EARLY EARTH & PROKARYOTES

- 4.5 billion years ago – Earth was formed.
- 3.5 billion years ago – Earliest life found in the fossil record emerged.
- Prokaryotes were the earliest organisms found in sedimentary rocks: stromatolites. (Layers formed due to the sticky capsule/slime layer of the prokaryotes)
- 2.5 billion years ago – First photosynthetic prokaryotes emerged and produced oxygen (their waste product) → aerobic atmosphere.
- Two types of prokaryotes that diverged early in the history of life: (1) Archaea (2) Bacteria
- 1.7 billion years ago – First eukaryotes emerged by the fusion of prokaryotes.
- Life on Earth has been confined to aquatic environments for nearly 90% of existence.
- First terrestrial organisms were plants in a mutualistic relationship with fungi (in the roots).
- Life evolved from inorganic substances that became ordered into molecules of life, which can be able to replicate and perform metabolism.
- 1920’s – some scientists believed that the primitive Earth favored reactions that formed oxygen compounds from inorganic sources. (Impossible today due to high levels of oxygen in the atmosphere and its affinity for electrons attacks chemical bonds).
- Organic compound production requires much energy provided by lightning and intense ultraviolet radiation since the early Earth lacked ozone.
- Miller & Urey Experiment:
  - Ingredients of the “Primordial Soup”: CH₄, NH₃, H₂, and H₂O.
  - Sparks were discharged to mimic lightning.
  - The solution went from clear to murky brown color—organic monomers formed.
- Polymerization occurs in vitro when monomers are dripped onto hot sand, clay or hot rocks. This process vaporizes water and concentrates monomers that form polymers/proteinoids: polypeptides made by abiotic means.
- Clay is important in polymerization because the monomers could bind to charged sites on clay particles. Functioned as lattice that brought monomers together, and metal atoms (Zn & Fe) functioned as catalysts joining them into polymers.
- Alternative to clay = Fe pyrite (fool’s gold)
- Protobionts: droplets of macromolecules that maintain an internal environment separate from their surroundings. Succeeded by living cells. Exhibit some properties of life, such as metabolism and stimulus reaction.
- RNA – first genetic material.
- The first proteins are believed to have been made from RNA alone. These first proteins would have been enzymes that aided in replication of RNA.
- One trend then led to DNA becoming the hereditary material = stable molecule.
- Pansperma: the idea that meteorites hitting the early Earth brought organic compounds with them.
- Life may have begun in shallow water (popular) or moist sediments. Others think that life began in deep sea vents and early life lived off of H₂S.
- The Five Kingdom classification system is outdated and has been replaced by the Three Domain system. It assigns more significance to the ancient evolutionary split between bacteria and archaea by using the superkingdom/domain.

PROKARYOTES

- Characteristics of Prokaryotes:
  - Prokaryotes are ubiquitous on Earth and most are invisible to the naked eye. (The largest is about the size of a period)
  - Only a minority of prokaryotes cause disease.
  - A great majority of prokaryotes are essential to all life on Earth.
- Some prokaryotes decompose dead organisms, returning nutrients to the soil which plants then use.
  - There are an estimated 4 million species of prokaryotes on Earth.
- Prokaryotes were the earliest organisms on Earth.
- Today, they still dominate the biosphere.
  - There are an estimated 4 million species of prokaryotes on Earth.
  - More prokaryotes inhabit a handful of fertile soil or the mouth or skin of a human than the total number of people who have ever lived.
- Why have these organisms dominated the biosphere since the origin of life on Earth?
  - Prokaryotes display diverse adaptations that allow them to inhabit many environments.
  - They have great genetic diversity.
- Some prokaryotes are pathogenic (disease-causing) whereas a great majority of prokaryotes are essential to all life on Earth.
  - Some prokaryotes decompose dead organisms, returning nutrients to the soil which plants then use.
- Prokaryotes are classified into two domains, Bacteria and Archaea, which differ in structure, physiology and biochemistry.
- Most prokaryotes are unicellular.
  - Some species may aggregate transiently or form true colonies, showing division of labor between specialized cell types.
- The most common shapes among prokaryotes are cocci (spheres), bacilli (rods), and helices (spirilla and spirochetes).

