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Domain and Kingdom Concept

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Biological Classification Hierarchy

Rank	Definition	Example
Domain	Highest taxonomic rank; primary divisions of life	Eukarya
Kingdom	Major groups within domains; organisms share fundamental characteristics	Animalia
Phylum	Division within kingdom	Chordata
Class	Group within phylum	Mammalia
Order	Subdivision of class	Primates
Family	Group within order	Hominidae
Genus	Closely related species	*Homo*
Species	Fundamental unit of classification	*Homo sapiens*

Domains represent the highest and most fundamental division of all cellular life based on molecular evidence.

Evolution of Classification Systems

Timeline:

- **1735:** Carl Linnaeus introduced the rank-based system of nomenclature, establishing Kingdom as the highest rank.
- **1969:** Robert Whittaker proposed Five-Kingdom Classification (Monera, Protista, Fungi, Plantae, Animalia)
- **1977-1990:** Carl Woese revolutionised taxonomy using 16S ribosomal RNA (rRNA) analysis
- **1990:** Three-Domain System introduced (Archaea, Bacteria, Eukarya)
- **1993:** Cavelier-Smith separated Chromista from Protista & Plantae due to the presence of their Chlorophyll in the Endoplasmic Reticulum

Why the Change?

- Molecular evidence (16S rRNA gene sequencing) revealed that prokaryotes were NOT a single group
- Archaebacteria and Eubacteria had fundamentally different molecular signatures
- Archaea found to be more closely related to Eukarya than to Bacteria

Why 16S rRNA?

The Molecular Revolution in Taxonomy

The Molecular Marker: 16S Ribosomal RNA (rRNA)

- **Why use rRNA?**
- Present in ALL organisms (universally distributed)
- Functionally similar across life forms
- Evolves slowly (good for ancient divergences)
- Sequences can be compared across organisms
- Acts as a "molecular clock" for evolution

Key Findings:

- Prokaryotes are NOT monophyletic (don't share a single common ancestor)
- Two distinct prokaryotic lineages identified
- Archaea are distinct from Bacteria
- Archaea share features with both Bacteria and Eukarya

Domain: The Highest Taxonomic Rank

Feature	Archaea	Bacteria	Eukarya
Cell Type	Prokaryotic	Prokaryotic	Eukaryotic
Nucleus	Absent	Absent	Present
Membrane-Bound Organelles	Absent	Absent	Present
Cell Wall Composition	Pseudopeptidoglycan or protein/polysaccharide	Peptidoglycan	Cellulose (plants) or absent (animals)
Membrane Lipids	Ether linkages, branched chains	Ester linkages, straight chains	Ester linkages, straight chains
Ribosomal Structure	70S	70S	80S (80S in cytoplasm, 70S in mitochondria/chloroplasts)
Antibiotic Sensitivity	Resistant	Sensitive	Variable
DNA Structure	Circular	Circular	Linear
Evolutionary Age	Oldest	Ancient	Most recent

Archaea - The Ancient Domain

Characteristics:

- **Cell Type:** Prokaryotic
- **Habitat:** Extreme environments (extremophiles)
- **Cell Wall:** Lacks peptidoglycan; contains pseudopeptidoglycan, polysaccharides, or pure protein
- **Membrane Lipids:** Unique ether-linked, branched-chain lipids
- **Metabolism:** Autotrophic or heterotrophic

Evolutionary Significance:

- Believed to represent the earliest form of life on Earth
- May provide clues to life on other planets

- **Major Groups of Archaea:**
- **Methanogens**
  - Produce methane (CH_4) from organic matter
  - Habitat: Anaerobic environments (marshes, digestive systems, ocean sediments)
  - Example: *Methanobacterium*
- **Halophiles (Salt-Lovers)**
  - Thrive in hypersaline environments
  - Habitat: Dead Sea, Great Salt Lake, salt marshes
  - Example: *Haloferax*
- **Thermoacidophiles**
  - Survive extreme heat and acidity
  - Habitat: Hot springs (75-80°C), volcanic vents
  - Example: *Sulfolobus*
- **Psychrophiles**
  - Cold-loving archaea
  - Habitat: Antarctic sea ice, deep ocean vents
  - Example: *Methanogenium frigidum*

