INTRO TO MICROBIAL COMMUNITIES

UO CHC 441H/431H : Microbes + social equity

Lecture 1

Dr. Sue Ishaq Pellegrini

Outline and learning objectives

- What are microbes?
- What are the selective pressures that determine which microbes live where?
- What is a mammal and what selective pressures do we create?
- What is a microbiome?
- Lots of info to provide some background
  - *Don't freak out*

MEET YOUR MICROBES

Microscopic + organisms = microorganisms

- Organisms that require a microscope to be seen

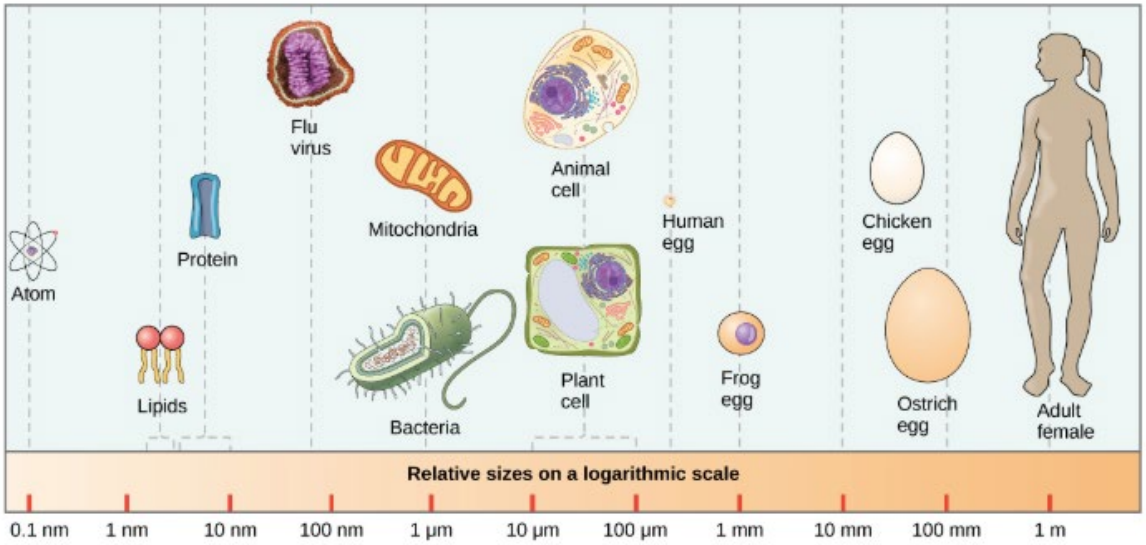
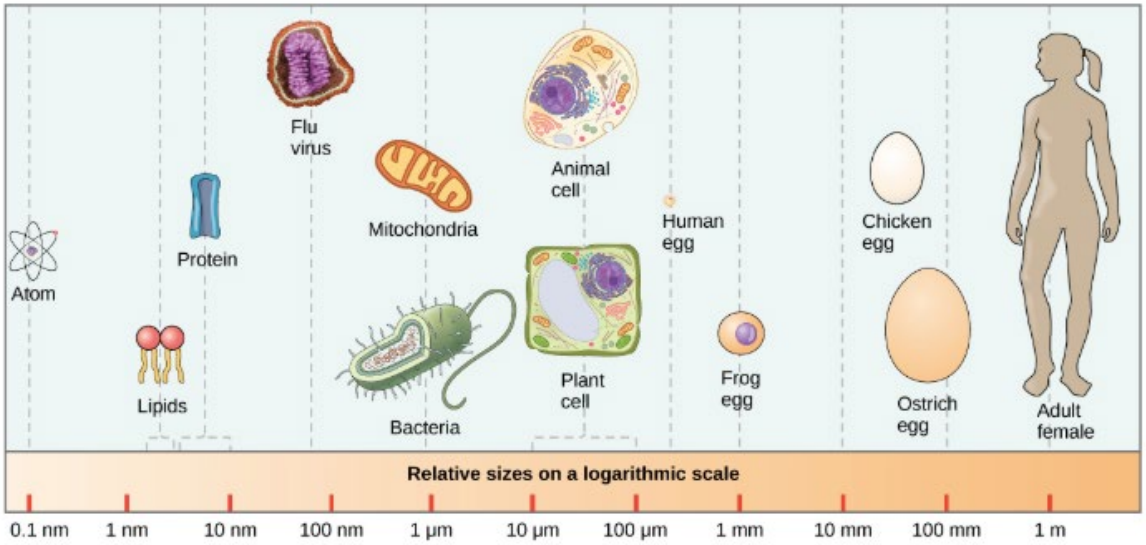


Image credit: "Prokaryotic cells: FIgure 2" by OpenStax College, Biology, CC BY 3.0

Paranema Under Light Microscope, Wikipedia

Microscopic + organisms = microorganisms

- Organisms that require a microscope to be seen
  - *viruses are included with caveats, need bigger scopes*



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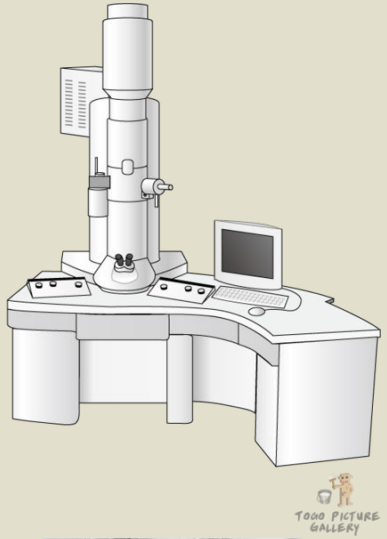
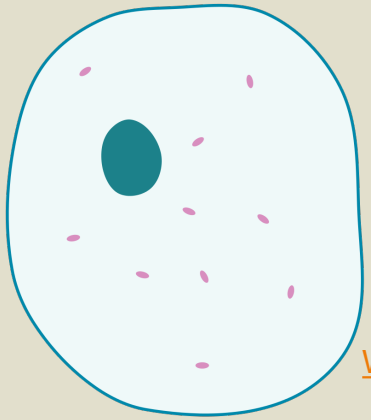


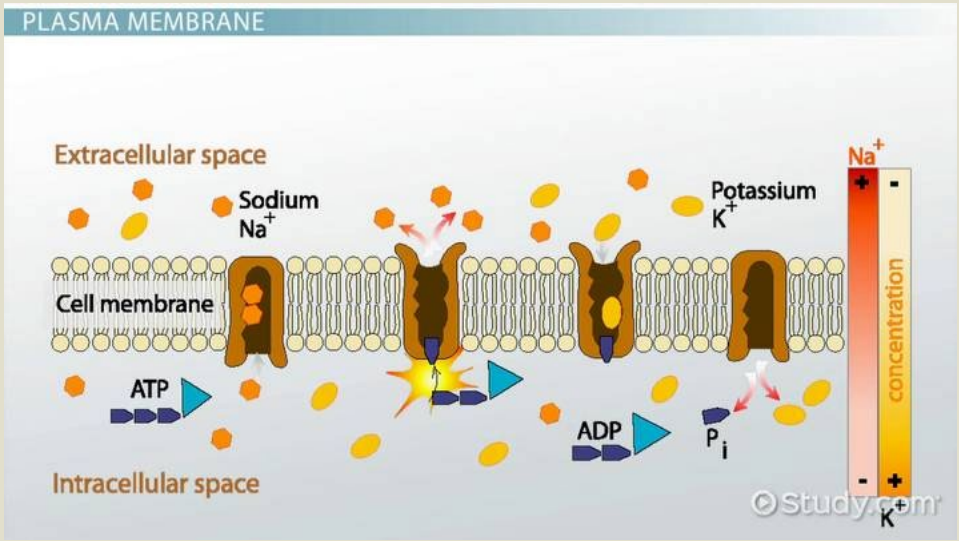
Smallpox virus virions Transmission Electron Microscope, Wikipedia

Life as a single cell – cell membrane

- All cells have a cell membrane to keep cell components insides
  - *Protection*
  - *Can act like batteries by setting up a charge gradient using chemicals*
    - Can make ATP to store energy as chemical bonds you can release later



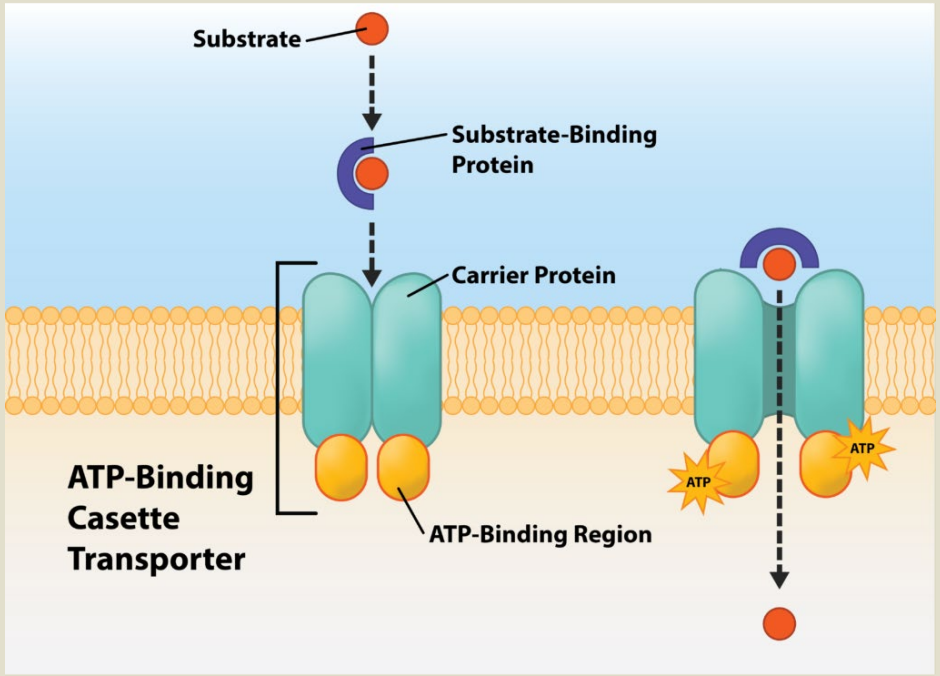
Wikimedia Commons



Study.com

Life as a single cell – feeding

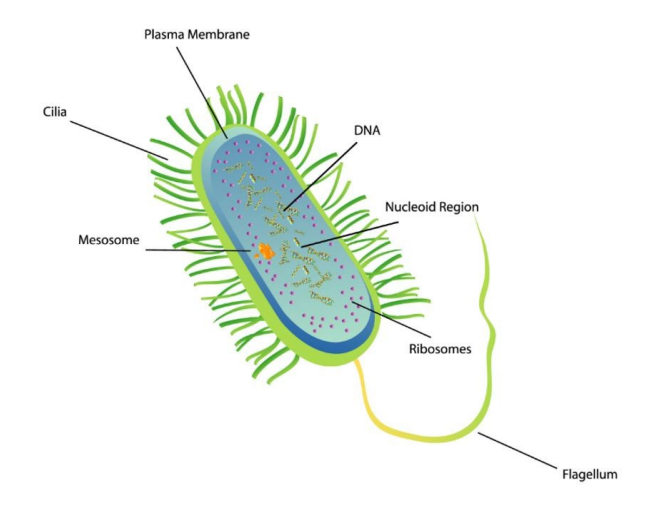
- Bring nutrients across cell membrane to eat
  - *Sometimes whole chemicals*
  - *Sometimes use enzymes to chop them into small bits outside cell*
    - Large nutrients are bulky



Microbial Nutrition | MicrobiologyOpen Oregon State

Life as a single cell – movement/motility

- Static/passive transport
- Cilia
- Flagella
- Ability to move affects virulence/infection potential and ability to stay in an ecosystem



