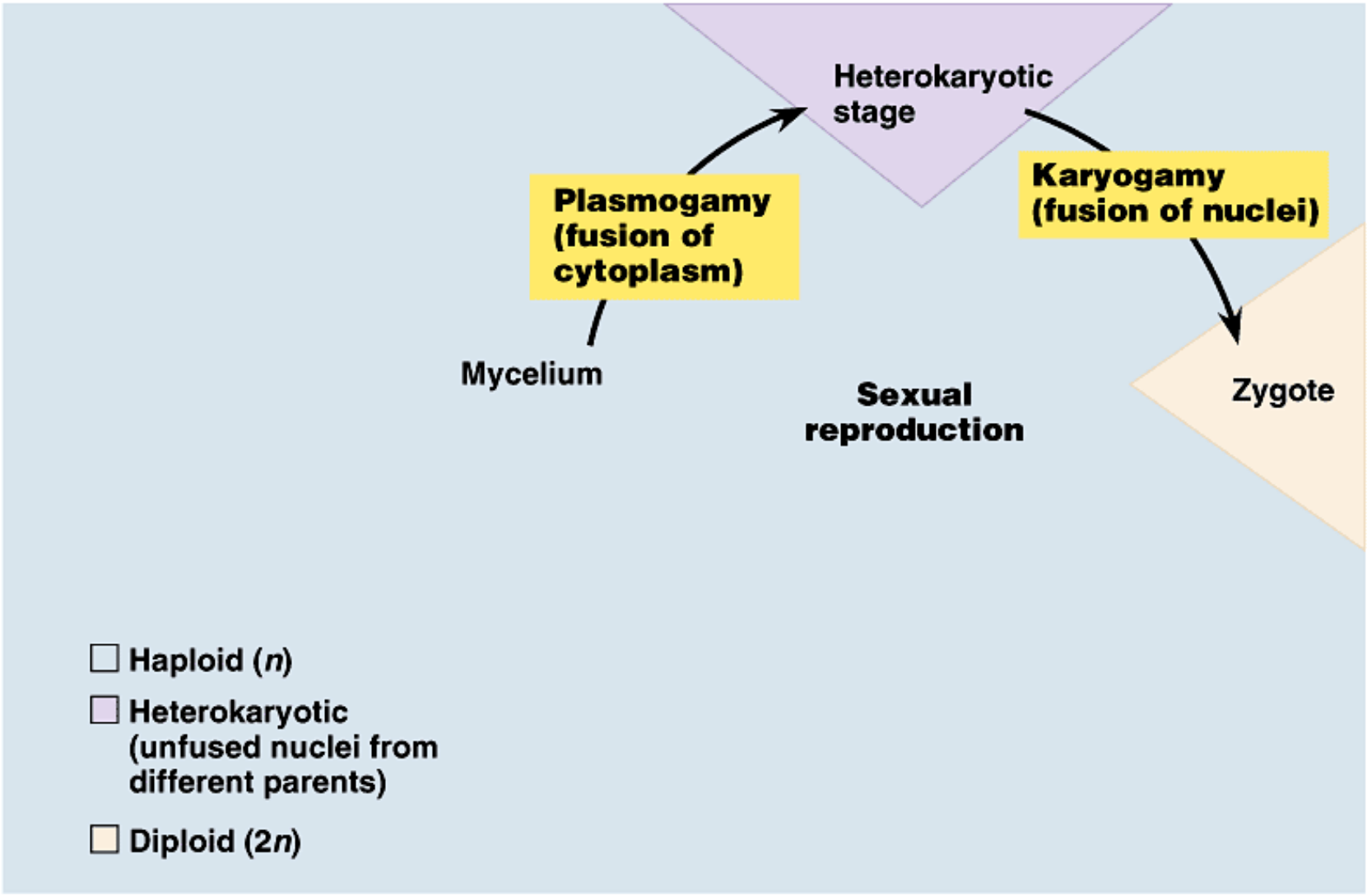



Zygotic Life Cycle

Sporic: The Alternation of Generations

# The generalized fungal life cycle: reproductive hyphae (1n), fusion of mating types to form a heterokaryon(n+n), a transient zygote (2n)