- Nearly all prokaryotes have a cell wall external to the plasma membrane.
- In nearly all prokaryotes, a cell wall maintains the shape of the cell, affords physical protection, and prevents the cell from bursting in a hypotonic environment.
- In a hypertonic environment, most prokaryotes lose water and plasmolyze, like other walled cells.
  - Severe water loss inhibits the reproduction of prokaryotes, which explains why salt can be used to preserve foods.
- Most bacterial cell walls contain peptidoglycan, a polymer of modified sugars cross-linked by short polypeptides.
  - The walls of archaea lack peptidoglycan.
- The Gram stain is a valuable tool for identifying specific bacteria based on differences in their cell walls.
  - **Gram-positive** bacteria have simple cell walls with large amounts of peptidoglycans.
  - **Gram-negative** bacteria have more complex cell walls with less peptidoglycan.
    - An outer membrane on the cell wall of gram-negative cells contains lipopolysaccharides, carbohydrates bonded to lipids.
Among pathogenic bacteria, gram-negative species are generally more deadly than gram-positive species. The lipopolysaccharides on the walls of gram-negative bacteria are often toxic, and the outer membrane protects the pathogens from the defenses of their hosts. Gram-negative bacteria are commonly more resistant than gram-positive species to antibiotics because the outer membrane impedes entry of the drugs. Many antibiotics, including penicillin, inhibit the synthesis of cross-links in peptidoglycans, preventing the formation of a functional wall, especially in gram-positive species. These drugs cripple many species of bacteria, without affecting human and other eukaryote cells that do not synthesize peptidoglycans. Many prokaryotes secrete another sticky protective layer of polysaccharide or protein, the capsule, outside the cell wall. Capsules allow cells to adhere to their substratum. They may increase resistance to host defenses. They glue together the cells of those prokaryotes that live as colonies. Another way for prokaryotes to adhere to one another or to the substratum is by surface appendages called fimbriae and pili. Fimbriae are usually more numerous and shorter than pili. These structures can fasten pathogenic bacteria to the mucous membranes of the host. Sex pili are specialized for holding two prokaryote cells together long enough to transfer DNA during conjugation. About half of all prokaryotes are motile: capable of directional movement. The beating of flagella scattered over the entire surface or concentrated at one or both ends is the most common method of movement. The flagella rotate like a corkscrew allowing prokaryotes to move through highly viscous environments like mucus in the throat. In a heterogeneous environment, many prokaryotes are capable of taxis: movement toward or away from a stimulus. Prokaryotes that exhibit chemotaxis respond to chemicals by changing their movement patterns. Solitary E. coli may exhibit positive chemotaxis toward other members of their species, enabling the formation of colonies. The cellular and genomic organization of prokaryotes is fundamentally different from that of eukaryotes. The cells of prokaryotes are simpler than those of eukaryotes in both internal structure and genomic organization. Prokaryotic cells lack the complex compartmentalization found in eukaryotic cells. Instead, prokaryotes use specialized infolded regions of the plasma membrane to perform many metabolic functions, including cellular respiration and photosynthesis. In the majority of prokaryotes, the genome consists of a ring of single DNA strand called the nucleoid (the prokaryotic chromosome). Prokaryotes may also have smaller rings of DNA called plasmids, which consist of only a few genes. Prokaryotes can survive in most environments without their plasmids because their chromosomes program all essential functions. Plasmid genes provide resistance to antibiotics, direct metabolism of unusual nutrients, and other special contingency functions. Plasmids replicate independently of the chromosome and can be transferred between partners during conjugation. Although the general processes for DNA replication and translation of mRNA into proteins are fundamentally alike in eukaryotes and prokaryotes, some of the details differ.
Prokaryotic ribosomes are slightly smaller than the eukaryotic version and differ in protein and RNA content.

Some antibiotics bind to prokaryotic ribosomes to block protein synthesis in prokaryotes but not in eukaryotes.

Antibiotics have in two primary targets: (1) cell wall and (2) prokaryotic ribosomes.

Some antibiotics do not perform mitosis or meiosis, but by **binary fission** (cloning).

Genetic variation occurs due to (1) mutation, (2) transformation (genes taken up from the environment), (3) transduction (genes transferred from a virus to a prokaryote), and (4) conjugation (genes from one prokaryote to another prokaryote).

Prokaryotes reproduce asexually via binary fission, synthesizing DNA almost continuously.

While most prokaryotes have generation times of 1–3 hours, some species can produce a new generation in 20 minutes under optimal conditions.