Bacteria - Ecological Roles - SCIENTIST CINDYSCIENTIST CINDY

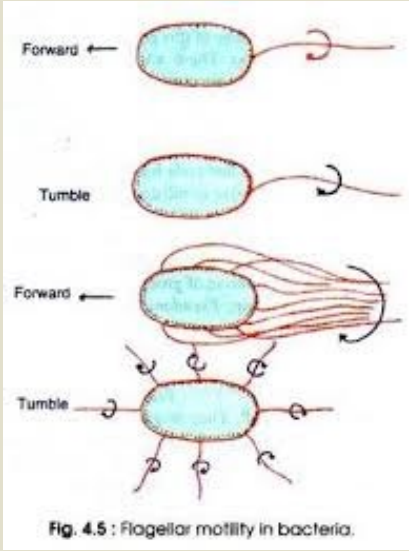
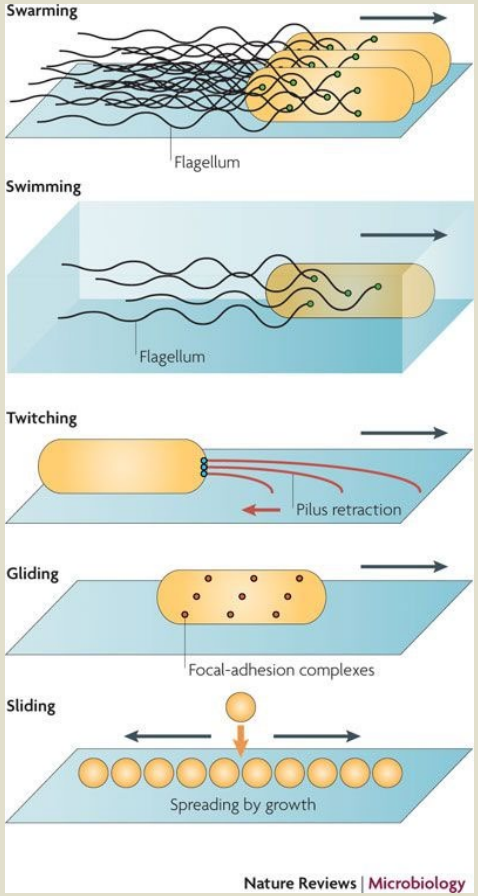


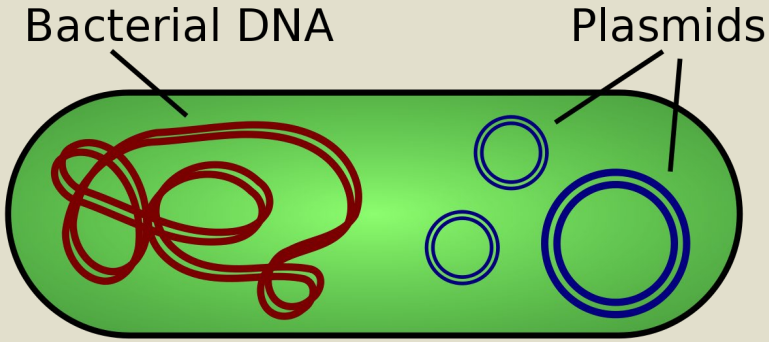
Fig. 4.5 : Flagellar motility in bacteria.

Bacterial Flagella: Definition and Locomotion | MicrobiologyBiology Discussion

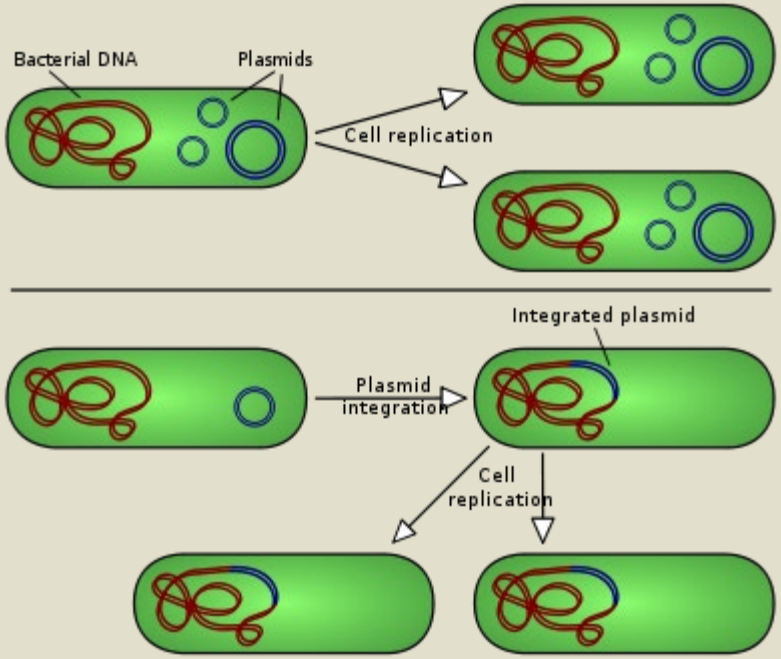


PROKARYOTES

Prokaryotes (bacteria and archaea)



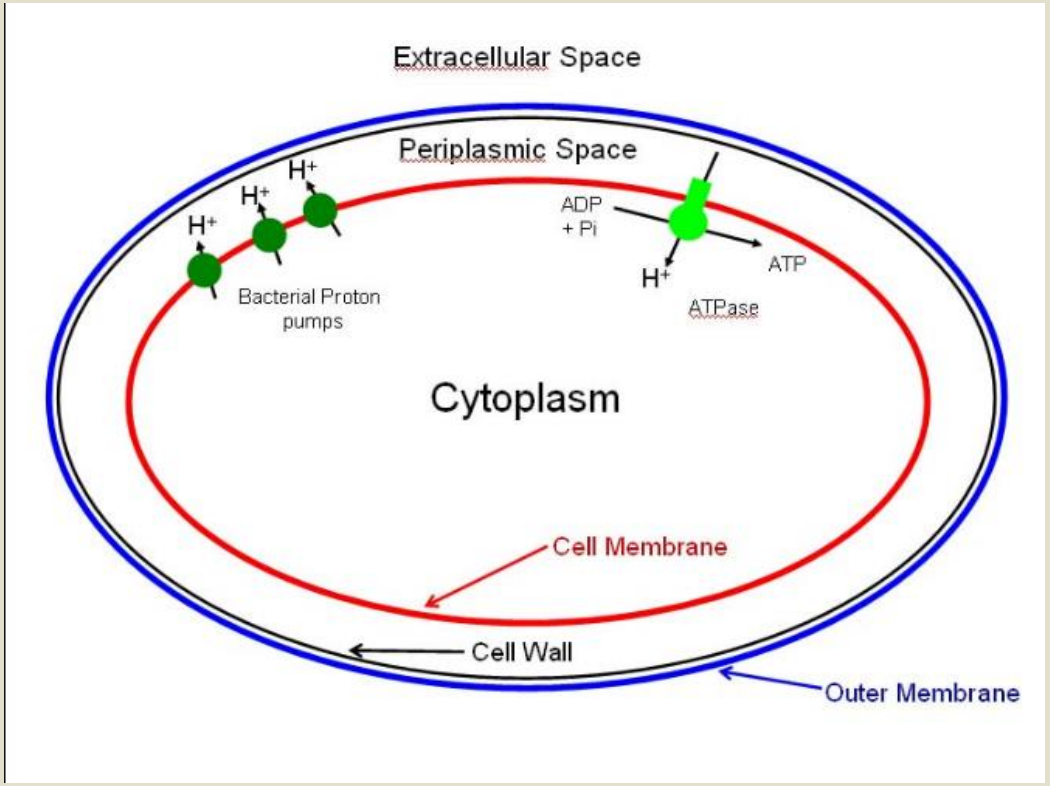
- **Microorganisms with no true nucleus**
  - *Greek origins, pro = before, kary = nut/kernel*
- No histone proteins on DNA
  - *DNA is looped to save on space, mediated by some proteins*
- +/- plasmids
  - *DNA "expansion packs" add functions*
  - *Can share between cells, pick up from environment*



Plasmid - Wikipedia

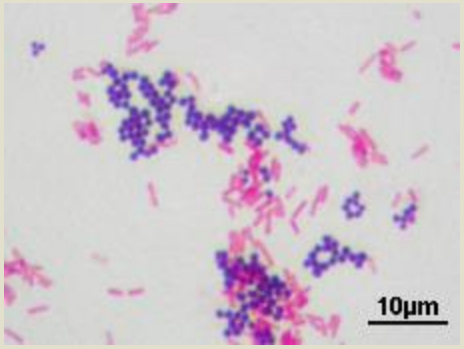
Prokaryotes
(bacteria and archaea)

- **No internal membranes or membrane-bound organelles**
  - *No nucleus, no mitochondria, no endoplasmic reticulum*
- Cell membranes can act like batteries
  - *Fewer membranes, smaller battery*



printablediagram.com

Bacteria cell walls



- Afford additional protection, adds shape and rigidity
- Sits outside of the cell membrane
- Two types, give different functions, alter host interactions, different drug targets

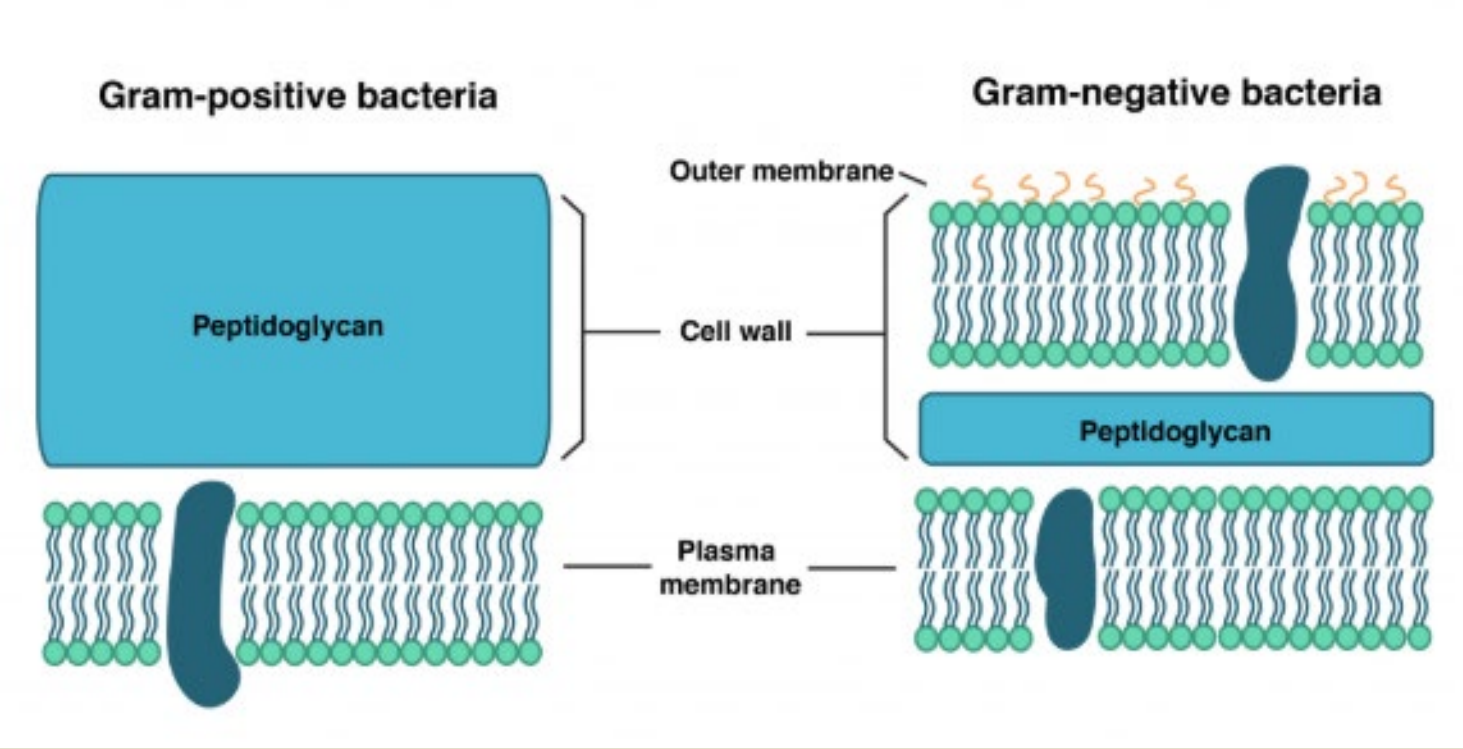
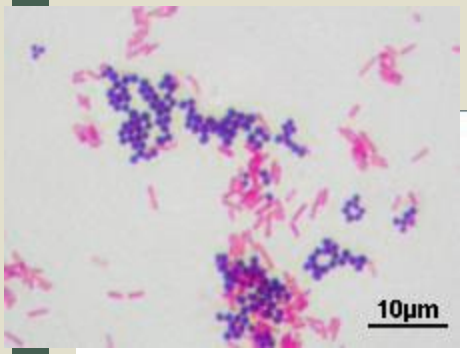