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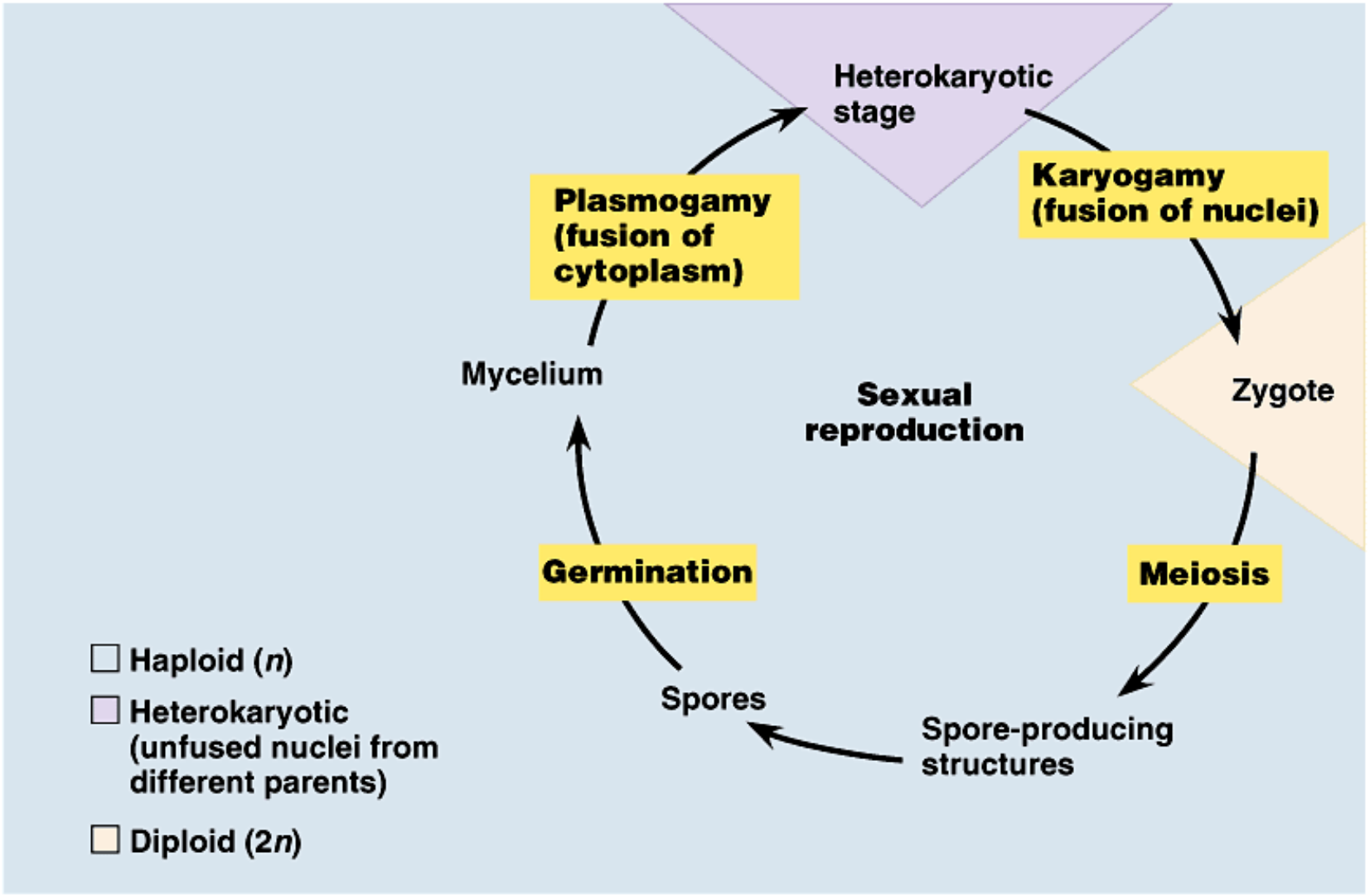