Prokaryotic reproduction is limited because cells eventually exhaust their nutrient supply, accumulate metabolic wastes, or are consumed by other organisms.

Some bacteria form heat-resistant/durable structures called **endospores** when an essential nutrient is lacking in the environment.

An endospore is resistant to all sorts of trauma:

- Endospores can survive lack of nutrients and water, extreme heat or cold, and most poisons.
- Most endospores can survive in boiling water.
- Endospores may be dormant for centuries or more.
- When the environment becomes more hospitable, the endospore absorbs water and resumes growth.
- Sterilization in an autoclave kills endospores by heating them to 120°C under high pressure.

**MODE OF NUTRITION**

Organisms can be categorized by their nutrition, based on how they obtain energy and carbon to build the organic molecules that make up their cells.

Nutritional diversity is greater among prokaryotes than among all eukaryote capable of metabolizing petroleum.

The majority of prokaryotes are **chemoheterotrophs**, including **saprobes**: organisms that live off of dead organic matter or a live host’s body fluids.

**Phototrophs**: organisms that obtain energy from **light**.

**Chemotrophs**: organisms that obtain energy from chemicals in their environment.

**Autotrophs**: organisms that need only **CO₂** as a carbon source.

**Heterotrophs**: organisms that require at least one **organic nutrient**—such as glucose—as a carbon source.

These categories of energy source and carbon source can be combined to group prokaryotes according to four major modes of nutrition.

**Photoautotrophs** are photosynthetic organisms that harness light energy to drive the synthesis of organic compounds from carbon dioxide.

- Among the photoautotrophic prokaryotes are the cyanobacteria.
- Among the photosynthetic eukaryotes are plants and algae.

**Chemooautotrophs** need only **CO₂** as a carbon source but obtain energy by oxidizing inorganic substances.

- These substances include hydrogen sulfide (H₂S), ammonia (NH₃), and ferrous ions (Fe²⁺) among others.
- This nutritional mode is unique to prokaryotes.

**Photoheterotrophs** use light to generate ATP but obtain their carbon in organic form.

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**Table 27.1 Major Nutritional Modes**

<table>
<thead>
<tr>
<th>Mode of Nutrition</th>
<th>Energy Source</th>
<th>Carbon Source</th>
<th>Types of Organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autotroph</td>
<td>Light</td>
<td>CO₂</td>
<td>Photosynthetic prokaryotes, including cyanobacteria; plants; certain protists (algae)</td>
</tr>
<tr>
<td>Chemo-autotroph</td>
<td>Inorganic chemicals</td>
<td>CO₂</td>
<td>Certain prokaryotes (for example, <em>Sulfobius</em>)</td>
</tr>
<tr>
<td>Heterotroph</td>
<td>Light</td>
<td>Organic compounds</td>
<td>Certain prokaryotes</td>
</tr>
<tr>
<td>Chemo-heterotroph</td>
<td>Organic compounds</td>
<td>Organic compounds</td>
<td>Many prokaryotes and protists; fungi; animals; some parasitic plants</td>
</tr>
</tbody>
</table>

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- This mode is restricted to a few marine prokaryotes.
  - **Chemoheterotrophs** must consume organic molecules for both energy and carbon.
  - This nutritional mode is found widely in prokaryotes, protists, fungi, animals, and even some parasitic plants.

- Prokaryotic metabolism also varies with respect to oxygen.
  - **Obligate aerobes** require O$_2$ for cellular respiration.
  - **Facultative anaerobes** will use O$_2$ if present but can also grow by fermentation in an anaerobic environment.
  - **Obligate anaerobes** are poisoned by O$_2$ and use either fermentation or anaerobic respiration.
    - In anaerobic respiration, inorganic molecules other than O$_2$ accept electrons from electron transport chains.

- Some types of prokaryotes that are involved in the nitrogen cycle can do the following:
  - Perform **nitrogen-fixation**: the conversion from N$_2$ to ammonia (NH$_3$).
  - Convert ammonia into nitrite (NO$_2^-$) and nitrate (NO$_3^-$).
  - Denitrify nitrates back to N$_2$.

- Glycolysis: an anaerobic process that breaks down glucose with enzymes. Glycolysis is found in nearly all organisms on earth, which implies that it is developed early in a common ancestor.