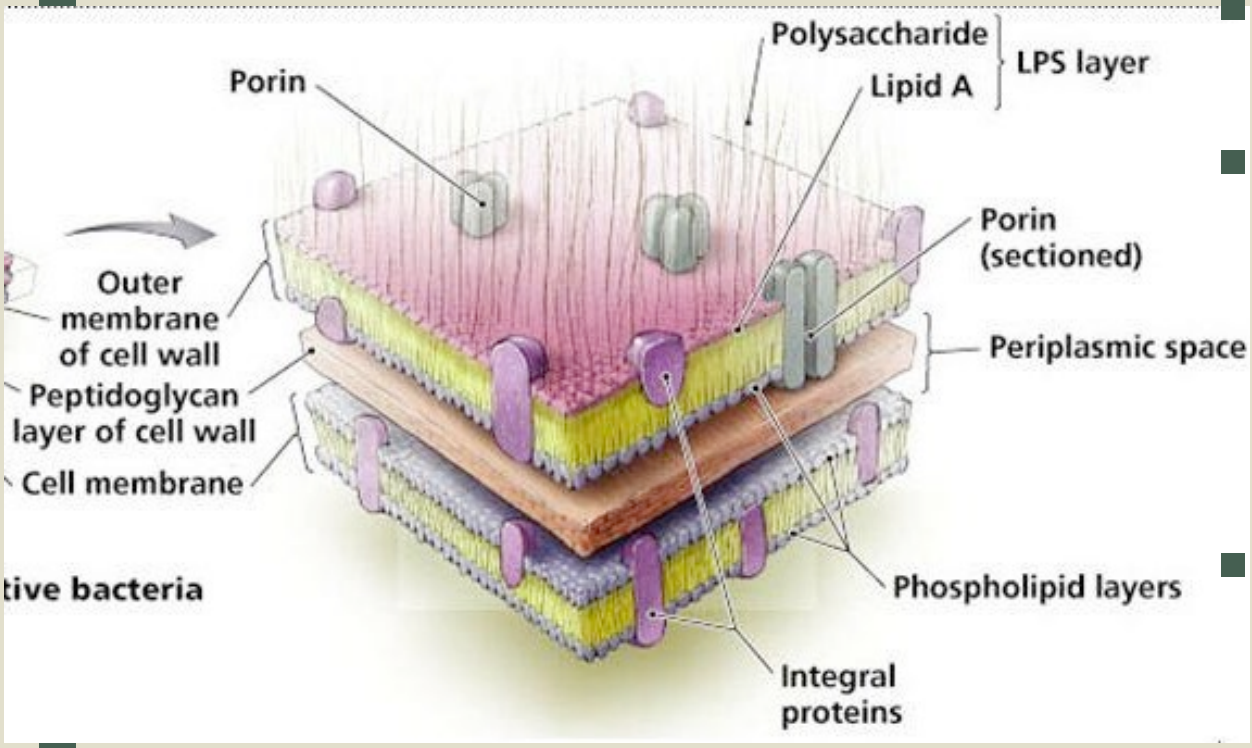
Image: http://www.onlinebiologynotes.com/bacterial-cell-wall-structure-composition-types/

Gram Positive Bacteria



- Wall is very thick, takes up crystal violet dye (positive Gram reaction)
- Peptidoglycan (70-80%)
  - *Sugar + amino acid*
- Teichoic acid
  - *carbohydrates + glycerol phosphate*
  - *Makes wall rigid*
  - *Target for antibiotics*
- Lipids (10-15%)
  - *Doesn't pick up red safranin stain*

Gram Negative Bacteria



- Peptidoglycan (10 - 15%)
- Lipids (30 - 50%)
  - *pick up red safranin stain well*
  - *More hydrophobic lipids are used to provide rigidity*
- Have an additional cell membrane outside of the cell wall
  - *Prevents wall from picking up the crystal violet dye (negative Gram reaction)*

Gram Negative Bacteria and Lipopolysaccharide

- Known as:
  - *Lipopolysaccharide A*
  - *LPS*
  - *Lipoglycan*
  - *Endotoxin*
- Component of outer cell membrane
- **Antigenic – cause immune reaction**
  - ***with or without a living bacterial cell present***

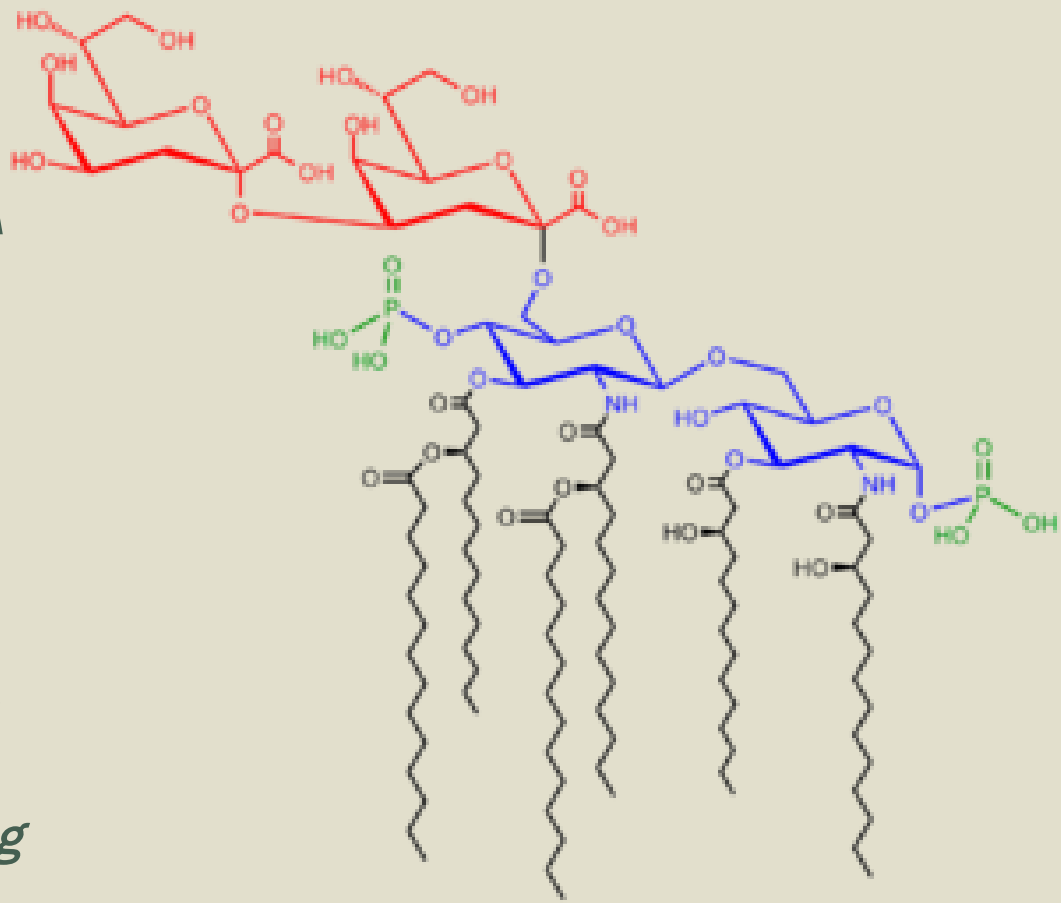
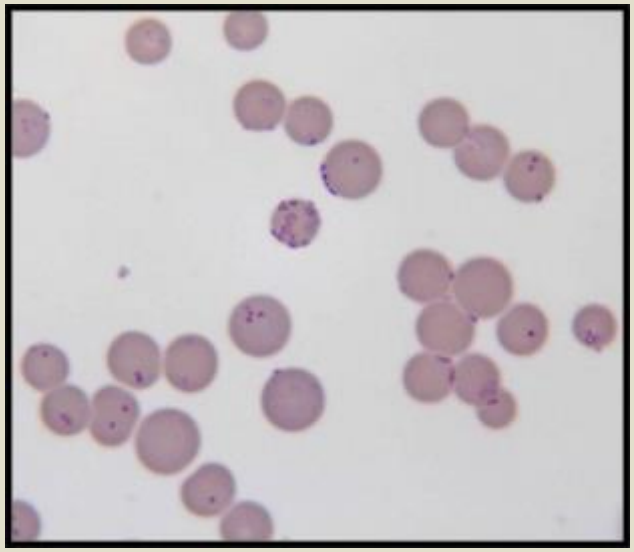


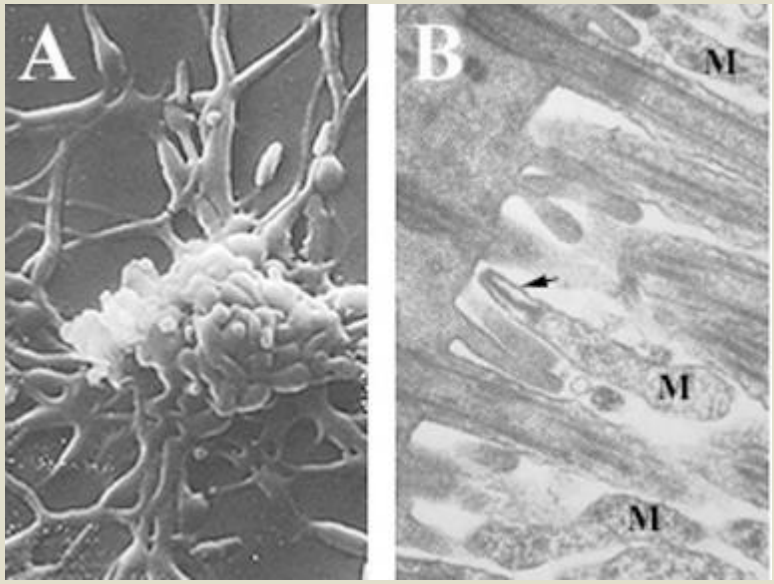
Image: Wikipedia

Mycoplasma bacteria

- Gets by with **only a cell membrane**
- Resistant to antibiotics which target cell membrane components!!

- Tend to be very small
- Have a variety of cell morphologies
- Slow growing
- Difficult to kill





Images: Wikipedia

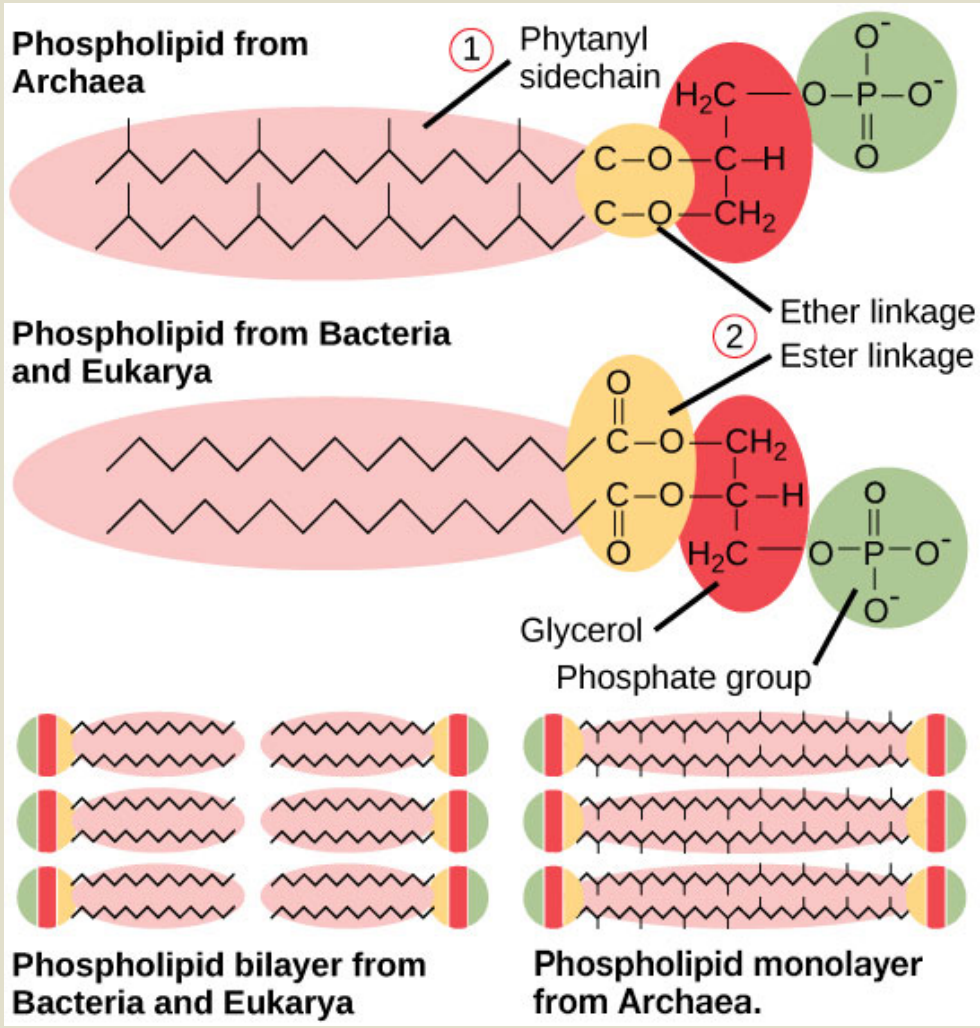
Archaea – a relatively new branch of life

