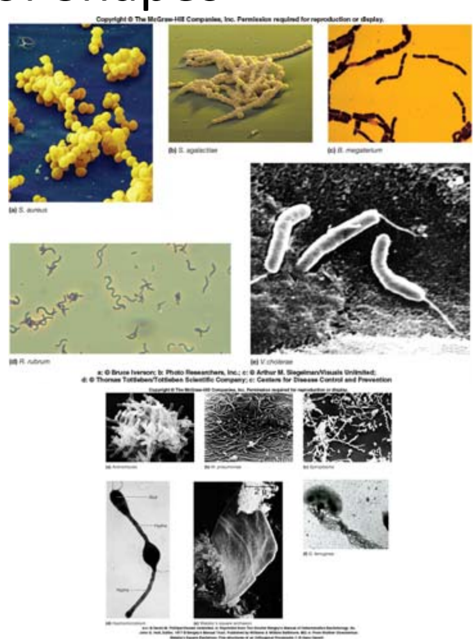
Bacterial Morphology

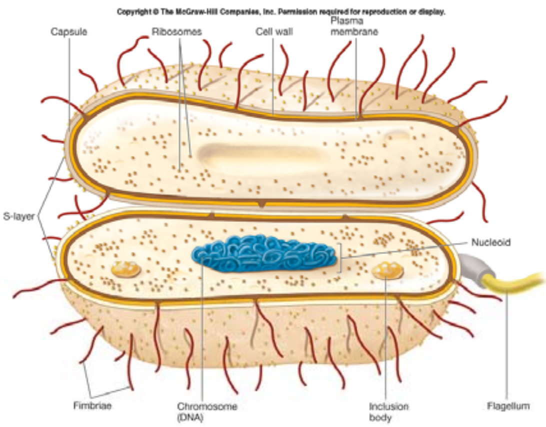
Overview of Shapes

- Cocci
  - Spherical
  - Diplococci, staphylococci, streptococci
- Bacilli
  - Can be single or in pairs and or chains
- Spirilla
  - Spiral shaped with flagella at both ends of cell
- Vibrios
  - Comma shaped, resemble bacilli
- Pleomorphic
  - Lack single characteristic shape



Prokaryotic Cellular Organization

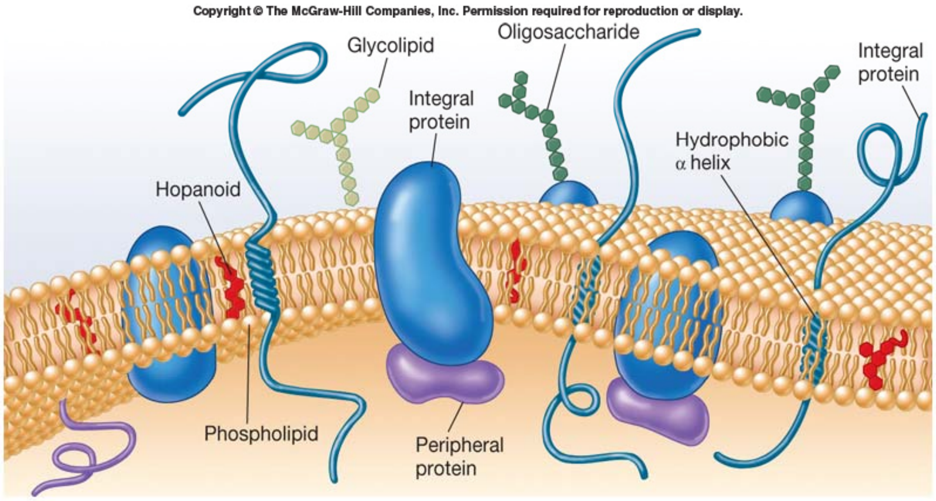
- Plasma Membrane
- Gas Vacuole
- Ribosomes
- Inclusion Bodies
- Nucleoid
- Periplasmic space
- Cell Wall
- Capsules and slime layer
- Fimbriae and pili
- Flagella
- Endospore



Plasma (Cell) Membrane

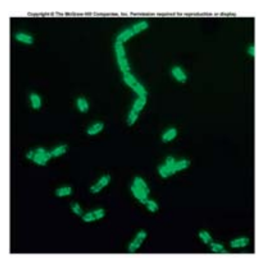
- Roles
  - Point of contact with cellular environment
  - Retain cytoplasm, selectively permeable
  - Prevents loss of important nutrients, regulates transport
  - Location of important cell processes: respiration, photosynthesis, synthesis of lipids and cell wall components
  - Receptor molecules to help detect and respond to chemicals in the environment

