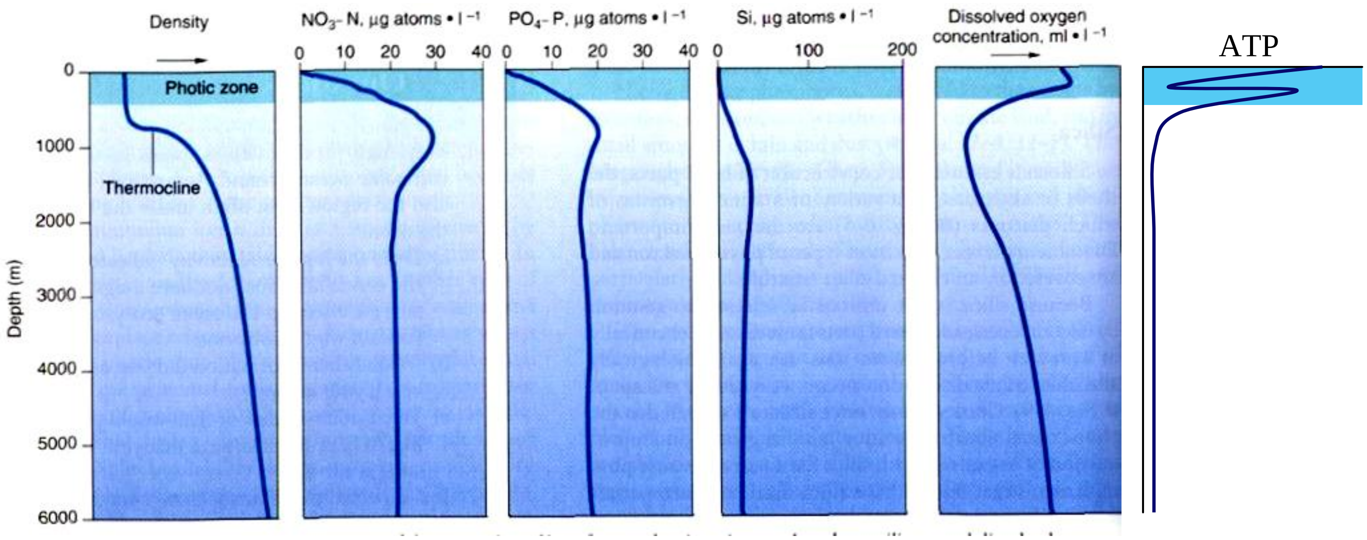
Historical Microbiology

- **Aristotle** (384-322 BC): frog & mice formation from damp earth & decaying grains, respectively
- Girolamo **Fracastoro** (1478-1553): causation of disease (**contagions** involved in disease process)
- Antony van **Leeuwenhoek**: (1670s): developed a solar microscope & was the 1st to observe bacteria
- Francesco **Redi**: (1688) Italian physician who attacked spontaneous generation (meat & maggots)
- Charles Cagniard-**Latour**: (1800s) yeast reproduced by budding & were non-motile
- Friedrich **Kutzing:** (1837) fermentation was caused by living organisms
- Edrico **Acerbi**: (1822) theorized that parasites entered the body & caused typhus fever
- Edward **Jenner:** (1749-1823) used "**cow-pox**" inoculations to **immunize** humans against **smallpox**
- Louis **Pasteur**: (1822-1895) chemist, contributed to every phase of microbiology
  - anti-spontaneous generation
  - **immunology**: anthrax, cholera, and **rabies** (9 year old boy)
  - **fermentation** & **anaerobiosis** (air microbes initiated fermentation, Napoleon & wine)
  - microbial techniques**: sterilization** methods (autoclaves)
- Robert **Koch**: (1843-1910) physician, evidence that a bacterium was the causative agent of a disease
  - **Pure culture** methods (**Agar** & **Petri** dishes)
  - Colony arose from a single cell
  - **Koch's postulates:** 1) a specific microorganism is present in all cases of the disease
    2) that microorganism can be obtained in pure culture outside the host
    3) the cultured microbe will cause the same symptoms in a new host
    4) the microorganism can be re-obtained in pure culture again
- Paul **Ehrlich:** (1854-1915) 606 "**magic bullet**" cure for **syphilis** (a protozoan infection)
- Ferdinand **Cohn**: (1812) microbes involves in the cycling of matter in nature
- Martinus **Beijerinck:** (1851-1931)
  - **Enrichment Cultures** (organism evolves to exist under specified conditions)
  - Discovered free-living **Nitrogen-fixing Bacteria**
  - 1st described **viruses**
- Sergei **Winogradsky:** (1856-1953) **sulfur-oxidizing** bacteria, autotrophy concept, *W.* column
- **Kluyver & van Niel**: developed equations for…
  - **Respiration** (**AH_2+B=A+BH_2**) oxidizer (B) is reduced to BH2 & reducer (AH2) is oxidized to A
  - **Photosynthesis** (**CO_2+2H_2A=CH_2O+H_2O+2A**) CH_2O is cell material, in plant photosynthesis A is O_2
- Karl **Landsteiner**: (1930) human **Blood Groups** (Types A,B, & O)
- Sir Alexander **Fleming** *et al.*: (1945) **penicillin**
- James **Watson** *et al.*: (1962) **DNA structure**
- M. **Nirenburg** *et al.*: (1968) **Genetic Code**