Bacteria - Prokaryotes with Peptidoglycan

- **Characteristics:**
- **Cell Type:** Prokaryotic
- **Cell Wall:** Contains peptidoglycan (unique to Bacteria)
- **Membrane Lipids:** Ester-linked, straight-chain lipids
- **DNA:** Circular chromosome; plasmids may be present
- **Reproduction:** Binary fission (asexual)
- **Habitat:** Ubiquitous - everywhere on Earth

Ecological and Medical Importance:

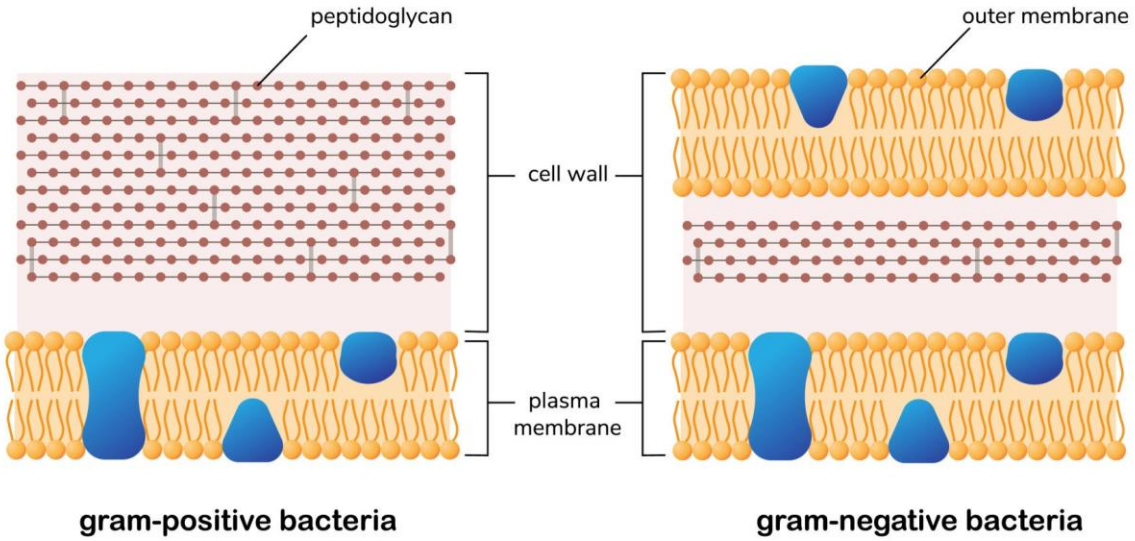
- Nutrient cycling (nitrogen fixation, decomposition)
- Photosynthesis
- Biotechnology (insulin, vaccines, antibiotics)
- Pathogenic species (disease-causing)