- Also prokaryotes
  - *Similar to bacteria and eukaryotes*
  - *But different enough genetically to be in own domain*

- discovered 1980, Carl Woese
  - *Previously thought to be bacteria*
  - *Very small, hard to see*
  - *Old publications refer to "methane-producing bacteria" but actually methanogenic archaea*

Archaea – a relatively new branch of life

- Often in extreme environments
  - *Cell membranes have lots of lipids with ester linkages – temperature stabile*
- Generally only good at living in one environment
  - *Specific substrates only*



Archaea | Microbiology

Host-associated archaea

- **Gut has very low archaeal diversity!!**
  - *Influenced by diet, host type*
  - *Sometimes just one genus*
- Mostly methanogens
  - *Families Methanobacteriaceae, Methanosarcinaceae,*
  - *Scavenge hydrogen and certain carbon compounds to make energy, generate methane in process*
- Some halophiles in wild animals
  - *but possibly from diet/water sources*

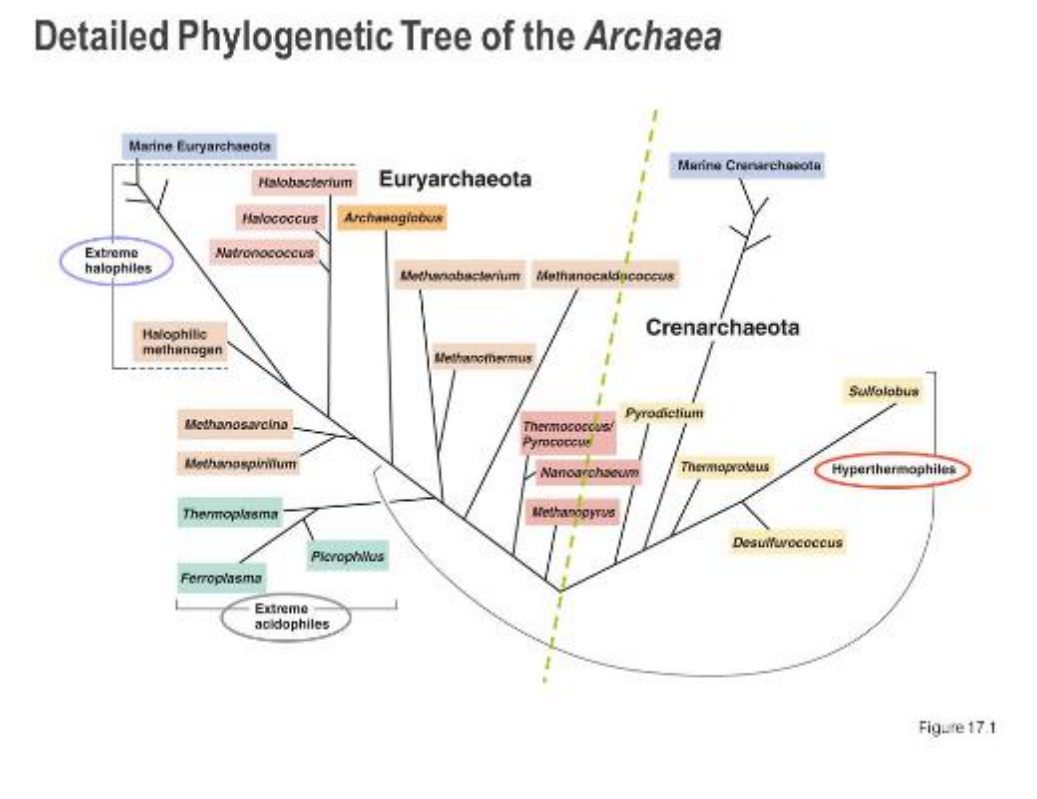


Image: https://slideplayer.com/slide/7743998/

Bacteria vs. Archaea

Different structures mean Archaea don't respond to most antibiotics

Bacteria

- Cell wall made of peptidoglycan (and lipopolysaccharide-A in gram-)
- Some have no cells walls
- Flagella use different structural proteins and mode of assembly
- Found almost everywhere
- Reproduction by binary fission, budding, or fragmentation
- **Can form spores in harsh conditions**
- Bacteriophages

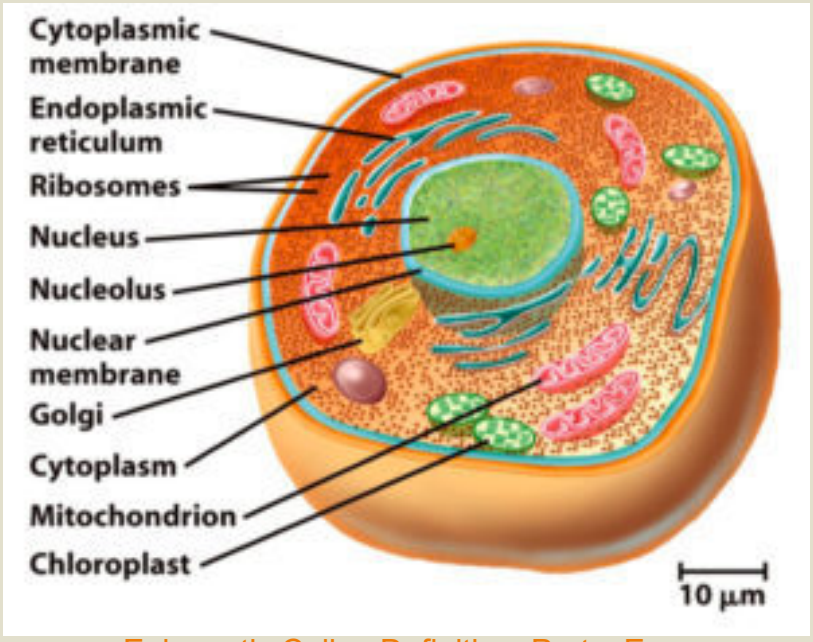
Archaea

- Cell wall made from pseudopeptidoglycan
- So far all have cell walls
- Flagella use different structural proteins and mode of assembly
- Usually in harsh or closed environments
- Reproduction by binary fission, budding, or fragmentation
- **No spore formation**
- Archaeophages- no evidence of gene transfer from bacteria to archaea via phages

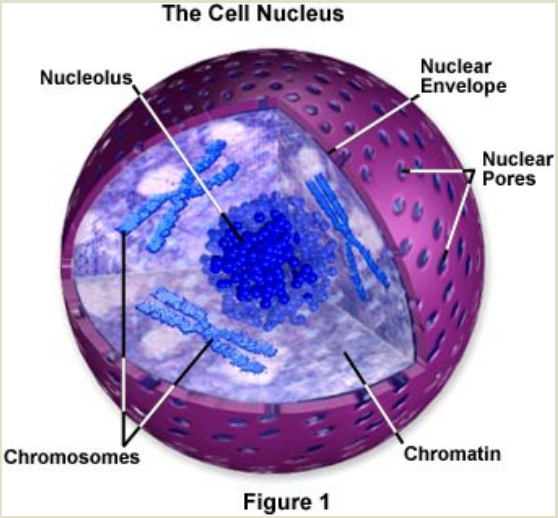
EUKARYOTES

Eukaryotes

- Single (microscopic) or multi-cellular
- Other membrane-bound organelles
  - *Mitochondria, chloroplasts, endoplasmic reticulum, nucleus*
- Nucleus contains DNA for added protection
- DNA arranged in linear chromosomes



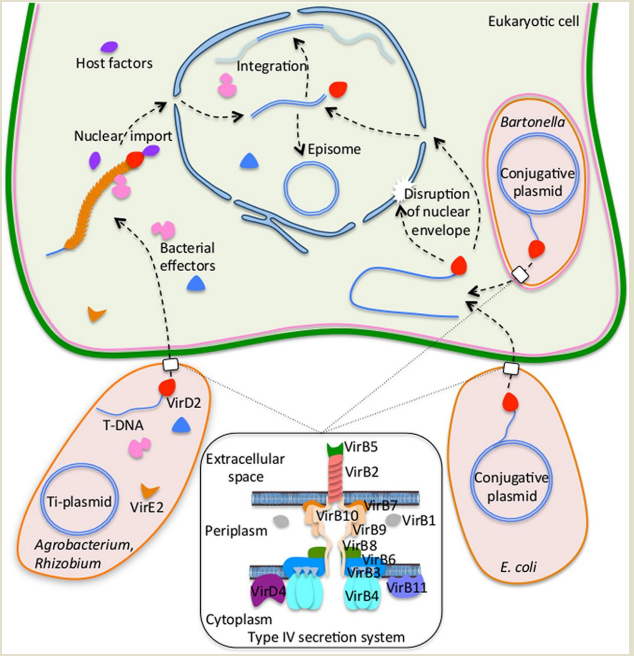
Eukaryotic Cells - Definition, Parts, Exam



Molecular Expressions - Florida State University

Eukaryotes

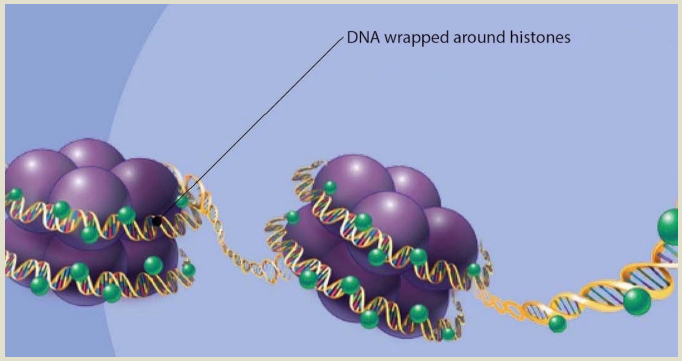
- +/- plasmid DNA
  - *Some bacterial plasmids can be transferred to eukaryotes*
  - *But not humans, it won't replicate without a vector.* *https://biology.stackexchange.com/questions/39197/why-cant-we-use-plasmids-to-add-genes-to-ourselves*
  - *BioShock is Sci-Fi*



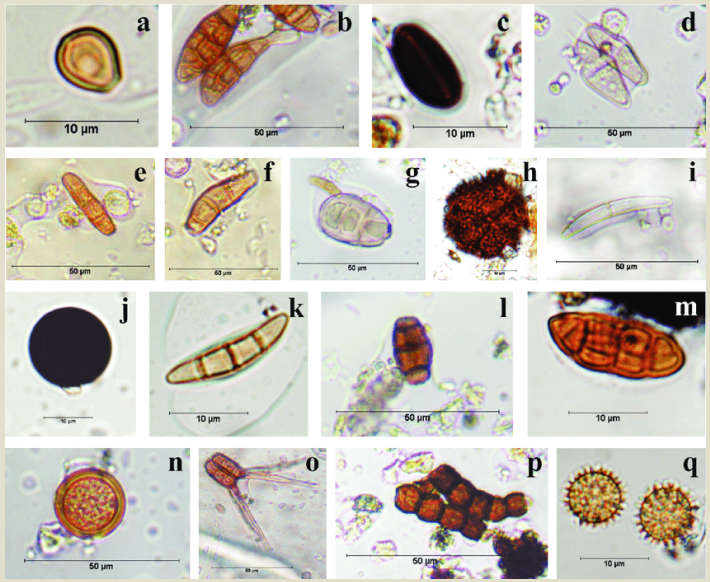
mBio - American Society for Microbiology