Chemical Parameters in the Open Ocean



- **O_2** exists in **dissolved form** in water**:** its either dissolved from the atmosphere or created by photosynthesis
- **O_2 min** is where the **CO_2 max** is → implies respiration
- **More O_2** in **cold water** than in warm, because O_2 molecules are agitated by heat
- **Density** equation: **σ_t = (density – 1)(1000)**; seawater $\sigma_t = 30$, zooplankton $\sigma_t = 27.3$, ocean floor $\sigma_t = 31$

Methods of Estimating Microbial Abundance

- **Enumeration**:
  - **Culture** Methods: works well for some bacteria, but not for others (viable but non-culturable)
  - **Microscopic** Methods: Phase Contrasts (environmental samples have too much debris)

- **Chemical Methods**:
  - Nucleotides (shows where activity is occurring & is culture independent, bad for count data)
  - Algae look at chlorophyll a (problem: it decays after cell death)
  - Fungi look at chitins & lipids (fumation respiration: kill everything & see how fast its re-colonized)

Viruses

- **Small**, **obligate, intracellular parasites,** consisting solely of **nucleic acids** & **proteins**
- Not technically viable living organisms, require a host for replication & growth
- Generally species specific, & are initially classified by the hosts they infect
- Public Focuses on: Plant (cash crop) & Human (herpes, warts, smallpox, rabies, etc) viruses
- May or may not be infectious (**Viron:** an infectious virus particle)
- They have **either** DNA or RNA, but not both (as bacteria do)
- Can't grow on non-living media & are NOT sensitive to antibiotics
- **Capsid**: protein coat of the virus
- Viruses use **specific receptor sites** in their capsid or envelope surfaces to target host cells
  →This is why plant viruses don't normally infect humans (& visa-versa)
- **Viruses are metabolically inert but infectious**
- **Survivability** & **infectivity** of viruses depends on:
  - **Environmental** Factors: temperature, solar radiation, heavy metals, salinity,
  - **Host** Factors: bacterial activity, weak immune system,
  - Viral **Mechanisms**: absorption (sticking), high mutation rates, adjusting their isoelectric point, infection, transmission
- Viral **Evolution**: largely unknown, 3 of the most common possibilities are:
  1) Degenerate descendents of larger pathogens
  2) Remnants from an Ancient pre-cellular environment
  3) **Came from nucleoproteins (genetic material) released from the host cell**
- Types of Viral **Emergence**
  1) Previously unrecognized strain
  2) Mutation from zoonotic strain
  3) Exposure of vectors to new environments
  4) Alterations in Host's immune system
- Methods of **Generating readable messenger RNA** (mRNA) (a key step in Viral Replication)
  - mRNA may be transcribe from viral DNA
  - viral RNA may act directly as the mRNA

  or
  - viral RNA may be used to synthesize DNA using a viral enzyme (reverse transcriptase),which is then transcribed to mRNA
- **DNA viruses** replicate in the **cell nucleus**, whereas **RNA viruses** replicate in the **cytoplasm**
- **Bacteriophage (phage):** viruses of bacteria , there are 3 general types of Bacteriophage:
  1) **F-Specific** (**appendage**) Phage: infects the host through sex pili or **flagella**
  2) **Capsule** Phage: enter through the hosts **outer layer** (polysaccharide capsule)
  3) **Somatic** Phage**:** enter through the hosts **cell wall**

- **Viroid**: infectious agents of plants
  - Viroids differ from Viruses in that they:
    - are free RNA sequences, consisting ONLY of RNA, never DNA, & their RNA weighs less
    - exist *in vivo* as free nucleic acids with capsid proteins present
    - RNA translation and Viroid replication are not well understood
    - Their unique molecular structures suggests they are not closely related to viruses

- **Prion:** infectious **proteins** affecting animals, ex. Mad Cow & Creutzfeldt-Jakob Disease
  - Prions differ from viruses in that they:
    - smaller than viruses
    - heat resistant
    - no immune response
    - difficult to detect in infected tissue

How do such phage-host interactions affect environmental ecology as a whole?