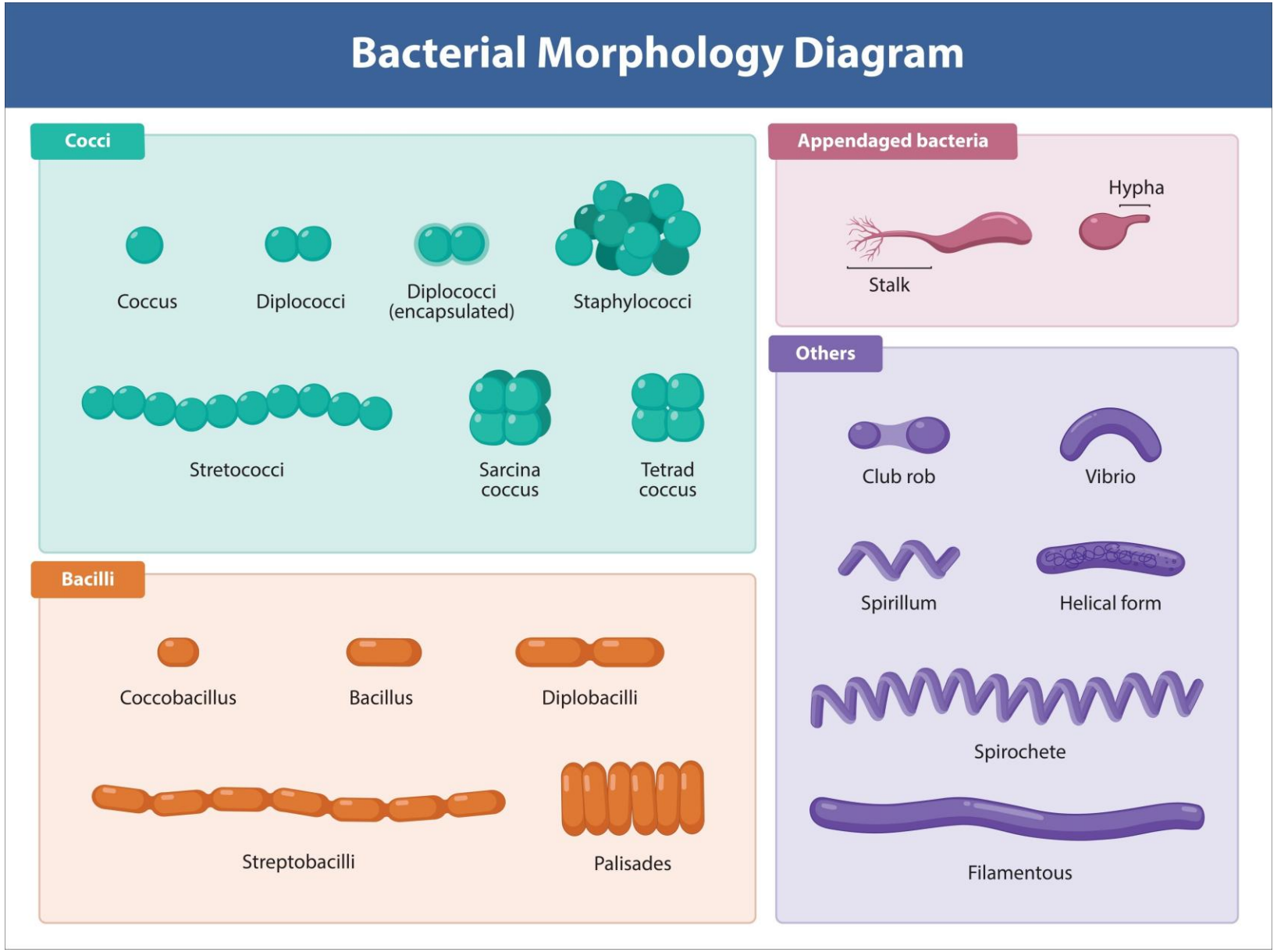
Cyanobacteria (Blue-Green Algae):

- Photosynthetic bacteria
- Contain chlorophyll and thylakoids
- Oxygen producers (responsible for Earth's atmospheric oxygen)

Classification according to gram stain

Feature	Gram-Positive Bacteria	Gram-Negative Bacteria
Cell Wall Thickness	Thick peptidoglycan layer (20-80 nm)	Thin peptidoglycan layer (2-7 nm)
Outer Membrane	Absent	Present (contains lipopolysaccharides - LPS)
Membrane Structure	Single cytoplasmic membrane	Double membrane (outer + cytoplasmic membrane)
Teichoic Acids	Present (in peptidoglycan layer)	Absent
Gram Stain Reaction	Retain crystal violet dye → appear purple	Lose crystal violet after decolorization; take up counterstain (safranin) → appear pink/red
Sensitivity to Antibiotics	More susceptible (due to lack of outer membrane)	Generally more resistant (outer membrane barrier)
Resistance to Lysozyme	More prone to cell wall disruption	Less prone
Examples	*Streptococcus*, *Bacillus*, *Staphylococcus*	*Escherichia coli*, *Salmonella*, *Pseudomonas*