- A commonly accepted hypothesis: the earliest cells on Earth were chemosynthetic prokaryotes that obtained their energy from inorganic chemicals like hydrogen sulfide (H$_2$S) and compounds of iron (Fe$^{2+}$).
  \[
  \text{FeS + H}_2\text{S} \rightarrow \text{FeS}_2 + \text{H}_2 + \text{energy}
  \]

- Although the earliest cells were chemosynthetic, they were probably opportunistic: obtaining some nutrients by absorbing organic compounds when available.

- **Cyanobacteria** (blue-green algae): the first photosynthetic prokaryotes that produced oxygen.
  - They altered the atmosphere by releasing oxygen as a by-product.
  - They evolved between 2.5 to 3.4 billion years ago.
  - Photosynthesis occurs in the infoldings of the plasma membrane where bacteriochlorophyll is located (not chlorophyll a). No chloroplast is necessary.
  - Water is used to make oxygen.

- Both green and purple sulfur bacteria perform photosynthesis.
  - Instead of splitting water, they use hydrogen sulfide (H$_2$S) as a source of electrons.
  - No oxygen is produced.

- There are three major groups of archaea: **methanogens**, **extreme halophiles**, and **extreme thermophiles**.
  - **Methanogens** metabolize methane (CH$_4$) and are among the strictest **anaerobes** = poisoned by O$_2$.
  - Some species live in swamps and marshes where other microbes have consumed all the oxygen.
    - “Marsh gas” is actually methane produced by the archaea.
  - Methanogens are important decomposers in sewage treatment.
  - Other methanogens live in the anaerobic guts of ruminant animals like cattle and termites, playing an important role in their nutrition.

- **Extreme halophiles** live in salty habitats (Great Salt Lake and the Dead Sea).
  - Some species merely tolerate elevated salinity; others require an extremely salty environment to grow.
  - Colonies of certain extreme halophiles form a purple-red scum from bacteriorhodopsin, a photosynthetic pigment very similar to the visual pigment in the human retina.

- **Extreme thermophiles** thrive in hot environments.
  - The optimum temperatures for most thermophiles are 60°C–80°C.
  - They are found in hot sulfur springs and in deep-sea hydrothermal vents.
Bacteria make up most prokaryotes. There are 12 bacteria groups, including cyanobacteria, gram-positive, and gram-negative.

Prokaryotes are decomposers that recycle essential elements (CHON) back into ecosystems so that these elements are available for other organisms.

The four criteria of Koch’s Postulates: used to link diseases to specific bacteria.
1. Find the pathogen in a diseased organism.
2. Grow the pathogen on agar and identify it with a microscope.
3. Infect a healthy organism with the pathogen.
4. Grow the pathogen again on agar from the dead organism and identify it with a microscope.

Exotoxins (botulism): pathogenic (disease-causing) prokaryotes that secrete toxins.
Endotoxins (gram-negative bacteria): prokaryotes with toxins in their cell membrane.

Protista

Protists/protista/protozoan:
- Are eukaryotes (have a nucleus & membrane-bound organelles)
- Are a very diverse group where some are animal-like, some are fungus-like, and some are plant-like in terms of modes of nutrition.
- Are found almost anywhere there is water
- Need moisture to live so if on land
- Found in damp soil or moist leaves
- Are a big part of plankton- the communities of microscopic organisms that drift passively or swim weakly near the surface (phytoplankton--plant-like protist; zooplankton—animal-like protist).

Some protists:
- Have no mitochondria and are therefore anaerobic.
- Are photosynthetic with chloroplasts.
- Are heterotrophic that absorb or engulf their food.
- Are mixotrophic both photosynthetic & heterotrophic.
- Only reproduce solely asexually, while others are sexual or can do both.
- Live in colonies.
- Are multicellular (seaweed).
- Are symbionts that inhabit hosts either in a mutualistic or parasitic relationship
- Live in humans & cause disease.

Most protists:
- Are motile at some point in their life cycles and move with flagella or cilia.
- Are aerobic.
- Can form a cyst under harsh conditions- similar to the endospore that bacteria can form.
- Are unicellular

Differences between prokaryotic and eukaryotic flagella:
- Prokaryote flagella are embedded in the cell wall.
- Eukaryote flagella are an extension of the cytoskeleton with its microtubules.

Endosymbiosis theory: one time mitochondria & chloroplasts were free-living prokaryotes and probably gained entry to a host cell as undigested food. The cell then found the relationship to be nutritionally beneficial, leading to a single organism.