- Phage become active members of the microbial food web by lysing bacterial cells that might otherwise have been available for predation by heterotrophic protozoans
- Phage can transfer genetic information from one host to another host
- viral DNA makes up ~3.7% of the total dissolved DNA in aquatic environments (Paul et al. 1991)
- high phage populations in unpolluted environments suggests indigenous viruses may be important in controlling populations

What factors control the fluctuation of virus populations over time?

- a **bacterial density threshold** must be reached before phage can multiply (~10^4 CFU in labs)
- **Environmental Factors**: Temperature, solar radiation, salinity, heavy metals

List the viral <u>mechanisms</u> that aid in their persistence & survivability in the environment.

- Infection
- Transmission
- High mutation rates
- Adjusting isoelectric point
- Adsorption (sticking)

Discuss the Advantages & Disadvantages associated with microscopic, cultural, & molecular detection of virus populations in the environment.

Comparing Methods of Microbial Detection		
	Advantages	**Disadvantages**
Microscopic	- Estimates Viral abundance - Depth profiles of bacterial and viral abundance - Helps to identify particular phage particles based on size & morphology	- enumeration of noninfective virus particles - overestimation of the impact of the infective phage on a certain bacterial population - TEM is difficult on low viral count or turbid samples (thus it doesn't work well on most environmental samples which are filled with debris)
Cultural	- gives information on the infective versus non-infective phages - work well for certain bacteria	- doesn't provide phage abundance information - difficult to culture some phage-host systems - not all microbes are culturable (ex. viable but non-culturable)
Molecular	- enables the discovery & study of total phage populations - enables the study of phage interactions with microbial communities - promotes the characterization of phage ecology - helps the understanding of phage contributions to environmental nutrient cycles - tells you where the activity is occurring - Culture independent	- doesn't facilitate abundance calculations

Prokaryotes vs. Eukaryotes

Prokaryotes: **Eubacteria** (bacteria) & **Archaea** (extremeophites)

- **Non**-membrane bound DNA = **nucleoid** (or nuclear area)
- Lack complex internall cell organelles
- Lack internal cell membranes
- Capable of **rapid growth**, **metabolism**, & **reproduction**

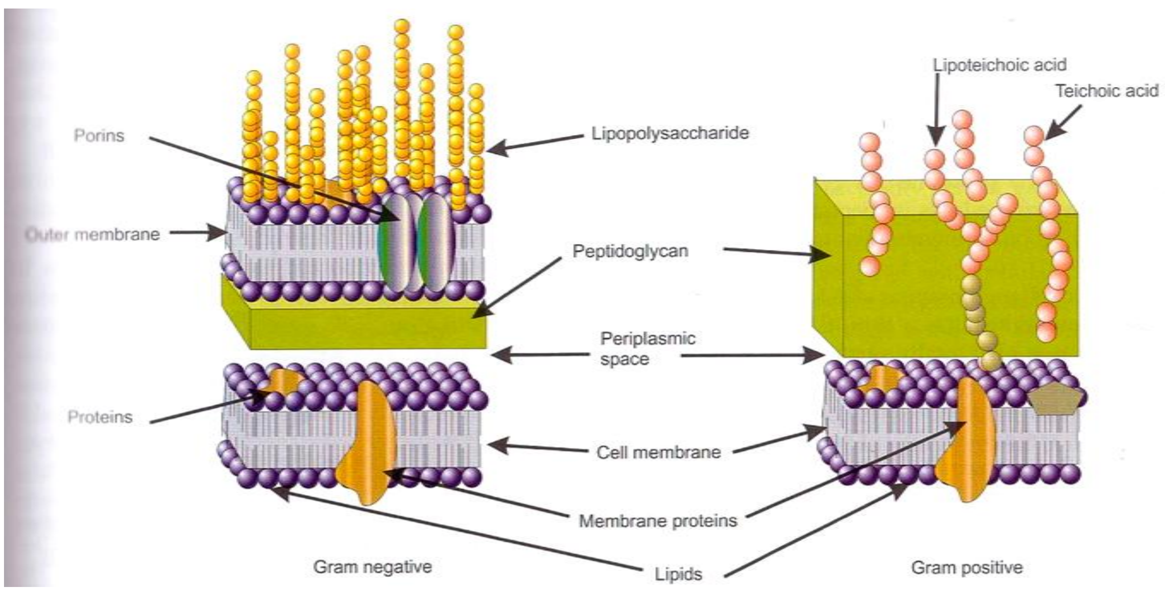
  - **Actinomyctes**: prokaryotic bacteria, that morphologically resemble fungi (elongated cells with branching filaments or hyphae) however their hype are much smaller than that of fungi