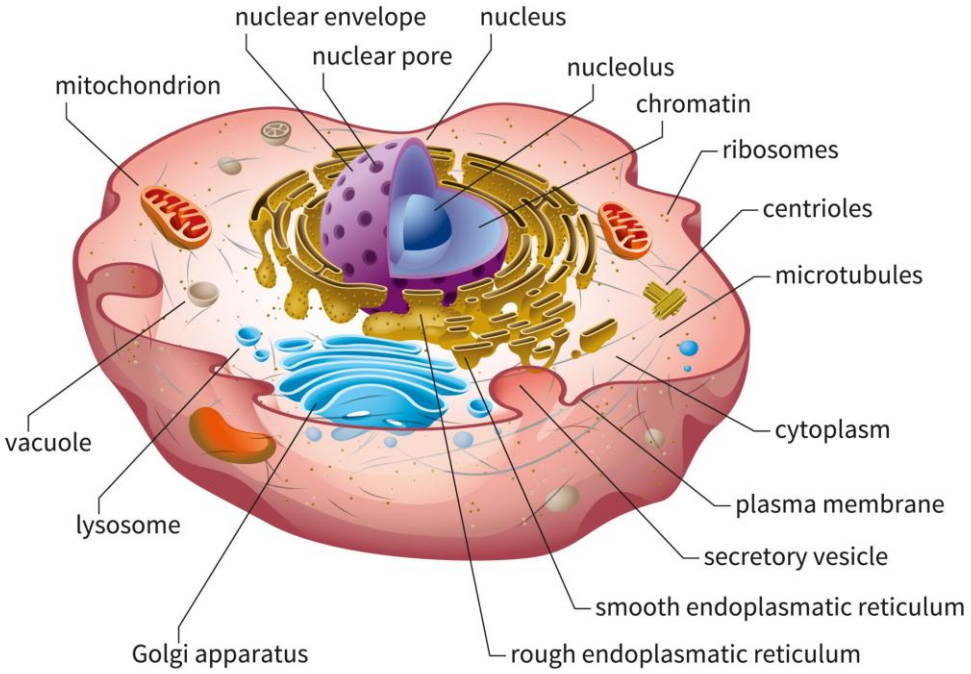


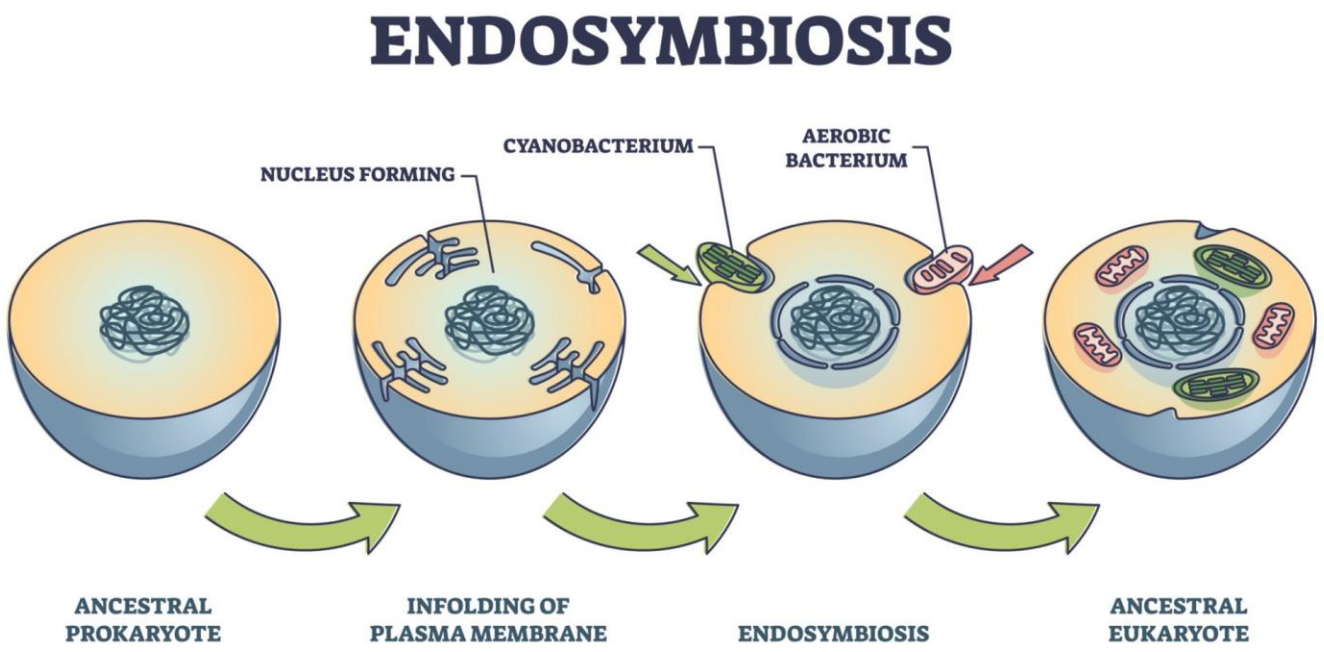
Bacterial classification by morphology

Shape	Description	Examples
Cocci	Spherical cells	*Streptococcus*, *Staphylococcus*
Bacilli	Rod-shaped cells	*Bacillus*, *Escherichia coli*
Spirilla	Spiral or helical cells	*Spirillum*, *Treponema*
Vibrio	Comma-shaped cells	*Vibrio cholerae*