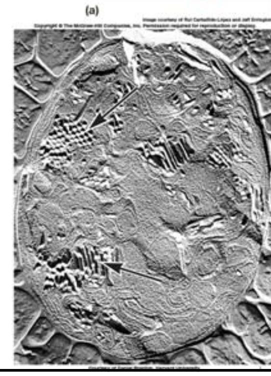
Bacterial membranes



Inclusion Bodies

- Present in the cytoplasm
- Used for storage
- Reduce osmotic pressure
- Metachromatic granules
  - Inorganic inclusion bodies, act as an energy reserve
- Gas Vacuole- provides buoyancy
  - Composed of many small gas vesicles
  - Creates structure impermeable to water, but permeable to atmospheric gases


(a)



Ribosomes

- Composed of protein and rRNA
- Located in cytoplasm, or attached to cell membrane
- Site of protein synthesis: those in cytoplasm make intracellular proteins, attached make proteins destined for transport out
- Smaller than eukaryotic ribosomes (70S vs. 80S)
  - 50S and 30S subunits

Nucleoid

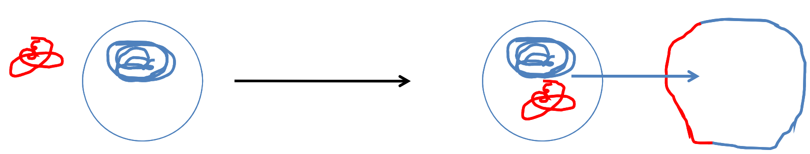
- Location/ region of the prokaryotic chromosome
- Fibrous appearance

Plasmids

- Extrachromosomal DNA, ds DNA: circular or linear
- Few genes, not essential to host- typically contain information beneficial to survival in environment (antibiotic resistance)
- Replicate autonomously, single or multicopy, some integrate into chromosome
- Prokaryotes, some yeast/ fungi
- Number varies by species

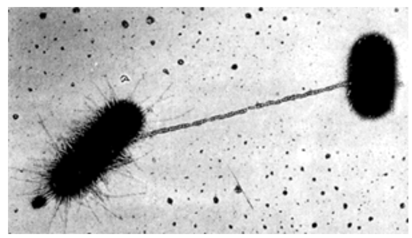
Transformation

- Introduction of foreign DNA into bacterial cell
- Take up of DNA from the environment by “competent” bacterial cells



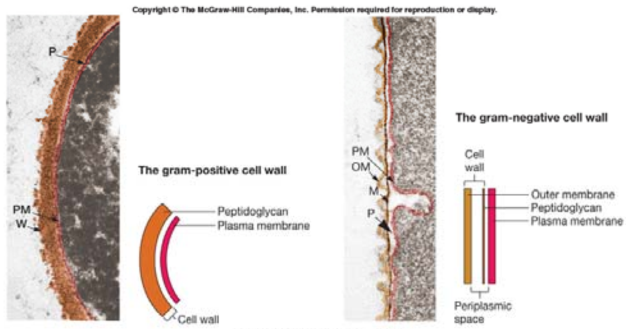
Conjugation

- Exchange of genetic material between bacterial cells
- Fertility Factor
- R plasmids
- Virulence Plasmids
- Metabolic



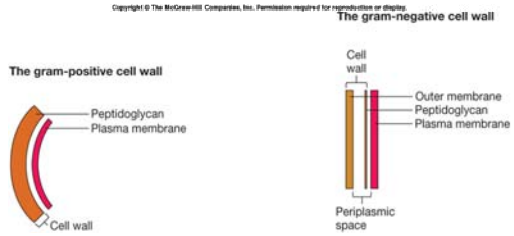
Cell Wall

- Determines shape of bacterial cell
- Protects from osmotic lysis
- Protect from toxic substances
- Can contribute to pathogenicity

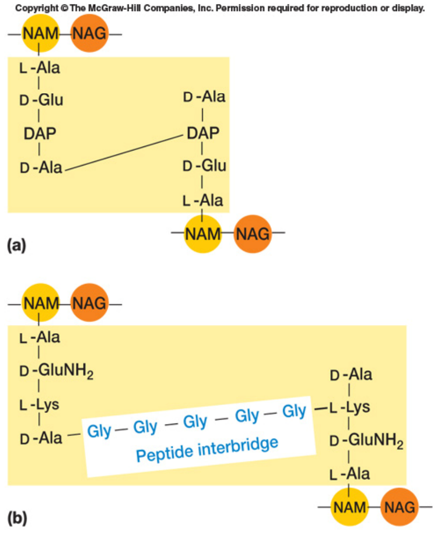


Gram Positive/ Negative

- Based on Gram stain technique
- Gram Positive- stains purple
- Gram Negative- stains red
- Gram Positive- thick layer of peptidoglycan
- Gram Negative- peptidoglycan, plus outer membrane



