# General Biology: The Origin And Diversification Of Eukaryotes

# AI-Generated Study Guide

(Based on lectures delivered by Dr. Ty C.M. Hoffman)

I. Defining Eukaryotes and Early History
A. Eukaryotic Characteristics
Eukaryotes emerged significantly later than prokaryotes, which dominated life for over a billion years. A defining characteristic of eukaryotes is the ability to undergo **drastic changes in cell shape**, allowing them to engulf cells as large as themselves without a fixed opening. This capacity is dependent on a very **complex cytoskeleton**, a system composed of three major protein components: microtubules, microfilaments, and intermediate filaments.
While prokaryotes are known for their biochemical diversity, eukaryotes are known for their **great variety of forms**, a trait especially characteristic of the **protists**.
B. Timeline of Evolution
The known history of eukaryotes spans at least 1.8 billion years, evidenced by fossilized remains. This history is categorized into three major periods:
1. **The Emergence:** Beginning around **1.8 billion years ago**. Eukaryotes evolved and diversified, existing mainly as **unicellular** organisms.
2. **The Age of Novelties:** Roughly **1.3 billion to 600 million years ago**. This period saw the evolution of specialized functions, including **eukaryotic photosynthesis** and **eukaryotic cellular respiration**, carried out in membrane-bounded organelles. Some initial multicellularity began to appear, but organisms remained small.
3. **The Age of Hugeness:** Roughly **600 million years ago to the present**. This era marks the evolution of large organisms and the emergence of the large, familiar groups: **plants, animals, and fungi**.

II. The Endosymbiotic Theory: Origin of Organelles
A. Origin of the Nucleus and Endomembrane System
The ancestor to all eukaryotes was an **anaerobic archaen** (a prokaryote), supported by molecular evidence showing archaens are more closely related to eukaryotes than to bacteria.
1. **Invagination:** The initial stage involved **infolding (invagination)** of the plasma membrane, which began to elaborate and approach the **nucleoid** (the region containing the DNA).
2. **Nuclear Envelope Formation:** These infoldings fused, surrounding the DNA and forming a **true nucleus**. The **nuclear envelope** is two membranes thick, which is consistent with this invagination and fusion process. The endoplasmic reticulum (ER) and eventually the Golgi

complex are continuous with the outer membrane of the nuclear envelope, suggesting they evolved from this same process. This first cell was an **anaerobic eukaryote**.

B. Primary Endosymbiosis (Mitochondria and Chloroplasts)

**Endosymbiosis** is the condition of one organism living inside another.

1. **Mitochondrial Origin:** The ancestral anaerobic eukaryote engulfed an **aerobic bacterium**. Instead of being digested, the bacterium survived and continued performing cellular respiration inside the host cell, becoming the first mitochondrion.
    ◦ **Evidence:** Mitochondria resemble bacteria in shape and possess two membranes, where the inner membrane is molecularly similar to a bacterial membrane. They have their own **circular DNA**, their own ribosomes (similar to bacterial ribosomes), and reproduce via **binary fission** (splitting into two).
2. **Chloroplast Origin:** Later, a eukaryotic cell (which already possessed mitochondria) engulfed a **photosynthetic bacterium**, forming the first chloroplast.
3. **Secondary Endosymbiosis:** This process explains plastids that have **three or more membranes**. It occurs when a eukaryotic cell that already contains a primary endosymbiont is subsequently engulfed by an even larger cell (serial engulfing).

III. Evolution of Multicellularity

The shift to complex life forms was gradual.

• **Colonial Lifestyle:** The first step involved cells benefiting from being connected, but all performing the same basic functions.
• **True Multicellularity:** This is defined by having **different types of cells performing specialized functions** for the benefit of the entire collection of cells (the organism).
• **Animals and Coanoflagellates:** The unicellular group **coanoflagellates** is the sister taxon to animals. A single coanoflagellate is morphologically almost indistinguishable from a collar cell (choanocyte) found in basal animals like sponges.
• **Genetic Adhesion:** The evolution of complex multicellularity in animals is linked to the acquisition of the **CCD domain** in certain proteins, which facilitates **cell-to-cell adhesion**, allowing cells to stick together. Coanoflagellates lack this domain.