Eukarya - The Eukaryotic Domain

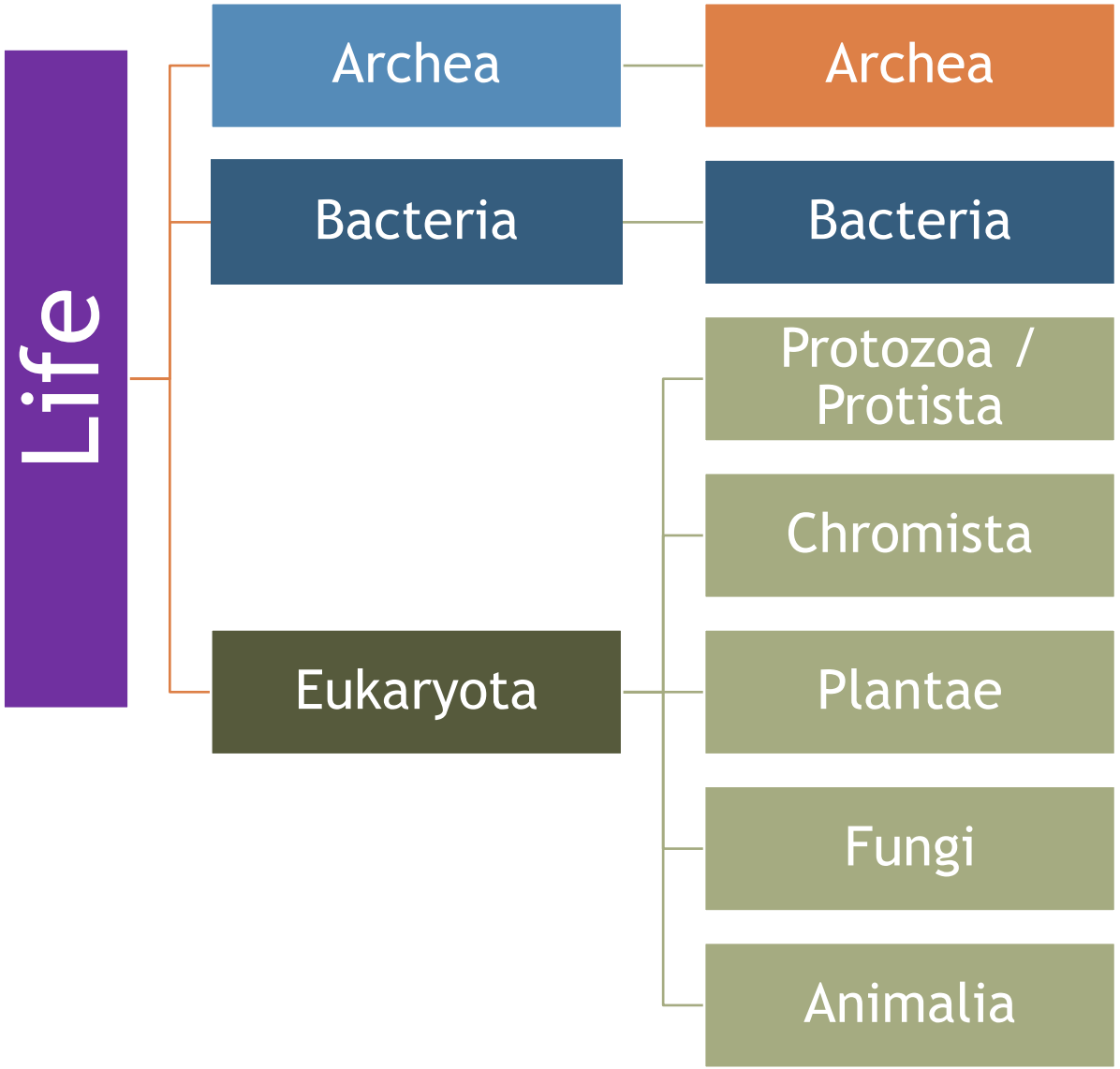
- **Defining Characteristics:**
- **Cell Type:** Eukaryotic
- **Nucleus:** Membrane-bound nucleus containing DNA
- **Organelles:** Membrane-bound organelles (mitochondria, ER, Golgi, etc.)
- **DNA:** Linear chromosomes within nucleus
- **Ribosomal Structure:** 80S ribosomes in cytoplasm
- **Reproduction:** Sexual and/or asexual
- **Size:** Generally larger and more complex than prokaryotes