Eukaryotes: **Eucarya** (Animals, Plants, Fungi, Ciliates, Flagellates, Microsporidia)

- **Membrane bound** DNA = **nucleus** (true nucleus)
- **Complex internal cell organelles** involved with growth, nutrition, or metabolism
- **Internal cell membranes**

Bacteria

- **Prokaryotic**, they're the simplest of the microbial cells
- Consist of **cell protoplasm** contained **within** a retaining structure **cell envelope**
- Among the most common & ubiquitous organisms on earth
- Less than 5% of bacteria are known (viable but non-culturable)
- Organisms geared toward **rapid growth** & **cell division** under **favorable conditions**
- Their ability to grow & reproduce quickly means they're able to **adapt quickly to changes** (e.g. changing environments or environmental stimuli)
- **Mutations** arise in the presence of stress (heavy metals, antibiotics, etc.) & their high reproductive rates allow these successful mutants to become the dominant organism (**survival of the fittest**)
- Prokaryotic Bacterial Domains (**Eubacteria** & **Archaea**) are **classified** by their **cell wall properties**:
  - Gram **negative**: more complex cell wall with an additional peptidogylcan layer (outer membrane)
  - Gram **positive**: inner membrane only, less peripasmic space
  - Cell wall **lacking peptioglycan** (Archaea)
  - **No cell wall** (mycoplasmas)



- **Size**: most bacteria are **0.5 to 1µm** in **diameter**, and **1-2 µm long**
  - Bacteria are usually colonial (*note:* colonies visible to the eye generally have a million bacterial cells)
  - **Ultramicrobacteria:** 0.3µm & are easily transported through porous media
    - Ex. SAR11, the smallest known microbe, <3µm, found in the Sargasso Sea
  - Their small spherical size allows them to have a higher surface area to volume ratio, which enables them to have more efficient nutrient exchanges with the environment, this is called **cell rounding**, and often happens in response to environmental stress
  - In undisturbed soils at least 50% of the cells may be dwarfed in size with volumes <1μm^3

- **Shapes**: 4 basic shapes, each with a multitude of variable forms within it
  - **Rods**: have **higher surface area per volume** they are **better able to take up nutrients** from dilute solutions (& thus are more efficient than cocci); can also have **flagella**
  - **Cocci**: overall **increased survivability** because they have **less surface area per volume** & therefore can better withstand desiccation, they're also less distorted after desiccation
  - **Helix** (*vibrios*), their spiral shape facilitates movement through water (better than rods)
  - **plemorphic** (amorphic)

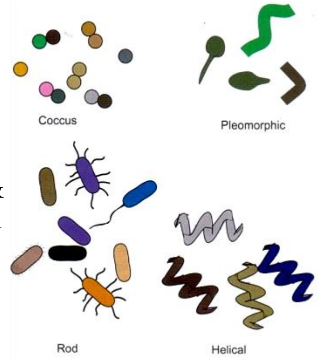
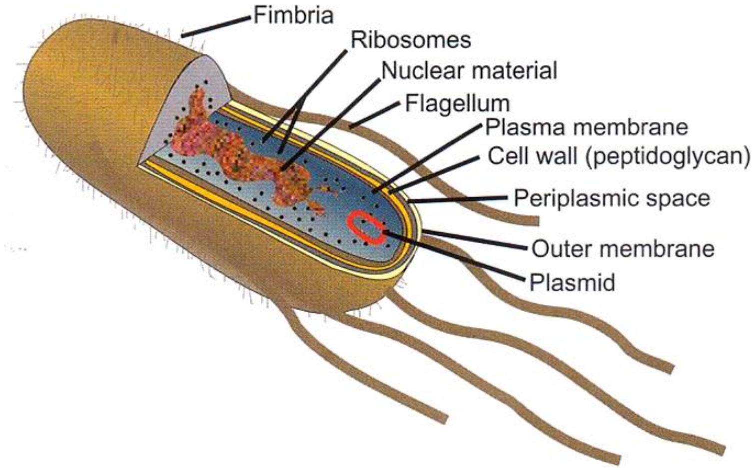


FIGURE 2.7 Typical shapes of representative bacteria.