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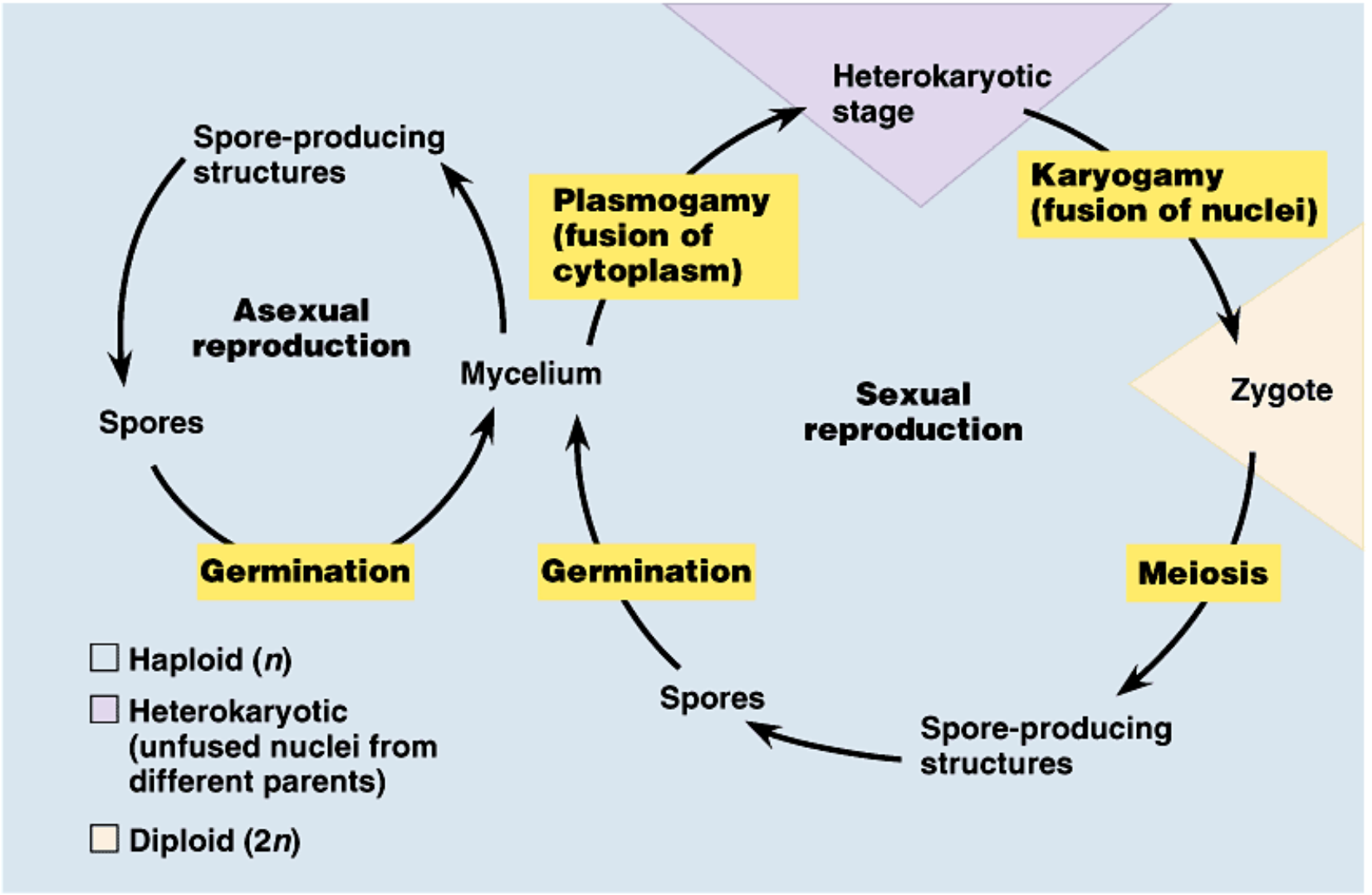