Evolutionary Origin

Mitochondria and chloroplasts originated from free-living prokaryotes



3 Domains 7 Kingdoms

Summary of the 7 Kingdoms Shown

1. **Archaea:** (From Domain Archaea)
2. **Bacteria:** (From Domain Bacteria)
3. **Protozoa / Protista:** (From Domain Eukaryota) - Mostly unicellular, heterotrophic "animal-like" organisms (e.g., amoebas, ciliates).
4. **Chromista:** (From Domain Eukaryota) - Mostly photosynthetic organisms, including **diatoms**, **brown algae (kelp)**, and **water moulds**.
5. **Plantae:** (From Domain Eukaryota) - Multicellular, autotrophic (photosynthetic), cellulose cell walls.
6. **Fungi:** (From Domain Eukaryota) - Heterotrophic (absorptive), chitin cell walls.
7. **Animalia:** (From Domain Eukaryota) - Multicellular, heterotrophic (ingestive), no cell walls.

3 Domains 7 Kingdoms

Characteristic	Bacteria	Archaea	Protozoa	Chromista	Fungi	Plantae	Animalia
Domain	Bacteria	Archaea	Eukarya	Eukarya	Eukarya	Eukarya	Eukarya
Cell Type	Prokaryotic	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Nucleus	Absent	Absent	Present	Present	Present	Present	Present
Cellularity	Unicellular	Unicellular	Mostly Unicellular	Unicellular & Multicellular	Mostly Multicellular	Multicellular	Multicellular
Cell Wall	Peptidoglycan	Pseudopeptidoglycan	Absent (Pellicle)	Varied (Silica, Alginates)	Chitin	Cellulose	Absent
Nutrition	Auto/Heterotrophic	Auto/Heterotrophic	Hetero (Ingestive)	Auto (Photosynthetic)	Hetero (Absorptive)	Autotrophic	Hetero (Ingestive)
Movement	Flagella	Flagella	Cilia, Flagella, Pseudopodia	Flagella (gametes)	Stationary	Stationary	Active locomotion
Examples	*E. coli*, *Streptococcus*	*Methanobacterium*, *Halophiles*	*Amoeba*, *Paramecium*, *Giardia*	Diatoms, Kelp, Water molds	Mushrooms, Yeasts, Molds	Mosses, Ferns, Flowers	Insects, Fish, Mammals

Kingdom Protozoa - The "Animal-like" Protists

Key Characteristics:

- **Cellularity:** Predominantly **unicellular**.
- **Cell Wall: Absent**. Many have a flexible outer layer called a "pellicle."
- **Nutrition: Heterotrophic** (ingestive). They are "hunters" that consume bacteria, algae, or other protozoans.
- **Movement:** Motile, classified by mode of locomotion:
  - **Amoeboids (Sarcodina):** Use **pseudopodia** (false feet). Ex: *Amoeba*.
  - **Ciliates (Ciliophora):** Use **cilia**. Ex: *Paramecium*.
  - **Flagellates (Mastigophora):** Use **flagella**. Ex: *Giardia*, *Trypanosoma*.
  - **Apicomplexa (Sporozoa):** Parasitic, non-motile in adult forms. Ex: *Plasmodium* (causes malaria).

Ecological & Zoological Importance:

- Form the base of many aquatic food webs (zooplankton).
- Many are significant **parasites** of animals and humans (e.g., malaria, sleeping sickness, dysentery).
- Important for nutrient cycling in soil and water.