- **Cell Structure:**

  All bacteria have…
  - **cell envelope:** layers that protect the bacteria from the external environment
  - **protoplasm** that contains a **cell membrane**, **cell pool**, **ribosomes**, & a **nucleoid**
  - **Ribosomes**: carry out **protein synthesis** (mRNA carries genetic info. from the genome to the ribosome)
  - **Gas Vesicles**: special membrane-bound structures used for **buoyancy** by aquatic prokaryotes

  some have…
  - **cell wall** though a few don't

  proteinacious tubes used to **bring in DNA**, they're essentially appendages **not used for motility**
  - **flagella:** aid in surface attachments
  - **pili**: involved in conjugation, only found in Gram **Negative** bacteria
  - **Spinae**: used by marine bacteria to increase surface area & create drag (maintain float)

- Methods of DNA Trasnfer:
  1) **Transduction:** virus incorporates hosts DNA into its own, then passes it along to next victim
  2) **Transformation:** DNA is released by lysis, this free-DNA is picked up by another microbe
  3) **Conjugation:** direct transfer of DNA by cell to cell contact

- **Plasmid-Chromosome Relationship:**
  - **DNA**: fibrous material found in the cytoplasm of the cell
    - **Chromosomal** DNA: essential for cell growth (carries genetic material)
    - **Plasmid** DNA: enhances survivability (doesn't carry genetic material)
  - **Chromosome:** contains most of the **genetic information** necessary for bacterial **cell function**
  - **Plasmid: additional DNA sequences that are separate from the chromosomes**
    - Plasmids are **autonomous** & **expandable**
    - there are 4 types of **plasmid function**
      1) **Cryptic** plasmids: encode unknown phenotypic traits, with non known function
      2) **Resistance** plasmids: code for protection of the bacterial cell against antibiotics, etc.
      3) **Degradative (catabolic)** plasmids: code for the breakdown of unusual metabolites
      4) **Plant-interactive** plasmids: 2 types,
         - 1^{st} concerns symbiosis between a bacterium and a legume
         - 2^{nd} involves a parasitism between bacterium & higher plants (ex. tumor inducing plasmids integrate host DNA & cause frown gall disease)

- **Metabolism:** bacteria require **water, nutrients, energy source,** & a **terminal electron acceptor**
  - **Macro**nutrients: nutrients required in large amounts, used for cell **structure** & **metabolism**
  - **Micro**nutrients (**trace elements**): required in small amounts, used to **catalyze for enzymes**
  - **Oligotrophic** organisms: can live in **nutrient-deficient environments**
  - **Copiotrophic** organisms: can live in **nutrient-rich** environments

Photoautotroph

- Use **light** as their **energy source**, and **CO_2** as their **carbon source**
- $CO_2 + H_2A \rightarrow (CH_2O)_4 + 2A + H_2$
- Obligate photoautotrophs (organisms grow only in the presence of light & CO_2) use **inorganics** (H_2O, H_2, H_2S) as their electron donor in order to reduce the CO_2 into cellular carbon (CH_2O)

Photosynthesis

$$2H_2O + CO_2 = (CH_2O) + O_2 + H_2O$$

$$\Delta G = +115 \text{ kcal mo1}^{-1}$$

- For this reaction energy supplied by sunlight is necessary.
- The fixed organic C is then used to generate energy via respiration.

Be aware that bacterial photosynthesis is significantly different from plant photosynthesis.

Photoheterotroph

- Photosynthesis is driven by an **electron donor** (**H_2** or an **organic**) which drives the reduction of CO_2
- Many require specific **growth factors** (B-vitamins)
- Many will grow on organic substrates when oxygen is available
- They can also use light as their energy source while they are assimilating the organic compounds to be used as a growth substrate from their surrounding environment

Respiration

(A) **Aerobic heterotrophic respiration**: Many organisms undergo aerobic, heterotrophic respiration,

$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$ $\Delta G = -686$ kcal mol^{-1}

(B) **Aerobic autotrophic respiration**:

The reactions on <u>reduced nitrogen</u> carried out by *Nitrosomonas* and *Nitrobacter* are known as **nitrification**. For *Nitrosomonas* Amonia (NH_3) is oxidized to produce Nitrite (NO_2)