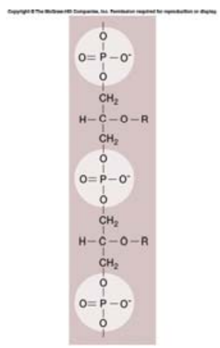
Peptidoglycan

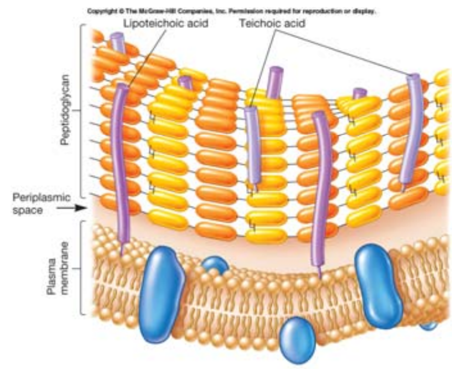


- Murein
- Polymer of many identical subunits
- N-acetylglucosamine, N-acetylmuramic acid

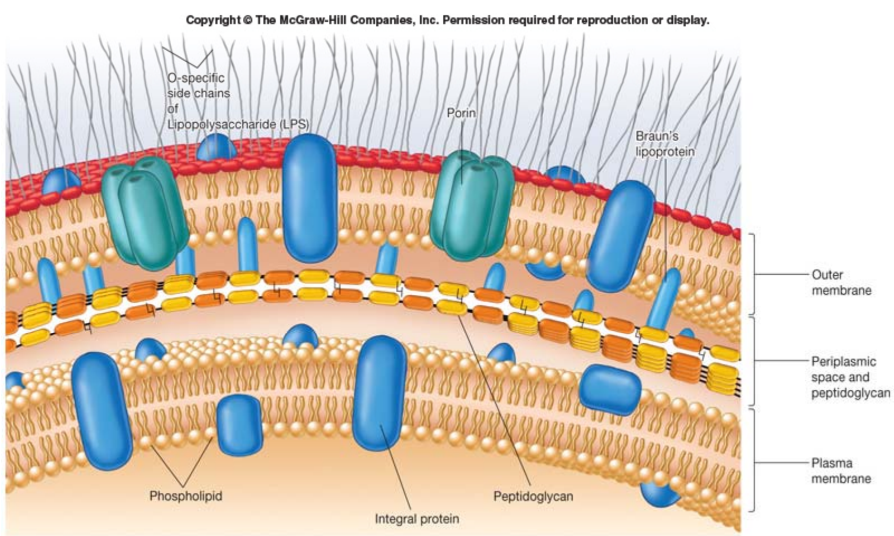
Gram Positive- In Detail

- Thick peptidoglycan
- Teichoic acids- polymers of glycerol or ribitol joined by phosphate groups. Amino acids attach to the sugar groups. Only in G+



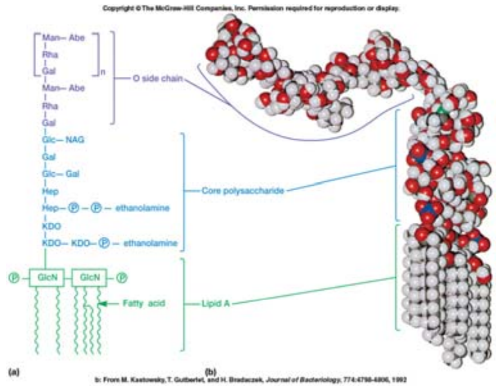


Gram Negative- In Detail



Lipopolysaccharide

- Functions:
  - Gives neg charge to cell
  - Stabilize outer membrane
  - Bacterial attachment
  - Permeability barrier
  - Protect from host defenses!
- Three components:
  - Lipid A: toxic-endotoxin
  - Core polysaccaride
  - O side chain: elicits immune response



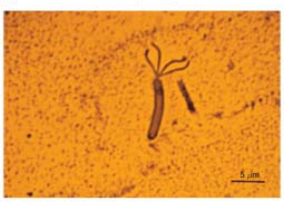
Components Exterior to Cell Wall

- Not required for growth and reproduction
- Typically composed of polysaccharides
- Capsule- well organized not easily washed off
  - Confer advantage, resist phagocytosis by host
  - Prevent dessication
- Slime layer- diffuse, unorganized, removed easily