Kingdom Chromista - The "Algal" Eukaryotes

Key Characteristics:

- **Cellularity:** Both **unicellular** and **multicellular** forms.
- **Cell Wall:** Present, but composition varies (e.g., silica in diatoms, alginates in brown algae).
- **Nutrition:** Predominantly **Autotrophic (photosynthetic)**.
- **Key Trait:** Their chloroplasts were acquired through **secondary endosymbiosis** (engulfing another eukaryote, a red alga), distinguishing them from Plantae.

Major Groups:

- **Diatoms (Bacillariophyta):** Unicellular algae with intricate silica shells.
- **Brown Algae (Phaeophyta):** Multicellular, includes giant kelp.
- **Water Molds (Oomycota):** Fungus-like in appearance, but are heterotrophic Chromists (formerly misclassified as fungi). Cause diseases like potato blight.

Ecological & Economic Importance:

- **Massive primary producers**; diatoms are responsible for a large percentage of Earth's oxygen.
- Form critical habitats (e.g., kelp forests).
- Diatomaceous earth is used for filtration and pest control.

Kingdom Fungi - The Absorptive Heterotrophs

Key Characteristics:

- **Cellularity:** Mostly **multicellular** (e.g., mushrooms, molds). Yeasts are a major **unicellular** group.
- **Cell Wall:** Made of **CHITIN** (the same substance in insect exoskeletons).
- **Nutrition: Heterotrophic (absorptive).** They secrete digestive enzymes into their environment and then absorb the nutrients.
- **Structure:** The main body is a network of filaments called **hyphae**, which all together form a **mycelium**.
- **Reproduction:** Via spores (both sexually and asexually).

Ecological & Economic Importance:

- **Critical decomposers (saprophytes)**, recycling nutrients back into the ecosystem.
- **Food and Drink:** Mushrooms, bread (yeast), beer/wine fermentation.
- **Medicine:** Source of antibiotics (e.g., Penicillin).
- **Pathogens:** Cause diseases in plants and animals (e.g., ringworm, *Candida*).
- **Symbiosis:** Form **mycorrhizae** (with plant roots) and **lichens** (with algae/cyanobacteria).

Kingdom Plantae - The Multicellular Autotrophs

Key Characteristics:

- **Cellularity: Multicellular**.
- **Cell Wall:** Made of **CELLULOSE**.
- **Nutrition: Autotrophic (photosynthetic).** Use chloroplasts to convert light energy into chemical energy.
- **Energy Storage:** Store energy as **starch**.
- **Structure:** Have differentiated tissues (e.g., roots, stems, leaves) in most groups.
- **Life Cycle:** Exhibit "Alternation of Generations" (switching between haploid and diploid stages).

Major Groups:

- **Bryophytes:** Non-vascular (e.g., Mosses).
- **Pteridophytes:** Vascular, reproduce with spores (e.g., Ferns).
- **Gymnosperms:** Vascular, "naked" seeds (e.g., Conifers).
- **Angiosperms:** Vascular, seeds enclosed in fruit (Flowering plants).

Ecological & Economic Importance:

- **Primary producers**; form the base of terrestrial food webs.
- Produce most of the atmosphere's **oxygen**.
- Source of food, fuel (wood, biofuels), fiber (cotton), and medicine.

Kingdom Animalia - The Ingestive Heterotrophs

Key Characteristics:

- **Cellularity: Multicellular**.
- **Cell Wall: ABSENT**. Cells are held together by proteins like collagen.
- **Nutrition: Heterotrophic (ingestive)**. They must eat other organisms to get energy.
- **Movement: Motile** (can move) at some point in their life cycle.
- **Structure:** Possess specialized tissues (e.g., **nervous tissue**, **muscle tissue**).
- **Reproduction:** Primarily sexual reproduction.