Evidence supporting endosymbiosis:
1. The size of mitochondria and chloroplasts are similar to bacteria.
2. Mitochondria and chloroplasts reproduce similar to bacteria by binary fission
3. Chloroplasts and mitochondria contain their own circular DNA, and the DNA doesn’t contain proteins/histones just like bacteria’s DNA.

4. The ribosomes of chloroplasts and mitochondria are small just like bacteria’s ribosomes and are thus sensitive to antibiotic.

- The kingdom potista has been broken up into 5+ “candidate kingdom”.
  1. **Archaezoa:**
     - Most ancient of candidate protist kingdoms
     - Lack mitochondria and thus live in anaerobic environments (fermentation)
     - Include protists that infect the human intestines and cause cramps/diarrhea transmitted via water containing human feces.

  2. **Euglenzoa:**
     - Have flagella
     - Are commonly called flagellates
     - #1 example: euglena: a green mixotrophic protist
     - #2 example: one that is spread by the bite of the tsetse (carries the trypanosoma protist) fly and causes the African sleeping disease.

  3. **Alveolata:**
     - All the protists in it have membrane-bound cavities/alveoli under their cell surfaces
     - Including: dinoflagellates: make up much of plankton and responsible for red tides when their population explodes; these blooms are toxic to fish and can be deadly to humans, too. Some dinoflagellates are bioluminescent.
     - Another example: plasmodium—parasite that causes malaria; have an intricate life cycle that requires at least 2 species for completion.
     - Ciliates—use cilia to move and feed; have both a macronucleus (control center) and micronuclei. Ex: paramecium—can reproduce both sexually and asexually.

  4. **Stramenopila:**
     - Have straw-like projections on their flagella
     - Includes diatom with their glass-like walls made of SiO₂ (silica)
     - Many have oil in them for buoyancy.
     - Have two parts (like the shoe box and its lid).
     - Water molds: fungus-like protist; grow as cottony masses on dead/injured animals and decompose them.
     - Golden algae
     - Multicellular brown algae (looks army-green color) includes:
       - Seaweed: in the “rough-and-tumble: intertidal zone
       - Kelp (giant sea weed): are multicellular and have slimy feeling due to a polysaccharide cushion in their cell wall→ lessens the effects of the beating tides.
     - Made for human food sushi, salad dressing, pudding & to make agar.

  5. **Rhodophyta:**
     - Red algae protist
     - Have no flagellated stage in their lifecycle
Not all red algae are red
Most are multicellular and “seaweed-like”
Too have an alternation of generations life cycle.

6. **Green algae:**
- All have chloroplasts
- Are bright green in color
- Closely related to plants and from a common ancestor
- Contribute to plankton in mostly fresh water
- Can be unicellular or multicellular or exist in colonies
- Ex: volvox live in colony.

7. **Nameless Candidate Kingdom:**
- Pseudopods (false feet): amoeba engulfs its prey as its cytoplasm streams around a tasty morsel like a bacterium. Some are parasites that can get into humans via contaminated drinking water or food.
- Slime mold: resemble fungus in appearance and lifestyle; are decomposers; are bright yellow in color and often growing on a rotting log.

<table>
<thead>
<tr>
<th>Plant-like (photosynthesis)</th>
<th>Animal-like (engulf)</th>
<th>Fungus-like (use enzyme to decompose then absorb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diatom</td>
<td>Amoeba</td>
<td>Water mold</td>
</tr>
<tr>
<td>Volvox</td>
<td>Paramecium</td>
<td></td>
</tr>
<tr>
<td>Algae (green, brown, golden, red)</td>
<td>Trypansoma</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dinoflagellates</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plasmodium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Euglena</td>
<td></td>
</tr>
</tbody>
</table>