Oxygen is the terminal electron acceptor

$KNO_2 + 0.5O_2 = KNO_3$ (*Nitrobacter*) $\Delta G = -17.5$ kcal $mo1^{-1}$

Oxidations carried out on <u>reduced sulfur</u>

Beggiatoa is a long, filamentous organism, that forms microbial mats. In *Beggiatoa's* respiration reaction, sulfur is being stored, instead of completing the cycle, this is why the energy produced is so low (-83 kcal $mo1^{-1}$) compared to the energy produced in *Thiobacillus'* reaction (-237 kcal $mo1^{-1}$) in which the cycle is completed.

$2H_2S + O_2 = 2H_2O + 2S$ (*Beggiatoa*) $\Delta G = -83$ kcal $mo1^{-1}$

(C) **Facultative anaerobic, heterotrophic respiration:**

Pseudomonas denitrificans can achieve this kind of metabolism by utilizing **nitrate** rather than oxygen as a **terminal electron acceptor** - Note that these organisms can use oxygen as a terminal electron acceptor if it is available and that aerobic resonation is more efficient than anaerobic respiration.

$5C_6H_{12}O_6$ H- $24KNO_3 = 30CO_2 + 18H_2O + 24KOH + 12N_2$ $\Delta G = -36$ kcal $mo1^{-1}$

(D) **Anaerobic heterotrophic respiration**: (*Desulfovibrio*) driven by sugar (the energy source)

$2CH_3CHOH\ COOH + SO_4^{-2} = 2CH_3COOH + H_2S + 2\ HCO_3$ $\Delta G = -40$ kcal $mo1^{-1}$
lactic acid — acetic acid

Chemoautotroph ("autotroph" for short)

- **CO_2 as the carbon source** & **<u>inorganics</u>** as **energy source**: H_2S, S^0, NH_3, NO_{2-}, Fe^{+2}, Mn^{+2}, $S_2O_3^{\equiv}$
- Use **reduced** inorganic substrates for both the reductive assimilation of CO_2 & their energy source

How do they generate reducing power? They obtain their energy by oxidizing reduced inorganic substrates

Chemoheterotroph ("heterotroph" for short) **most bacteria are chemoheterotrophs**

- energy is derived through the oxidation of organic compounds via re respiration.
- assimilate **preformed organic substrates** as their source of both **carbon & energy**
  - This is often a single substrate (glucose, succinate, etc.)
- Though the carbon & energy sources may also be different substrates
  - Sulfate reducers use H_2 as their energy source & an organic carbon for cellular biosynthesis

Heterotrophic: derive carbon from pre-formed organic compounds that are broken down enzymatically

Phototrophic: Sulfur Oxidizing Bacteria, uses organic Carbon as its Energy Source for reducing powe

Mixotroph - Use **inorganic energy** source and **organic compound** for C source and reducing power.

During the oxidative process, electrons are removed from the substrate and passed via the electron transport chain to a **Terminal Electron Acceptor** (**TEA**).

- For **aerobic organisms** the TEA is **oxygen**.
- For **anaerobic organisms** the TEA is a **combined form of oxygen** such as an **organic metabolite (C02, $N0_3^-$, or SO_4^{2-}) or an oxidized metal (Fe^{3+})**

Fungi

- Eukaryotic, divide through **mitosis**
- **Heterotrophic** in nature, with different genera metabolizing simple sugars & complex hydrocarbons
- Important **degraders** of **plant polymers** (**cellulose** & **lignin**) & other **complex organic molecules**
- 4 types of Fungi: Motile, Zygomycota, Ascomycetes, & Basidiomycetes
- **Yeasts**: **unicellular** fungi that reproduce through **budding**
- **Molds**: have filamentous structures (**hyphae**) which entwine into a mass (**mycelium**)
- Lack surface appendages (like flagella), they move by means of their hyphae
- Glycocalyx (~bacterial slime layer) is the outermost layer used for protection, surface attachment
- Nuclear envelope contains the nucleus, which contains **chromatin**
- **Chromatin** is a network of **DNA** & **protein** fibers which make up eukaryotic **chromosomes**

Algae

- **Aerobic** eukaryotes, which have a true nucleus & several membrane bound organelles
- Classified by their **chlorophyll types** (Green, Brown, or Red Alage)