Major Phyla

- **Porifera** (Sponges)
- **Cnidaria** (Jellyfish, Corals)
- **Platyhelminthes** (Flatworms)
- **Nematoda** (Roundworms)
- **Mollusca** (Snails, Clams, Octopus)
- **Annelida** (Segmented worms)
- **Arthropoda** (Insects, Spiders, Crustaceans) - the most diverse phylum.
- **Echinodermata** (Starfish, Sea Urchins)
- **Chordata** (Includes all Vertebrates: Fish, Amphibians, Reptiles, Birds, Mammals)

Essential Points to Remember

Domain Level

- Three primary domains: **Archaea**, **Bacteria**, **Eukarya**.
- Based on molecular evidence (**16S rRNA**).
- Distinguishes prokaryotes (Archaea, Bacteria) from eukaryotes (Eukarya).

Kingdom Level (7-Kingdom System)

- **Archaebacteria:** (Domain Archaea) - Prokaryotic extremophiles.
- **Eubacteria:** (Domain Bacteria) - Prokaryotic "true" bacteria with **peptidoglycan**.
- **Protozoa:** (Domain Eukarya) - Unicellular, ingestive heterotrophs ("animal-like").
- **Chromista:** (Domain Eukarya) - Unicellular & multicellular, photosynthetic ("algal-like").
- **Fungi:** (Domain Eukarya) - Absorptive heterotrophs, **chitin** walls.
- **Plantae:** (Domain Eukarya) - Multicellular autotrophs, **cellulose** walls.
- **Animalia:** (Domain Eukarya) - Multicellular ingestive heterotrophs, **no cell walls**.

Essential Points to Remember

Fundamental Distinctions

- **Prokaryotic vs. Eukaryotic:** Presence/absence of a nucleus.
- **Autotrophic vs. Heterotrophic:** How they obtain energy (make vs. consume).
- **Cell Wall Composition:** Peptidoglycan, Chitin, Cellulose, or absent.

Classification is Dynamic

- It is not static. It evolves as new molecular data (genomics, proteomics) refines our understanding of evolutionary relationships.

Common misconceptions

Misconception	Reality
Archaea are "primitive bacteria"	Archaea are a distinct domain; as complex as bacteria and genetically closer to Eukarya in some ways.
All prokaryotes are bacteria	Archaea are also prokaryotes but are fundamentally different.
Fungi are plants	Fungi are heterotrophic, have chitin walls, and are evolutionarily closer to animals than plants.
Protists are all simple and microscopic	Some protists are large (e.g., giant kelp) and complex. "Protista" is a grouping of convenience, not a true evolutionary clade.
Animals are the "most evolved"	All living organisms are equally evolved to fit their specific environments and ecological niches.
Viruses belong in a kingdom	Viruses are acellular (not cells) and are not classified within the Three-Domain system.

Quiz

- What molecular marker did Carl Woese use to establish the 3 Domains?
- Name one key difference between Archaea and Bacteria.
- Why are fungi not classified as plants?
- What is the main feature of Domain Eukarya?

Tell the Domain and Kingdom

Tell the Domain and Kingdom

Tell the Domain and Kingdom

Tell the Domain and Kingdom

Unanswered Questions!

Unanswered Questions:

- What was the nature of the Last Universal Common Ancestor (LUCA)?
- How many undiscovered species exist, especially in microbial domains?

Key taxonomic databases

Catalogue of Life (CoL)

- **Link:** https://www.catalogueoflife.org
- The most comprehensive and authoritative checklist of all known species. It aims to be a single, consensus classification of all life. It's the best place to check for currently accepted scientific names and their synonyms.

NCBI Taxonomy

- **Link:** https://www.ncbi.nlm.nih.gov/taxonomy
- The definitive database for genetic and molecular data. It provides the standard classification used by researchers for genetic sequencing (GenBank). If you're looking up a species' genetic information or its formal classification in scientific literature, this is the primary source.

GBIF (Global Biodiversity Information Facility)

- **Link:** https://www.gbif.org
- The top resource for *where* species are located. It aggregates occurrence data (specimen records and observations) from museums, research institutions, and citizen scientists worldwide. It's essential for biogeography and viewing species distribution maps.

ITIS (Integrated Taxonomic Information System)

- **Link:** https://www.itis.gov
- A highly authoritative taxonomic database, used as a standard by many North American government agencies but with broad global coverage. It provides a reliable taxonomic backbone for linking various biological datasets.

ZooBank

- **Link:** https://zoobank.org
- The official registry of the International Commission on Zoological Nomenclature (ICZN). This is where new species names, nomenclatural acts (like changing a name), and their original publications are officially registered.