Eukaryotes

- DNA is wrapped around histones to regulate transcription
  - *DNA replication more complicated*
- Cell membrane contains sterols
  - *flexible*
- +/- cilia, flagella, cell walls
- Different sizes of ribosomal RNA and number of associated proteins
  - *More on this tomorrow*
- Some Fungi produce spores



Histone Code: A Challenge to Evolution,



Fungal spore types found during sam…

Prokaryotes

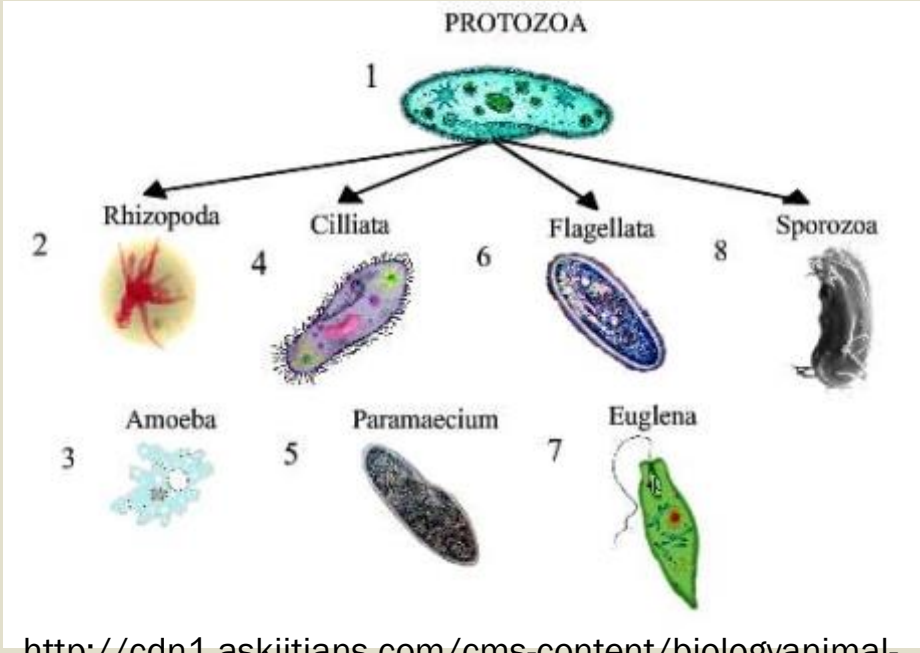
- Nucleoid mass of DNA
- One circular chromosome
- +/- plasmid DNA
- No membrane-bound organelles, used cell membrane to generate energy
- Only Archaea in phyla Thermoproteales and Eukaryota have histones
- +/- cilia, flagella, pili, fimbriae, cell walls
- Different sizes of ribosomal RNA and number of associated proteins
- Some Bacteria produce spores

Eukaryotes

- Nucleus
- Linear chromosomes
- +/- plasmid DNA
- Other membrane-bound organelles
- Histones to regulate transcription
- +/- cilia, flagella, cell walls
- Cell membrane contains sterols
- Different sizes of ribosomal RNA and number of associated proteins
- Some Fungi produce spores

Protozoa

- Eukaryotes
  - *Very diverse*
  - *Originally classified as animals because they are motile and may be predatory (protozoa = "primitive animals"*



http://cdn1.askiitians.com/cms-content/biologyanimal-kingdomphylum-protozoa_5.jpg

- Eventually got their own Kingdom, classified by
  - Type of motility
  - Nutrition
    - Animal-like: heterotrophs
    - Plant-like: (also called algae) autotrophs
    - Fungus-like: heterotrophs, decomposers, external digestion

Host-associated protozoa

- Commonly found in the rumen (4-chambered stomach)
  - *Ciliated protozoa*
  - *Digest bacteria or fiber*

- In monogastrics (animals with one stomach chamber)
  - *(Beneficial) ciliated protozoal may be in cecum*
  - *Typically only pathogenic flagellated species found*
  - *Motility in monogastrics may be too high, GI tract too short, to support many protozoa*

Ophryoscolex, Wikipedia

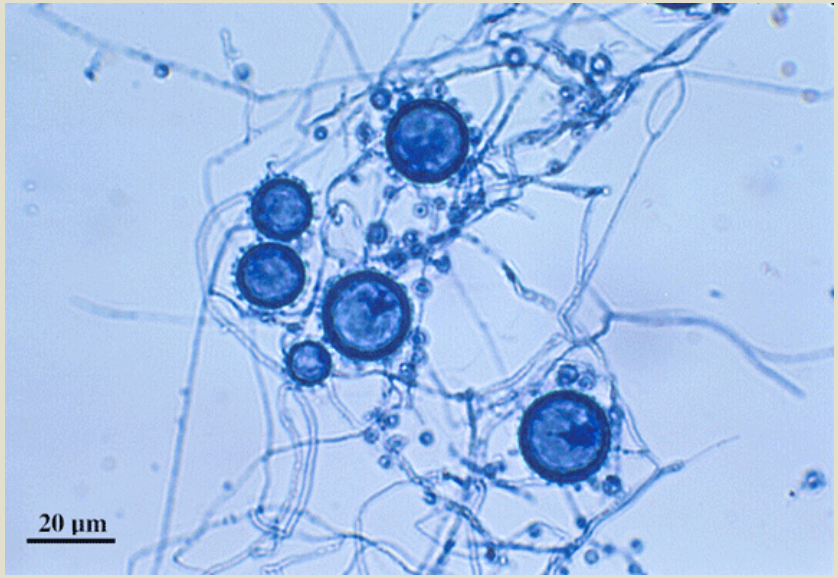
Giardia, Pixnio

Microscopic fungi (microfungi)

- Eukaryotes
- Unicellular: yeasts
- Filamentous (multicellular): molds
- Distinguished from macrofungi because lack a large fruiting body

- Cell walls have chitin
- Have hyphae
- Produce spores

- *Penicillium* and *Aspergillus* are microfungi



http://www.mycology.adelaide.edu.au/gallery/dimorphic_fungi/histo6.gif

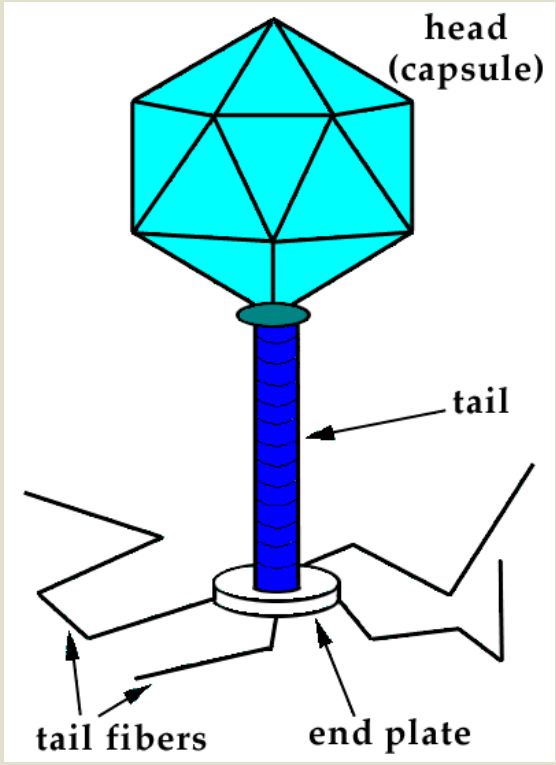
Comparison across domains (Wikipedia)

Property	Archaea	Bacteria	Eukarya
Cell membrane	Ether-linked lipids, pseudopeptidoglycan	Ester-linked lipids, peptidoglycan	Ester-linked lipids, various structures
Genestructure	Circular chromosomes, similar translation and transcription to Eukarya	Circular chromosomes, unique translation and transcription	Multiple, linear chromosomes, similar translation and transcription to Archaea
Internal cellstructure	No membrane-bound organelles (questioned[56]) or nucleus	No membrane-bound organelles or nucleus	Membrane-bound organelles and nucleus
Metabolism[57]	Various, with methanogenesis unique to Archaea	Various, including photosynthesis, aerobic and anaerobic respiration, fermentation, and autotrophy	Photosynthesis, cellular respiration and fermentation
Reproduction	Asexual reproduction, horizontal gene transfer	Asexual reproduction, horizontal gene transfer	Sexual and asexual reproduction

VIRUSES

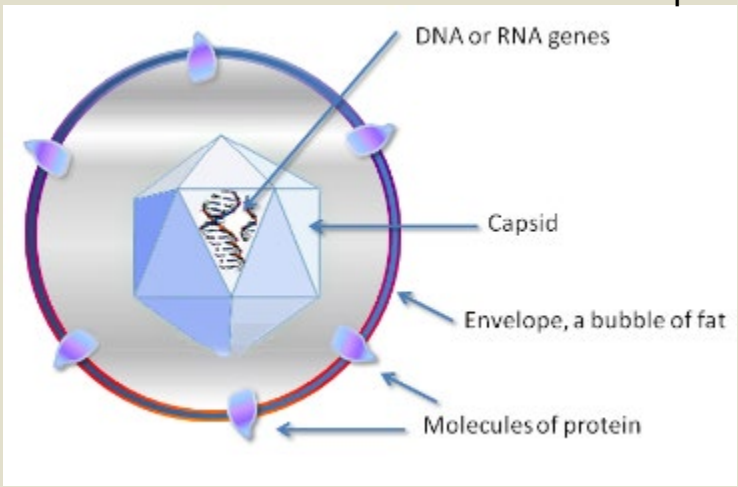
Viruses

- Parasitic in nature- only replicate inside other cells using that cells' machinery
- (Usually) specific to host or a host type (ex. plants, bacteria, or archaea)
- Contain:
  - *Genetic material (DNA or RNA)*
  - *Capsid protein coat*
  - *+/- lipid envelope*



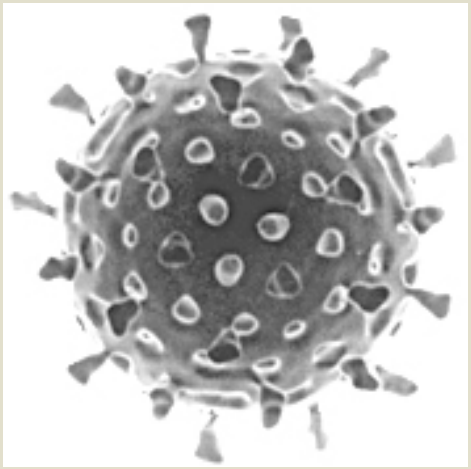
http://www.ucmp.berkeley.edu/alllife/virus.gif

Wikipedia

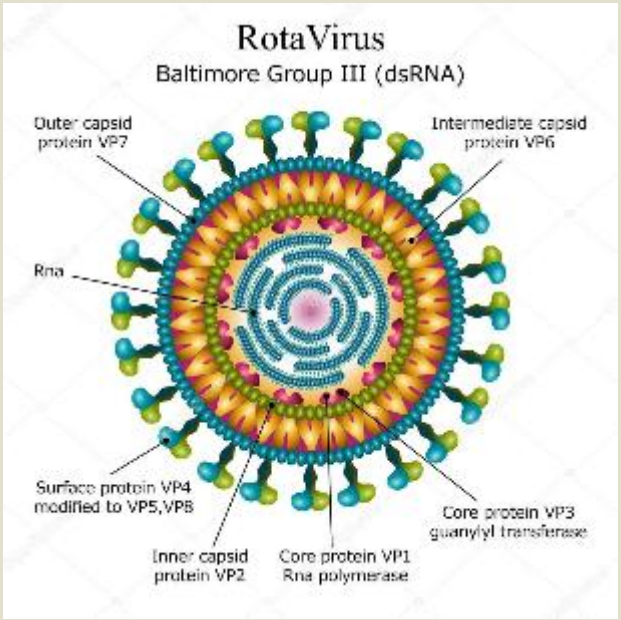


Viruses

- Are all very different – no core set of genes
  - *Need to use sequencing tech that gets everything (i.e. shotgun metagenomics or metatranscriptomics)*