Protozoa

- **Unicellular** eukaryotes, **lack cell walls**, reproduce **asexually**, & require water to live
- **Free-living, parasitic,** or **opportunists**
- 3 types of **parasitic protozoan** relationships**: commensalism, symbiotic, tissue parasitic**
- **Cause Diseases:** malaria, Chagas , sleeping sickness
- **Beneficial roles:** recycle nutrients, provide nitrogen, phosphorous, & carbon to plants & surrounding microorganisms from metabolic waste products
- 3 major feeding categories (*note:* during feeding they help to control bacterial biomass)
  1) **Photoautotrophs: capture light** (with **chloroplasts**) for **energy** & use **CO2** as **carbon** source
  2) **Photoheterotrophs: phototrophic energy capture** & must have **organic carbon compounds**
  3) **Chemohetertrophs: require chemical energy** & **organic carbon**

Protozoa are some of the most diverse organisms on the planet, what specific characteristics have enabled their proliferation in a multitude of adverse conditions?

- protozoa are free living (can grow & reproduce outside host)
- they are opportunistic (adapt to changing environment)
- they can reproduce either sexually or asexually
- They can feed either phototrophically (auto-& hetero-), chemotrophically, or even phagotrophically
- They can withstand long periods without water through encystment (inactive, nonmotile, cycsts)

Bacterial Growth

- **Anabolic** reactions: **synthesis** of cell constituents & metabolites
- **Catabolic** reactions: **breakdown** of cell constituents & metabolites
- 2 types of bacterial cultures: **Batch** & **Continuous**
- Growth under **Anaerobic Conditions**: in the absence of O_2 **organic substrates** can be **mineralized to CO_2 by fermentation** (TEA = **organics**) or by **anaerobic respiration** (TEA=inorganic)
- Often under anaerobic conditions, organic compounds are degraded by an interactive group or consortium of microorganisms (e.g. **methanogenesis**)
- **Community:** highest biological unit in an ecological hierarchy, made of individuals & populations
- **Microbial community**: integrated assemblage of microbial populations in a given habitat
- **Population**: group of the same individuals (**micro-colony**) that use & compete for the same resources

R vs K strategists

- organisms must **optimize** <u>**either**</u> their **reproductive capacity** (**R**) or **conservation of resources** (**K**)
- **R-strategists:** "the invaders"
  - Respond to added nutrients with **rapid growth rates**
  - **Rate of population change** is dominated by R when the population **density is low**
  - Growth rate is Not limited by the carrying capacity when the population density is low
  - Few competitive adaptations
  - Thrive in **resource rich environments**
  - Use most of their **resources for reproduction**
  - Form **abundant** & **resistant spores** for **dispersion** & **survival** during **long inactive periods**
  - **Pioneer Organisms**
- **K-strategists:** "the resource monitors"
  - High affinity for **nutrients in low concentrations**
  - **Rate of population change** is dominated by K when the population **density is high**
  - **Growth rate** is **limited** by the **carrying capacity** (K) when the **population density is high**
  - Depend on either their **physiological adaptations** to the environment or its **carrying capacity**
  - Thrive in **resource poor environments**
  - Use their **resources for growth**, **competition**, & **survival**, not reproduction→reproduce slowly
  - Usually the most **stable** & **permanent members of the community**
  - **Climax community**

Gross Production (P) & Community Respiration (R)

- **Autotrophic succession**: **P/R > 1** (organic matter accumulates)
- **Heterotrophic succession: P/R < 1** (consumption is greater than production)

Terrestrial Environments

- Terrestrial microorganisms can degrade most anthropogenic chemical pollutants
- Soil has 3 regions: 1) **Surface** Soils; 2) **Vadose** (unsaturated) Zone; 3) **Saturated** Zone (aquifers)
- Each of these regions are made of **Porous media**, which also have 3 phases:
  1) **Mineral inorganic** (Solid) Phase: often associated with organic matter (silicates & carbonates)
  2) **Solution** (Liquid) Phase
  3) **Atmospheric** (gas) phase

Mineral inorganic Phase (Solid Phase)

- Surface area increases with decreasing soil particle size
- increased surface area causes cations to be charged
- **Cation Exchange Capacity (CEC)**: charge associated with both clay & organic particles
  → clays are negatively charged which will store or remove cations from solution
  The negative charge of clays will attract positively charged solutes
- **Absorption** affinity of a cation is a function of its charge density, which depends on the total charge & size of the cation
- **Sand**: **2mm** organic debris, surface area **0.0003 m^2/g**
- **Silt**: **50 µm** organic debris, surface area **0.12 m^2/g**
- **Clay: 2 µm** amorphous organic matter & humic substances, surface area **3 m^2/g**
- **Fine Clay: 0.2 µm,** surface area **30 m^2/g**