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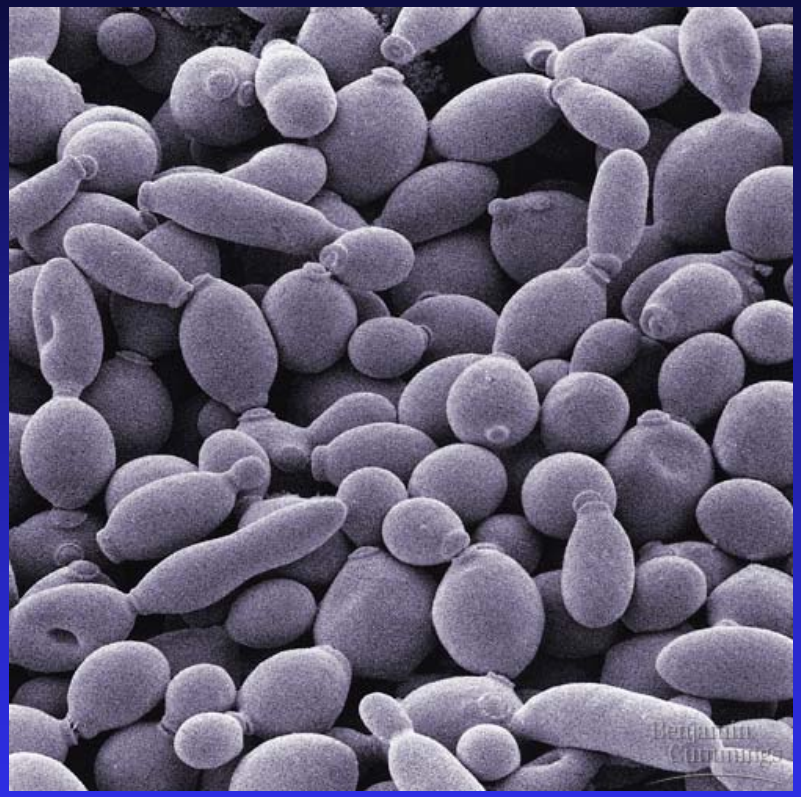
# Mold

- Rapid growth form
  - Hyphae and mycelia
- Asexual reproduction
  - Sporangia or conidia
- Sexual reproduction
  - Fruiting bodies

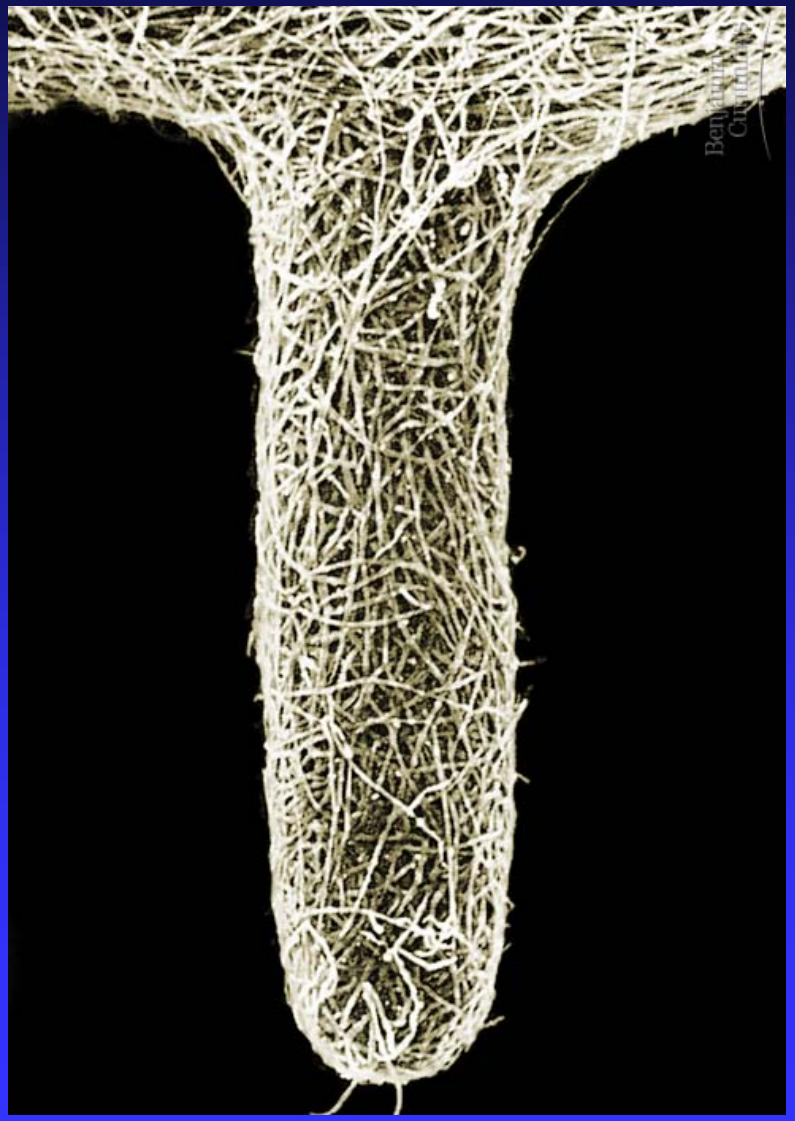
# Yeast



- Single celled stage
- Usually asexual
  - Budding
- Fermentation
- Cloning
- Opportunistic pathogens