- Not alive
  - *can't replicate on their own*
  - *technically can't be killed*
  - *can be destroyed (decay rate)*



- Can remodel microbial ecosystems by killing off microbes
- Affect the host and susceptibility to bacterial infection

Image: nl.depositphotos.com

MICROBES ON THE TREE OF LIFE

Environmental (host environment) factors are important to determine "who" is found where

- Temperature
- pH
- Salinity
- Available nutrients
- Flow/stability
  - *Abrasion off surfaces*
  - *Transit through GI tract*
  - *Movement of mucus through airways, GI, vagina*
- Contact/transfer with other microbial sources
  - *Ex. Skin contact*

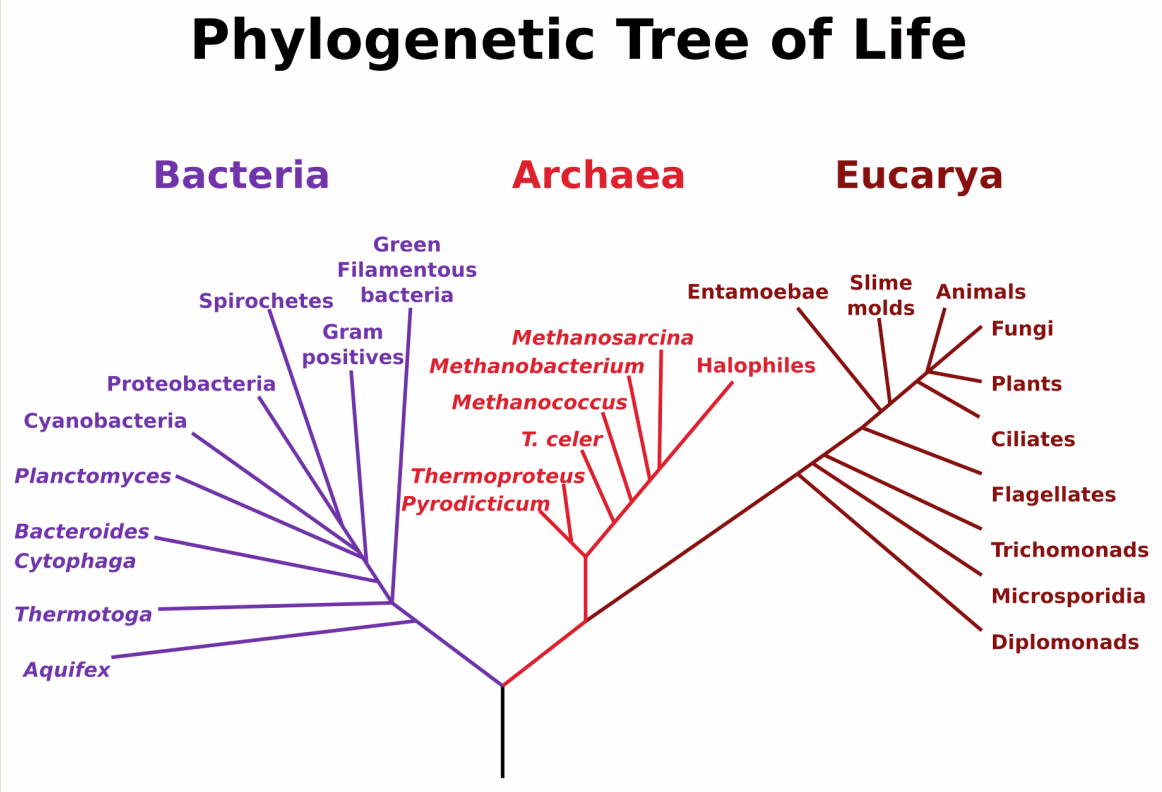
Environmental conditions select for genetic traits that help an organism survive

Genetic selection, natural selection

- Different environments require different genetic abilities
- Over time, only certain organisms survive and those genetic abilities are more common

Phylogeny

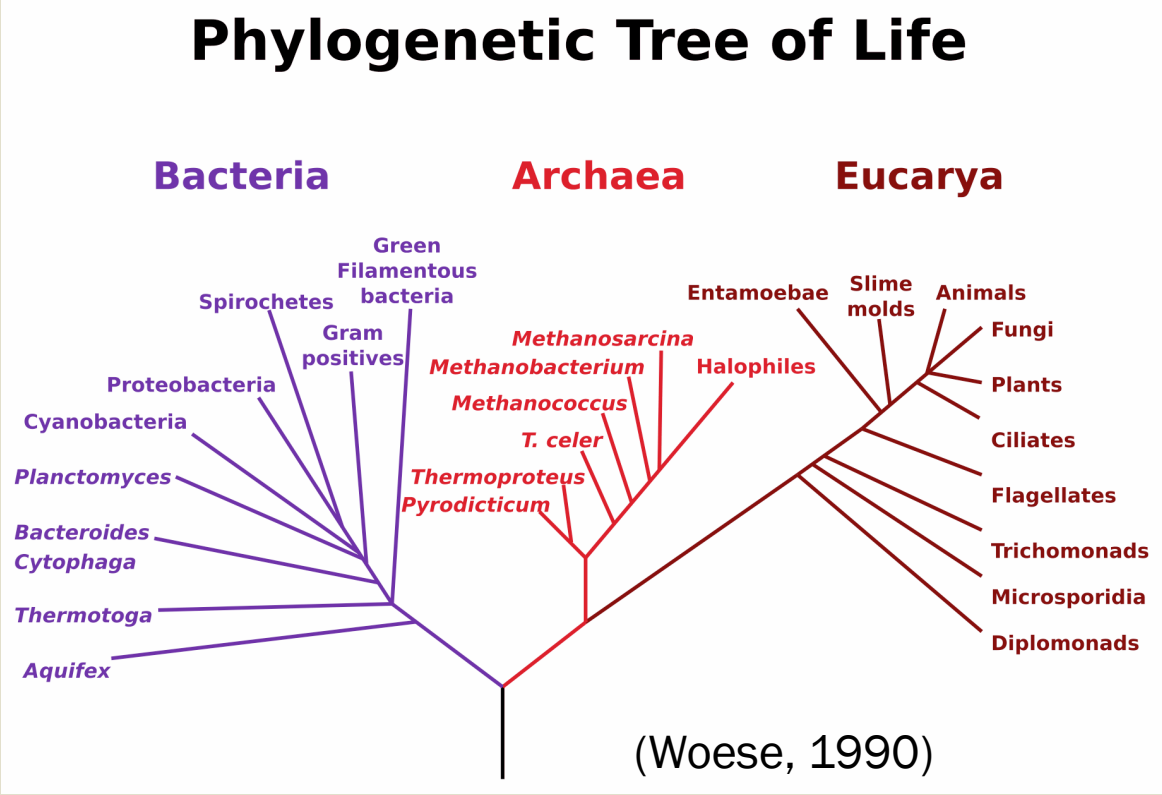
- evolutionary development of a gene/species/group of organisms
- Compare genomes between organisms to look for changes



The Three Domains of Life : the biological filing system

Phylogeny helps us answer questions

- How do living things change over (very) long periods of time?
- How are different organisms related?
  - *And when did we become different?*



The Three Domains of Life: microorganisms

Prokaryotes:

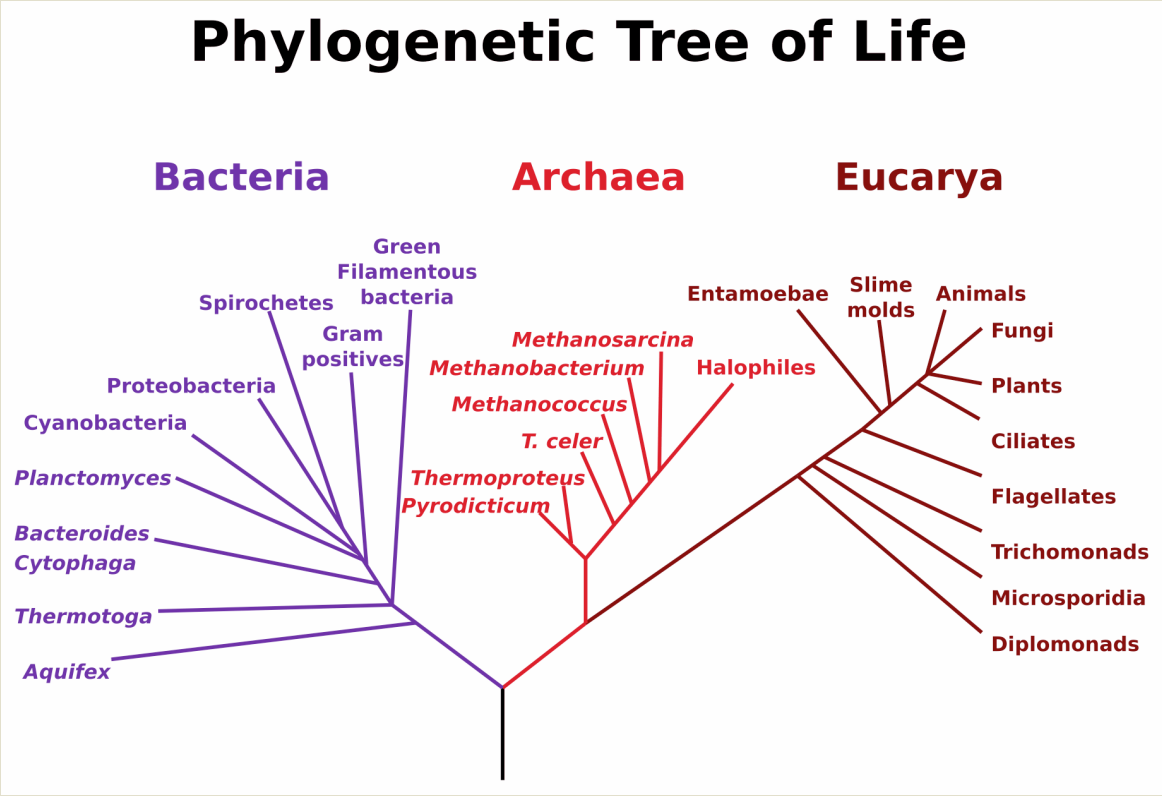
- Bacteria
- Archaea

Eukaryotes:

- Protozoa
- Microscopic Fungi
- Microscopic Algae

?:

- Viruses

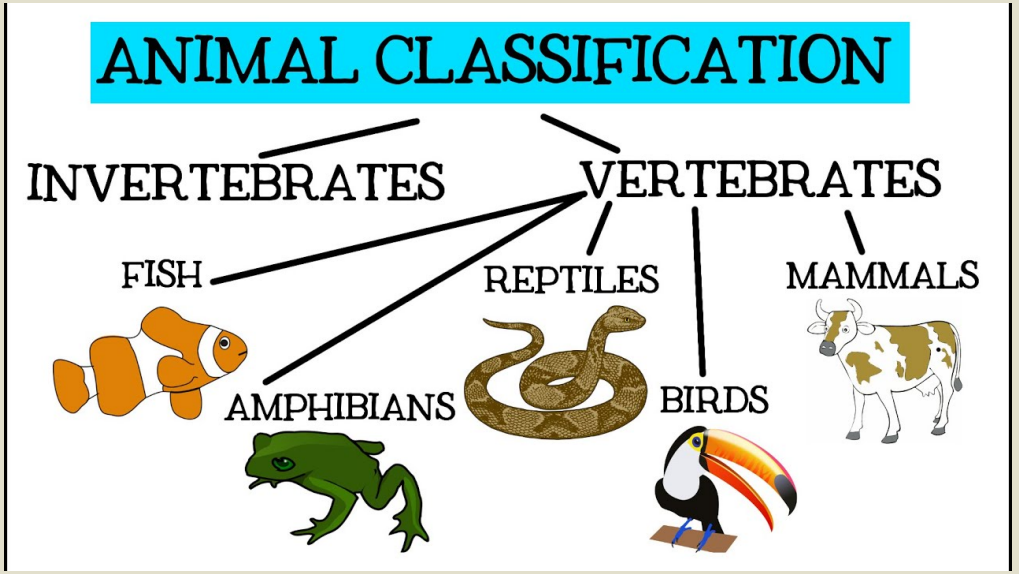


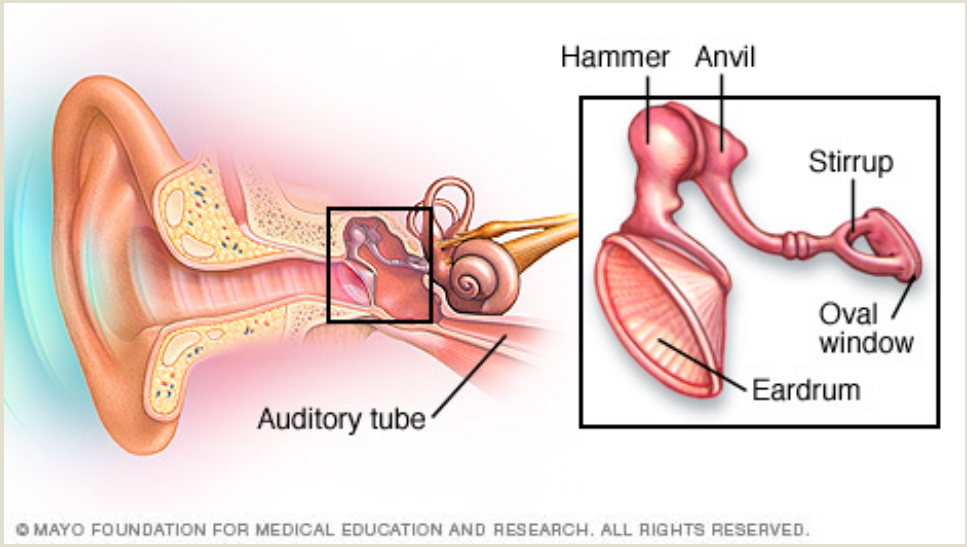
WHAT IS A MAMMAL?