Organic Matter: live biomass, recognizable dead/decaying biological matter, **humic** substances

Humic Substances: heterogeneous polymers formed during the decay of organic matter

- provides **stable**, **long-term microbial nutrient base** in porous media
- some of their **components are degraded rapidly**, while **others resist degradation**
- **molecular weights** range from **700-300,000**
- **similar to clays** because they're negatively charged & have a large surface area
- they're carbon based (not silicon based) so they are much more reactive, in that they undergo slow but constant change as a result of biological activity
- the **stable fraction of soil organic matter mineralizes** at a **rate** of **~2-5%** per year, depending mostly on **seasonal soil temperatures**

- Thus organic matter serves as a slow release source of carbon & energy for the autochthonous (indigenous) slow-growing microorganisms in the soil
- Numbers of microorganisms are high in the surface soils directly surrounding plant roots
  - **Root exudates are a mixture of organic acids/sugars** and **other soluble plant components** that either **diffuse out of the root** or **are released as a result of root damage**
  - **Below the root zone**, the **organic matter content is very low**

The Liquid Phase

- Microorganisms are ~70% water, & **most require high levels of water activity (>0.95) for active metabolism**
- Cations are found in **more soluble form** in **acidic environments (most soils are acidic)**
  - For **Magnesium** & **Calcium** this results in **extensive leaching** of the soluble form of the cation, leading to decreased concentrations of the nutrient
  - For **Iron** & **phosphate** a **slightly acidic** pH provides **optimal availability of the element**
  - in **acidic soils** things will be **soluble**, whereas in **alkaline soils** things will **precipitate out**
- the **optimal environment** for **active aerobic microbial growth** in a porous medium is one which **water is easily available**, but the **medium is not completely saturated**
  - as the water potential becomes less negative, the soil will become saturated
  - in a **completely saturated environment oxygen may become limiting** because of **its limited solubility in water**.

Surface & Subsurface Zones

- The weathered end product of soil forming factors involving climate & living organisms
- Parent materials are: igneous, sedimentary, & metamorphic rocks
- During soil formation, distinctive layers (**horizons**) are formed
  - O horizon: dark, organic-rich surface layer
  - **A** horizon: **humidified organic matter accumulates**
  - E horizon: eluviation (removal or leaching of nutrients & inorganics) from the A horizon
  - **B** horizon: **illuviation** (**deposition of substances**) from the E horizon into the B horizon
  - **C** horizon: generally **unweathered parent material** form which the soil was derived
  - **R** horizon: bedrock
- **Bogs** are composed of **deep layers of waterlogged peat** & **a surface layer of living vegetation**
  - In **anaerobic** conditions, the **rate** & **extent** of **decomposition** of **organic** material is **lower**
  - Bogs become **highly acidic** (pH 3.2-4.2) as a **result of sphagnum (peat) moss growth**
  - The **combination** of **anaerobic & acidic** conditions **suppress microbial growth** which is essential for plant decomposition

The Vadose (Unsaturated) Zone

- Unsaturated **oligotrophic** zone, containing mostly **unweathered parent materials**, with **very low organic carbon content (<1%)**
- Wetlands have virtually no vadose zone
- **Endolithic Algae**: in deserts night dew seeps into rocks providing microbes with water, a thermally stable & protected habitat.

The Saturated Zone (Aquifers, Water Table)

- Oligotrophic with organic carbon content <1%; ~50% of US's potable water comes from here

Exam 1: Bonus Question

The finding of a large chemosynthetic bacterial community in the thermal vent area driven by sulfide pouring out of the vents is often referred to as a non-photosynthetic food chain; i.e. organic carbon is being produced without input from the sun.

I maintain that the sun's input is required & the chemosynthetic community could not function without the sun's participation & thus the carbon produced is in fact dependent on the sun.

Why am I correct?

Deep Sea hydrothermal vent organisms use chemotrophy (instead of photosynthesis) to fix CO_2

However, the energy used to fix the CO_2 comes from the oxidation of the sulfur excreted from the thermal vents, and this oxidation process requires the presence of dissolved O_2 in the water

Oceanic dissolved O_2 comes from either dissolved atmospheric O_2 (created largely from terrestrial photosynthesis) or is created by marine phototrophs

Thus the creation of the dissolved oxygen, needed to fixate the CO_2 at depth, is dependent on the sunlight