**PLANT DIVERSITY**

- **Plants:** multicellular eukaryotes & photosynthetic autotrophs; differ from the green algae in that they are almost all terrestrial.
- **Problems of plant life on land:**
  - Avoiding dessication → waxy cuticles help prevent excess water loss.
  - New mode of reproduction → in water, algae gametes swim to fertilize; on land, gametes of early land plants developed within moist chambers (mosses and ferns).
- **All plants have an alternation of generations life cycle.**
- **Four branches in plant evolution:**
  1. Bryophytes
  2. Pteridophytes
  3. Gymnosperms
  4. Angiosperms
- **Bryophytes (mosses, liverworts, and hornworts):**
  → 1st plants to live on land.
  → Consists of male antheridium and female archegonium; both are fertilized and developed within the female archegonium.
  → Are not totally liberated from aquatic habitats.
  → Need water (rain or dew) for the flagellated sperm to swim from antheridium to archegonium.
  → Small plants (1-2cm) that lack vascular tissue: vessels that transport water and nutrients throughout the plant; lack stems, leaves, and roots.
  → Move water (osmosis) to all parts of the plant like sponges.
  → Live in damp, shady areas.
- **Pteridophytes (seedless vascular plants: fern and horsetail):**
  → 1st plants to have a vascular system (xylem and phloem).
  → **Xylem:** made of dead cells that carry water and minerals up from the roots.
  → **Phloem:** living cells that carry food (sugar and amino acids) throughout the plant.
Grow from haploid spore: unicellular plant gamete/zygote.
Have flagellated sperm cells that must swim to reach eggs.
Abundant in swamps and other damp habitats during the Carboniferous period.
Dead pteridophytes → peat + (heat & pressure) → coal & fossil fuels.

Gymnosperms ("naked seeds"):
1st vascular plants to have seeds.
Grow from seed: multicellular plant gamete/zygote.
Seed consist of a sporophyte embryo with endosperm (food reserve) in a seed coat.
Pollen: "sperm" that is protected by a tough coat and is carried by wind or animals.
Discharge 1 or 2 into the ovule; the 2nd pollen disintegrates.
Have NO flagellated pollen sperm.
Examples: conifers, cycads, and ginkos.
Needle-shaped leaves are adapted to dry conditions.
Thick cuticle covers the leaves, and stomata are located in pits to reduce water loss.
Conifers have both male and female cones on the same tree.
Cones take 3 years to pollinate to form mature seeds (scattered by wind).

Angiosperms (flowering plants):
Most diverse and widespread of all plants.
Monocots: one seed leaf. Ex) grasses and corn.
Dicots: two seed leaves. Ex) beans, roses, and oak.
Two successful features: (1) xylem more specialized for water transport (2) increased efficiency of seed dispersal (attraction of pollen-carrying animals & wind).
Petals are bright in color to attract pollinators; wind-pollinated angiosperms are drab in color.
Seeds are enclosed in the ovary, unlike gymnosperms.
Fruit: mature ovary that protects dormant seeds inside and aid in their dispersal through the deposition of feces by animals (seed coat prevents digestion of the seed).
Have double fertilization: two pollen cells unite within the egg to form 3n nucleus.
Seed consists of (1) seed coat, (2) rudimentary root, (3) cotyledons, and (4) endosperm.
Germination: the coat ruptures and embryo emerges as a seedling using the food stored in the endosperm and cotyledons.

Natural selection favors the interaction between plants and animals: plants get pollinated, animals get fed.
Coevolution: the mutual evolutionary influence between two species.
For example, some flowers are pollinated by birds, bees, or bats.
Fruits that are not yet ripe are usually green, hard, and distasteful → helps the plant retain the fruit until the seeds are mature. As it ripens, the fruit becomes softer, sugar content increases and colors brighten to advertise to animals.

THE FUNGUS KINGDOM

Decomposers: organisms that recycle elements back to the environment. Ex. Fungi and bacteria.
All plants depend on a mutualistic fungus living on their roots to absorb water and nutrients from the soil.
Mycorrhizae: fungus + plant roots in a mutualistic association.
*Note: Rhizobia are bacteria that live on the roots of legumes and fixes nitrogen.
Fungus: eukaryotes; most are multicellular (yeast = unicellular); all are heterotrophs that acquire nutrients by absorption.
Fungi secrete enzymes onto the food source, which decompose the complex molecules into simple molecules for the fungi to absorb.
Fungi can be saprobes, parasites, or mutualistic symbionts.
Different Phyla of Fungi (based on reproduction):