Spoiler alert, it's you

Mammalian characteristics

- Vertebrate (has a spinal cord)
- Three middle ear bones (hammer, anvil, stapes)





https://www.youtube.com/watch?v=mRidGna-V4E

Mammalian characteristics

- Neocortex (region in the brain)

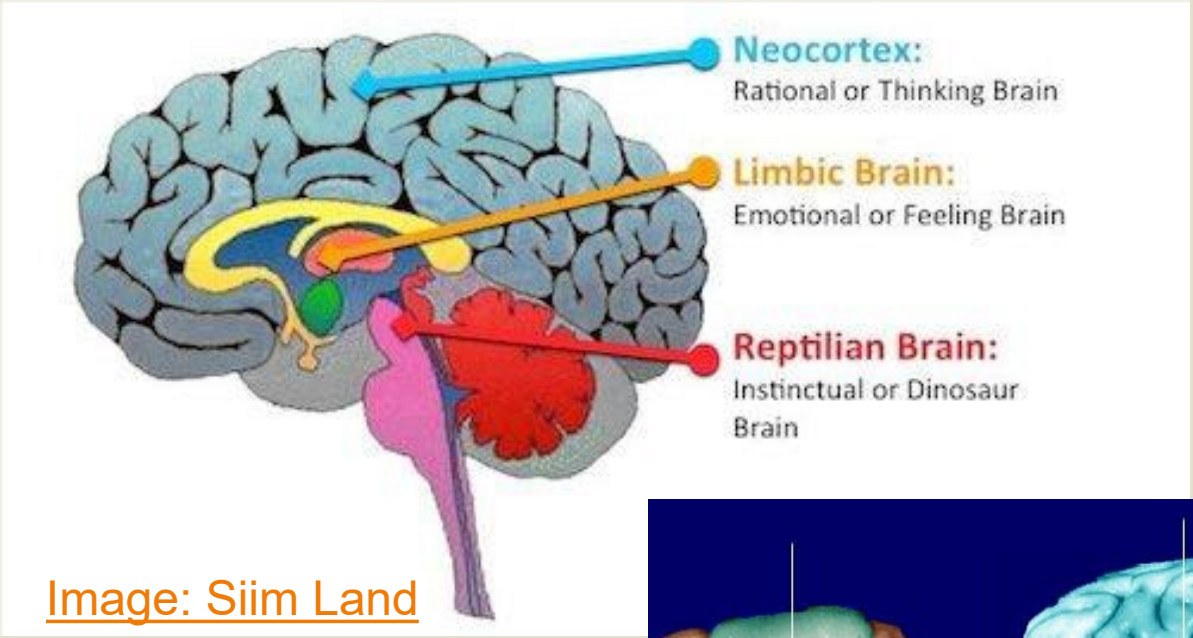
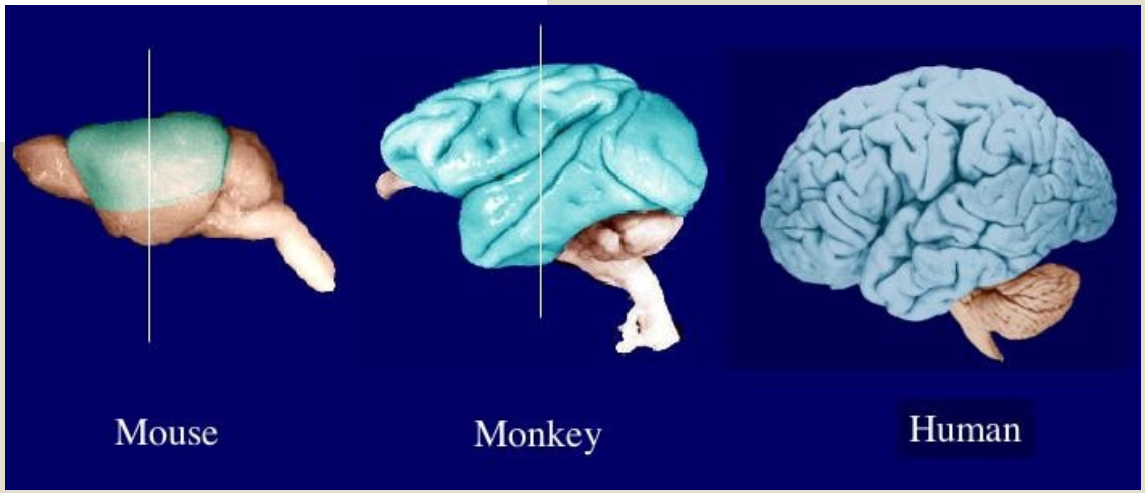


Image: Siim Land

graduatesocialpsych.weebly.com



Mammalian characteristics which affect our microbial community

- Exothermic (makes own heat, warm blooded)
- Hair
- Females secrete milk from their **mammary gland**
  - *Breastmilk has microbes in it*
- Typically give birth to live young
  - *Have placenta and mother-fetus tissue connection*
  - *Exception: platypus and 4 types of echidnas lay eggs*

Images: Wikipedia

Host environments select for different microbial populations

If body ecosystems select for microbes…
we can intentionally select for microbes by changing the ecosystem!

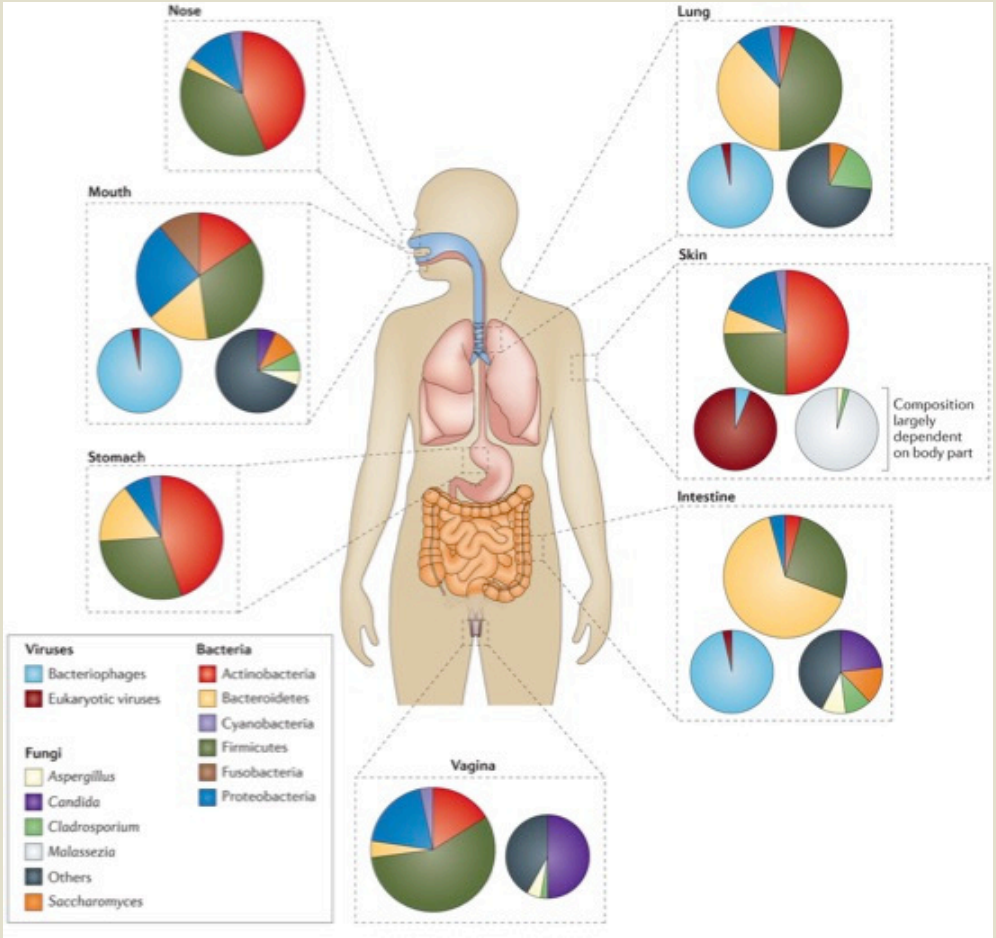


Image: Marsland & Gollwitzer 2014

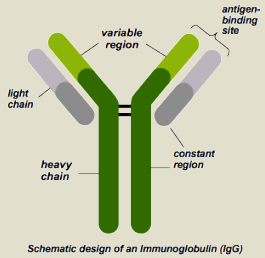
Mammalian body ecosystems are actively interacting with microbes

- Maternal transfer of
  - *Antibodies (last a few months)*
  - *Microbes*
- Maternal transfer occurs:
  - *+/- across placenta*
  - *Colostrum/milk*
    - Colostrum is produced in first few days of milk
    - Higher in fat, protein, antibodies, and microbes than regular milk

Colostrum Milk

Image: Wikipedia

Immune systems regulate host-microbe interactions



Schematic design of an Immunoglobulin (IgG)

Passive (innate)

- Born with it
  - *automatic*
  - *reacts similarly to all challenges*
- Skin as a barrier
- Mucus and cilia on epithelial lining
- Inflammation response
- Fever response

Active (acquired)

- Lymphocytes are cells of immune system
  - *B cells mature in Bone marrow, produce antibodies*
  - *T cells mature in Thymus, kill body cells infected by virus*
- Foreign chemical or microbe that triggers innate system is found, chewed up, and pieces are displayed on the outside of Antigen-Presenting Cells
- B-cells build antibodies to match/bind
- Allows other immune cells to recognize and destroy the microbe or chemical

WHAT DOES IT MEAN TO BE HOST-ASSOCIATED?