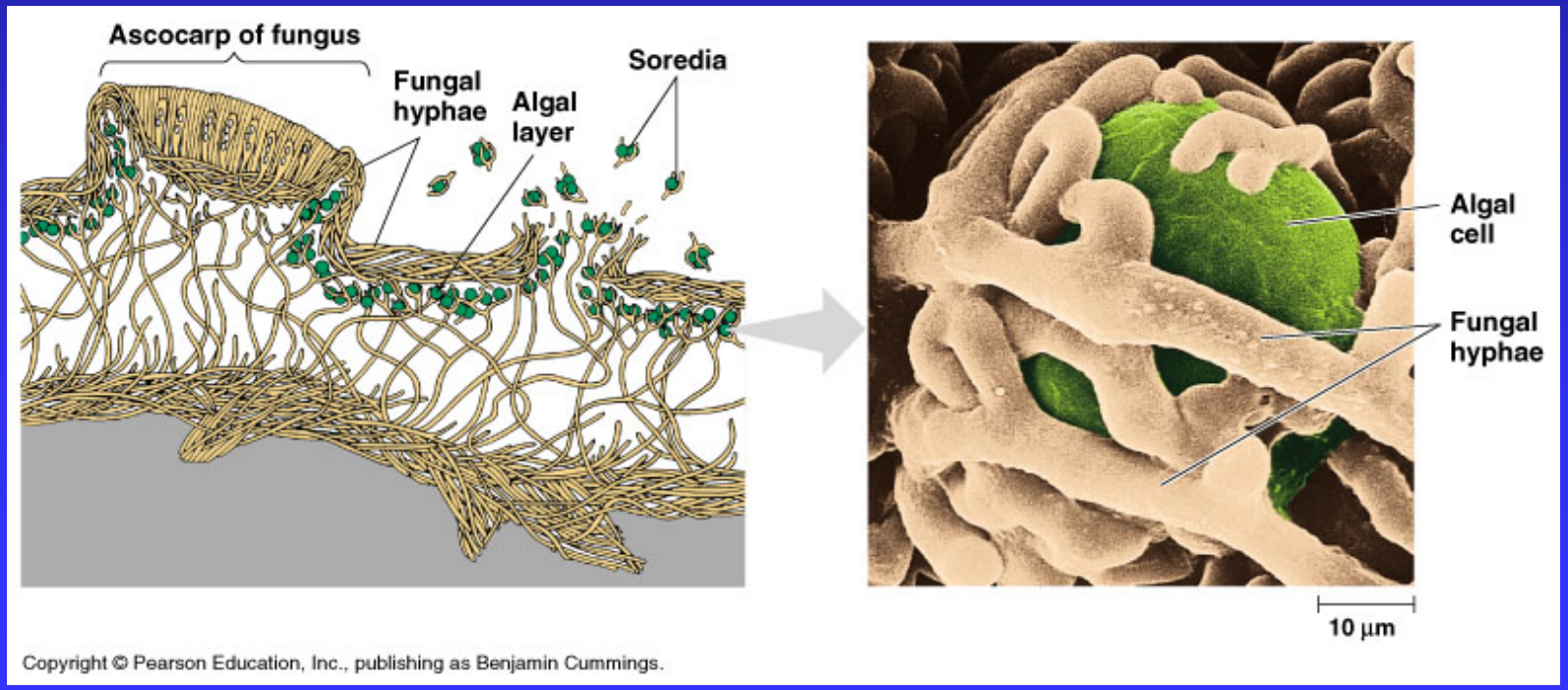
# Mycorrhizae

- Mutualistic association with roots
- Found on >95% of plants
- permanent



# Lichens

- Fungal/algal symbiosis
- Food or fixed $N_2$ exchanged for physical env't

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# Kingdom Animalia- Eukaryotic

- Eukaryotic and multicellular
- Digestive heterotrophs
- Found in all environments
- Capable of movement
- Some microscopic
- Greatest diversity of form






# Each kingdom is further subdivided according to this hierarchy:

- Kingdom
  - Phylum (Division)
    - Class
      - Order
        - Family
        - Genus
        - Species

(e.g., *Escherichia coli*, *Staphylococcus aureus*)