<table>
<thead>
<tr>
<th>Examples</th>
<th>Phylum</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Chytrids (primitive fungus in water)</td>
<td>Chytridiomycota</td>
</tr>
<tr>
<td>B. Common bread molds</td>
<td>Zygomycota</td>
</tr>
<tr>
<td>C. Mildew, morels, truffles, yeast, and lichen</td>
<td>Ascomycota</td>
</tr>
<tr>
<td>D. Mushroom, puffballs, toadstools, and shelf fungus</td>
<td>Basidiomycota</td>
</tr>
<tr>
<td>E. Penicillium, athlete’s foot, and ringworm</td>
<td>Deuteromycota</td>
</tr>
</tbody>
</table>
- **Hyphae**: minute threads that secrete enzymes/absorb nutrients.
- **Mycelium**: interwoven mat of hyphae threads that have a large surface area to increase absorption.
- **Chitin**: a strong nitrogen-containing polysaccharide similar to chitin found in the exoskeletons of arthropods (insects). Makes up the cell walls of fungi.
- Most fungi reproduce both sexually and asexually by releasing millions to trillions of spores (not seeds) into the environment.
- **Mycologist**: people who study fungi (have discovered about 1.5 million species of fungi).
- **Characteristics of Different Phyla (divisions):**
  - **Chytridiomycota**:
    - Most ancient of the fungi and the evolutionary link between fungi and protists.
    - Live mostly in water and have flagellated cells.
  - **Zygomycota**:
    - Can form a heat, cold, and drought-resistant structure called a **zygospore** under harsh conditions.
    - Example: black bread mold (Rhizopus stolonifer)
    - Grow in dark, moist, and warm habitats.
    - Bread mold is made of 3 types of hyphae: (1) stolon, (2) rhyzoids, and (3) sporangiophores.
    - **Stolon**: spreads horizontally over the food source.
    - **Rhyzoids**: anchor to the substrate, secrete enzymes to digest the substrate, and absorb the digested food.
    - **Sporangiophores**: grow upwards and have a spherical spore case called a **sporangium** at their tip.
    - **Sporangium**: spherical spore case that carries thousands of spores to be carried off by the wind.
  - **Ascomycota** (**the sac fungi**):
    - **Ascus**: a sac-like reproductive structure that usually contains 8 sexually produced **ascospores**.
    - Examples: mildew, morels, truffles, lichens, and yeast.
    - **Lichen**: algae/cyanobacteria living in a mutualistic relationship with fungi.
    - The algae perform photosynthesis and give the fungi food (glucose) → the fungi give the algae water, nutrients, and shelter.
    - Lichens are usually the 1st organisms into a new area and help break down rocks for plants to grow = primary succession.
    - **Budding**: the reproduction of yeast under favorable conditions.
    - Under unfavorable conditions, yeast produce spores and remain inactive until the condition improves.
    - Yeast can be both aerobic (cellular respiration) AND anaerobic (fermentation). Under anaerobic conditions, they produce alcohol.
  - **Basidiomycota** (**the club fungi**):
    - Reproduce both sexually and asexually.
    - Sexual reproduction = produces spores on the gills (beneath the cap).
    - **Basidia**: extensions on the gills that release spores called **basidiospores**.
    - **Fairy rings**: a circular formation of mushrooms (basidiomycetes) that occurs due to the expansion of the mycelium from its source of food. Older portions at the center of the mycelium deplete all the nutrients and die as a result (vacant center remains).
    - **Toadstools**: non-edible mushrooms.
    - **Puffballs**: round or pear-shaped basidiomycota that contain spores. Size range: from golf ball to watermelon size.
    - Puffballs release spores by (1) cracking open to allow the wind to carry the spores, (2) allowing the wind to suck the spores out through the small openings, or (3) puffing out spores when they are hit by raindrops.
  - **Deuteromycota** (**imperfect fungi**):
    - Only known to reproduce asexually (not both sexually and asexually like the other phyla).
    - Include fungi that are benevolent or malevolent to humans and plants.
    - **Tinea pedis** (**Athlete’s foot**): a common fungus that is found between the toes and on the soles of feet. It grows in moist, damp areas (sweaty feet and wet socks).
    - **Tinea corporis** (**ringworm**): usually in the form of a circle with a scaly center on the skin. Causes the skin to be itchy, and behaves exactly like a “fairy wing.”
    - **Penicillium**: a blue and green mold that grows on citrus fruits.
- Some species of penicillium are used to flavor cheese (blue cheese, Camembert, and Roquefort cheese).
- Others are importantly used for the production of antibiotic penicillin.

  > Alexander Fleming: in 1929, he discovered that the penicillium destroyed much of a bacterial colony by stopping bacteria from multiplying.