IV. Major Eukaryotic Clades

The Domain Eukarya is often depicted with four major clades springing from a simultaneous node (a **polytomy**), reflecting uncertainty in their exact phylogenetic relationships.

A. Non-Monophyletic Groups

• **Protists:** A **paraphyletic taxon** defined as any eukaryote that is **not an animal, a plant, or a fungus**.
• **Algae:** A descriptive term for **photosynthetic protists**. Algae are found distributed across all four major clades.

B. The Four Major Clades

1. **Excavata:** Named because many members have an excavated surface area on the cell. This group includes many **unicellular parasites** (e.g., those causing sleeping sickness or sexually transmitted diseases) and photosynthetic species (e.g., Euglena).
2. **SAR Clade:** An enormous group acronymed for three constituent clades:

◦ **Stramenopiles (S):** Includes **Diatoms** and **Brown Algae**. Diatoms are crucial oceanic producers (algae) encased in elaborate microscopic **tests** made of silicon dioxide. Brown Algae are often the largest algae, sometimes reaching tree size, though their structures (holdfasts, stipes, blades) are superficial resemblances to plants.
◦ **Alveolates (A):** Named for small, bag-like structures called alveoli. This group includes **Dinoflagellates** (important photosynthetic organisms whose population blooms can cause red tides) and **Ciliates** (e.g., Paramecium, which use cilia for movement and feeding).
◦ **Rhizarians (R):** (Not detailed in the sources).
◦ *Note:* Some members of this clade have photosynthetic structures called **chromatophors** that perform the function of chloroplasts but are morphologically distinct, potentially suggesting an independent endosymbiotic event.

3. **Archaeplastida:** The clade of photosynthetic eukaryotes, including **Red Algae, Green Algae, and Plants**.
◦ **Red Algae:** Their pigments absorb blue light efficiently, enabling them to live in deeper waters where blue light penetrates farthest.
◦ **Green Algae:** A paraphyletic grouping that excludes land plants. The **Charophytes** (a type of green algae) are the sister taxon to land plants.

4. **Unikonta:** This clade contains **Animals** and **Fungi** (which are more closely related to each other than to plants), as well as protest groups like the **Amoebozoans**.
◦ **Amoeba:** A loose, paraphyletic term for any cell that moves via **pseudapodal locomotion** (using temporary extensions or "false feet").
◦ **Slime Molds:** These are unique organisms that alternate between lifestyles. They live as **haploid (N) solitary amoebas** when resources are available. When conditions worsen, these individuals aggregate into a large, cohesive, **multicellular mass** that moves across the substrate and eventually forms fruiting bodies that release haploid spores.

V. Ecological Roles of Protists

Eukaryotes, particularly protists, are vital components of ecosystems, often engaging in symbiotic relationships.

A. Producers and Global Ecology

**Autotrophs** (Producers) form the essential base of all ecosystems. In marine environments, key producers include cyanobacteria (prokaryotic) and **unicellular algae (protists)**, which constitute much of the plankton. Data tracking oceanic chlorophyll levels indicate a **widespread global decrease** in these producers.

B. Symbiotic Relationships

1. **Mutualism (Both Benefit):** Termites eat wood, which is primarily **cellulose** (a polymer of glucose). Since termites, like all animals, lack the necessary enzymes to digest cellulose, they rely on an **endosymbiotic protist** living in their digestive tract. The protist digests the cellulose for itself, freeing up glucose that the termite can also utilize.
2. **Parasitism (One Benefits, One Harmed):** Many protists are parasites. For example, the parasite that causes malaria has a highly complex life cycle requiring **two specific hosts**: a kind of mosquito and a human. The parasite spends its entire life cycle in either host, infecting and destroying liver cells and red blood cells in humans.