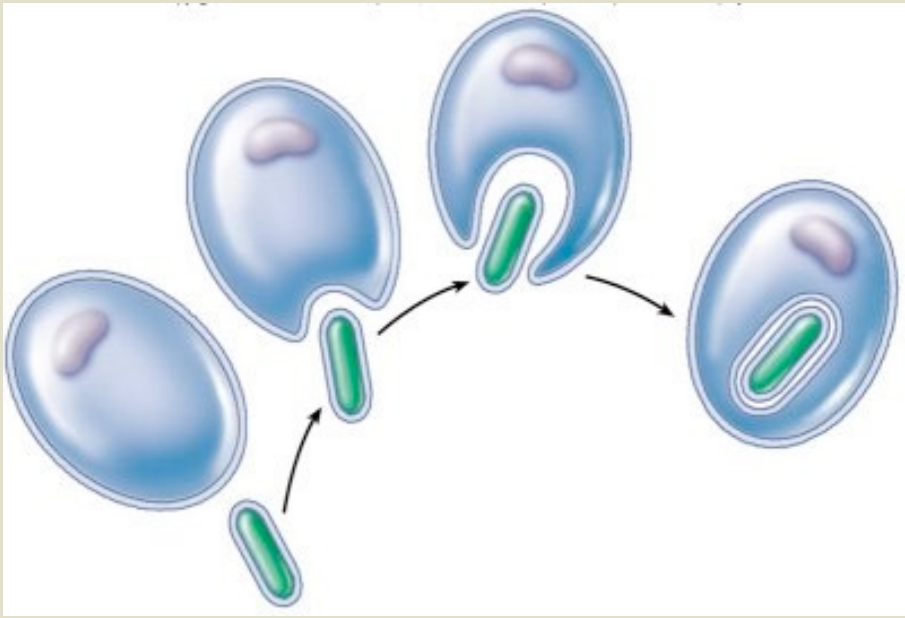
Long history of bacteria-eukaryote association

- Cyanobacteria produced enough oxygen to change atmosphere
  - *Allowed for larger organisms*

- Chloroplasts and mitochondria used to be bacteria
  - *Evolved from symbionts living in large cells to part of the cell*
  - *Have their own DNA*
    - Mitochondrial DNA related to *Rickettsia*
  - *Added secondary membranes to allow more energy generation*
    - More energy = larger cells possible

Phylogenetics and Endosymbiotic Theory

- 1981 Lynn Margulis
  - *New species may arise from the merger of other organisms*
  - *Bacteria + bacteria = first nucleated cells*
    - Happened again to become chloroplasts and mitochondria



- Tested using phylogeny and finding the same DNA in phenotypically unrelated organisms

endosymbiotichypothesis.wordpress.com

Mitochondria in Eukaryotic cells

- Mitochondrial DNA somewhat related to ancestral *Rickettsia* (bacteria)

- Bacterial association would have added oxidative phosphorylation
  - *More energy generation per cell size*
  - *Large cells (volume per surface area) because have more membrane along which to generate energy*

What makes them host-associated?

- Microbial community found in/on a host

- Native populations; **indigenous**, **autochthonous** (aw-talk-tho-nus)
  - *Form a symbiotic relationship with host?*
    - Interacts with host immune system
  - *Have adapted to that environment?*
    - Motile or good at attaching to epithelia
  - *If removed from the host will likely come back?*

What makes them host-associated?

- Diet-borne populations (heterochthonous)
  - *Presumably would die out if stopped eating that food*
- Transient populations (heterochthonous)
  - *Infections*
  - *Ingested from air, soil, etc. but not well suited to host*
- These still impact host health
- Source of nutrients or water
- Source of genes that can be transferred

Images: Pixabay, Max Pixel

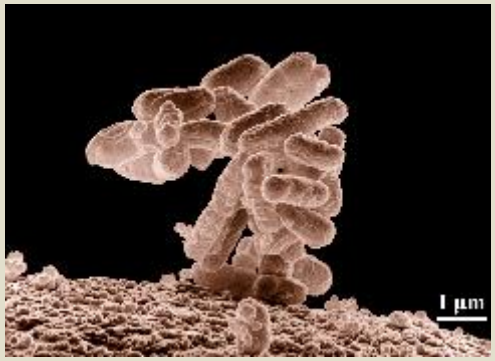
Word play- microbe/host relationships

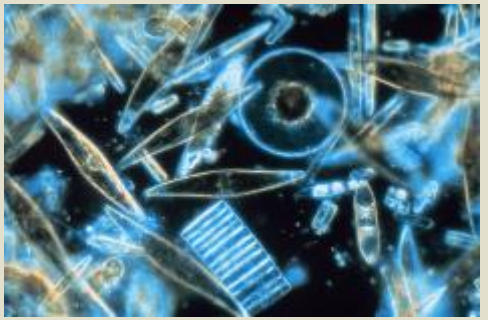
- Symbiont/Mutualist
  - *Both organisms benefit from the association*
- Syntrope
  - *Cross-feeding between organisms*
  - *Particularly helpful in low-nutrient environments*
- Commensal (‘eating at the same table”)
  - *No cost to the host, but benefit to the microbe*
  - *What about opportunistic pathogens?*
- Pathogen
  - *Causing harm to one of the organisms in the association*
- Pathobiont/opportunist
  - *Symbiont that occasionally is pathogenic*

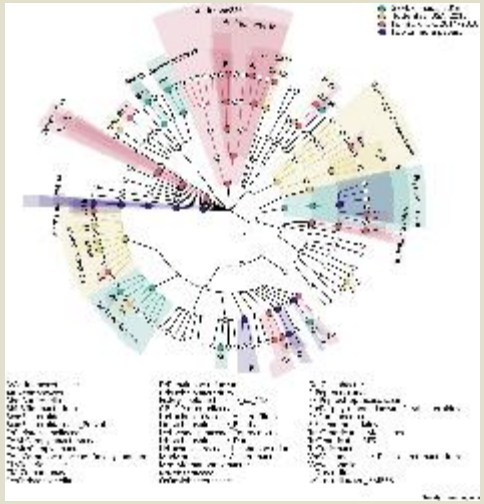
Images: Wikipedia, Cell

Word play

- Microscopic + organisms = **microorganisms**
- **Microbe** = slang, and sometimes just bacteria?
- **Microbiota/Microbial Community** = <u>all the MICROORGANISMS</u> in a community/environment
  - *Who*
- **Microbiome** = **<u>all the GENETIC material</u> in a community/environment**
  - *Who and What*
  - *Just looking at bacteria DOES NOT COUNT AS MICROBIOME*







FINDING OUT WE'RE JUST 1 TRILLION MICROBES DRESSED UP IN A TRENCH COAT

Host-associated microbiomes become a thing

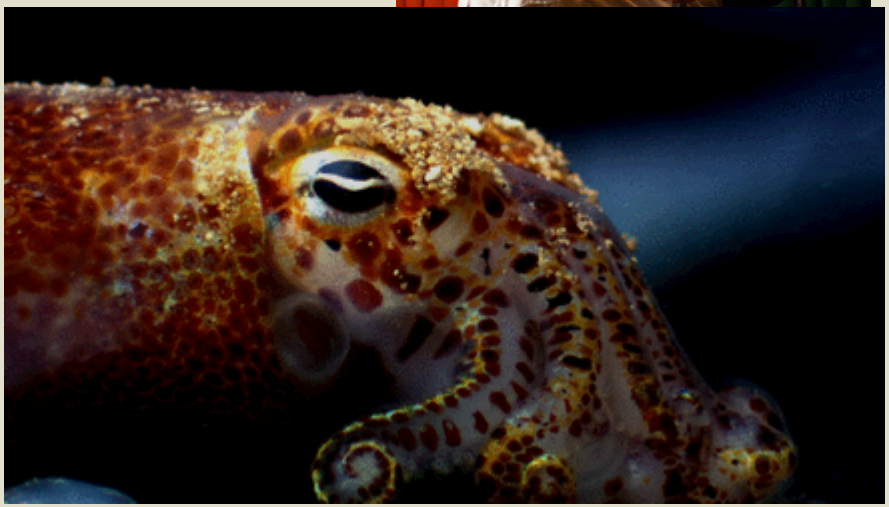
- Robert Hungate (1906 – 2004), from Cheney, WA
- Initially studied termites and fermentation
- Began working on ciliate protozoa in the rumen in the 1970s
  - *Developed roll tube culture method for **anaerobes***
    - Can inject/remove headspace gas
  - *Sparked interested in host-associated microbiomes and ability to culture them!*

Hungate, R. E.; J. Macy (1973). "The roll-tube method for cultivation of strict anaerobes". Bulletins of the Ecological Research Committee: 123–126.

Learning that the host microbiome interacts with host tissue

- Margaret J. McFall-Ngai
- Began research in 1978 and microbes were only thought to be pathogens or for decomposition

- Discovered that Hawaiian bobtail squid (*Euprymna scolopes*) need symbiotic bacteria (*Vibrio fischeri*)
  - *Microbes produce molecules so that host recognizes them*
  - *Squid undergoes circadian rhythm in the tissues that host the microbes that facilitate their growth*



Hawaiian bobtail squid, Images: Viegas 2017

Human Microbiome Project

- Launched in 2007
- Understand the microbial community in different body locations
- Understand what the microbial community is doing
- https://hmpdacc.org/

Host environments select for different microbial populations

If body ecosystems select for microbes…
we can intentionally select for microbes by changing the ecosystem!

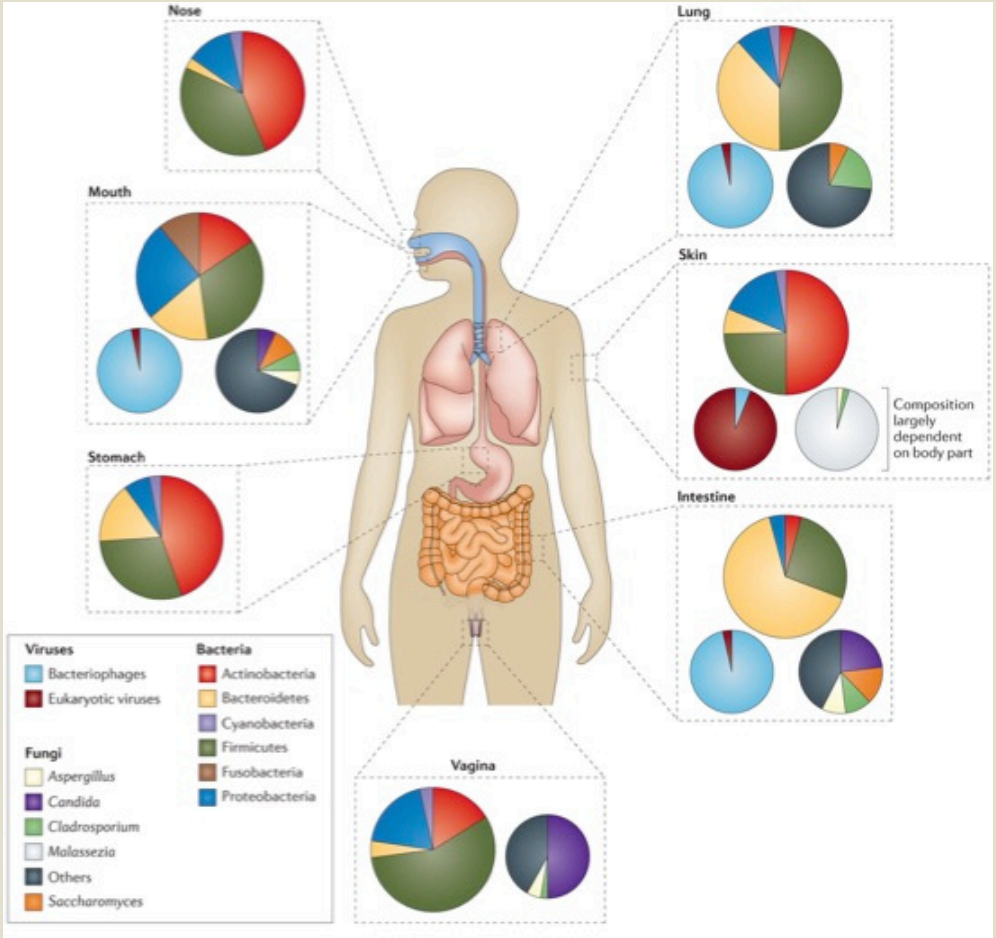


Image: Marsland & Gollwitzer 2014

What does any of this have to do with social equity?

- Access to food, high-quality diet
  - *Nutrition*
  - *Microbes*
  - *Gut health/systemic infections*
- Maternity care, postnatal care
  - *Developing immune system and tolerance for microbes*
- Building and urban planning
  - *Zoning and air quality*
  - *Building quality and microbial VOCs*
  - *Access to natural environments and microbes*
  - *Waste water treatment and antimicrobial resistance*

We are framing the discussion for microbes and social equity, not solving all contemporary social issues.

HOMEWORK

Homework

- **Reading**: Gilbert_2014_life in a world without microbes
  - *Available on canvas*
- **Assignment (4 pts):** Quiz: what is plagiarism? Due 6/25
  - *Available on canvas*

- (OPTIONAL) Concept check videos
- "What is DNA" (6 min): https://www.youtube.com/watch?v=zwibgNGe4aY
- "What are microbes?" (2min): https://www.youtube.com/watch?v=_Vj0cIgwpQI