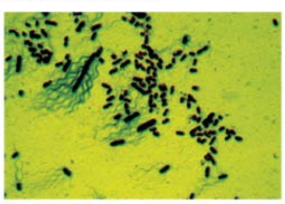
Components External to Cell Wall

- S-layer: composed of protein or glycoproteins
- Protect against fluctuations in ions, pH, osmotic balance, enzymes or predacious bacterium Bdellovibrio
- Helps maintain shape, cell adhesion, protect against host defenses

(a) *Pseudomonas*—monotrichous polar flagellation



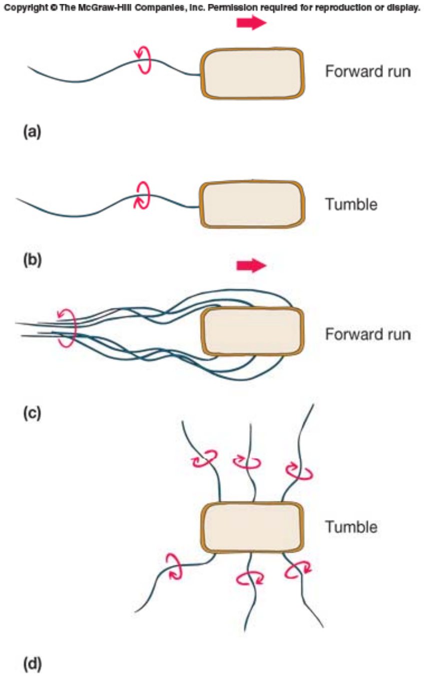
(b) *Spirillum*—lophotrichous flagellation



(c) *P. vulgaris*—peritrichous flagellation

Flagella

- Means of locomotion
- Monotrichous
- Amphitrichous
- Lophotrichous
- Peritrichous



Chemotaxis

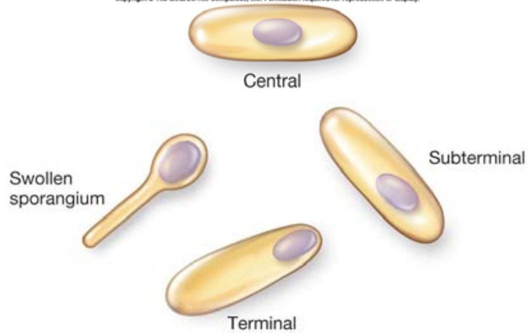
Movement towards or away from substances: can react to very low levels of chemicals

Attracted to amino acids, sugars

Repelled from harmful substances and waste products

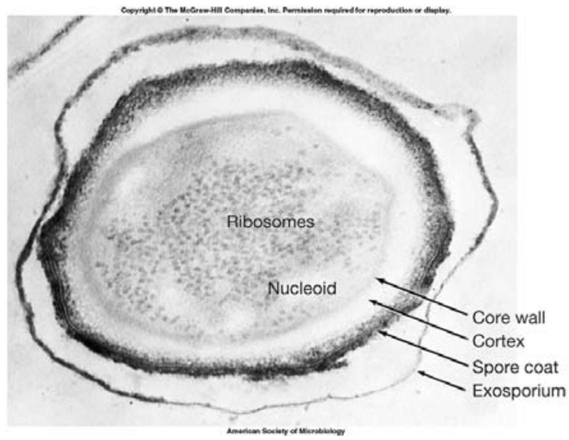
Endospores

- Resistant dormant structure
- Bacillus, Clostridium
- Resistant to: UV, gamma radiation, chemical disinfection and dessication



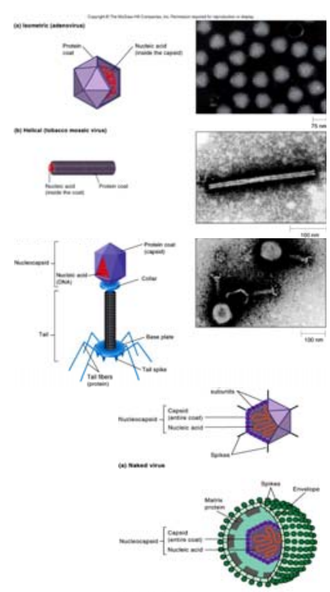
Endospore

- Core wall
- Cortex
- Spore coat
- Exosporium



General Characteristics of Viruses

- Infect bacteria, plants, animals
- Virus architecture
  - Virus particle called virion
  - Consists of nucleic acid surrounded by protein coat
    - Protein coat termed capsid
      - Capsid composed of capsomers
  - Viruses have different shapes
    - Isometric
    - Helical
    - Complex
  - Two types of virion
    - Naked – without envelope
    - Enveloped – surrounded by lipid membrane

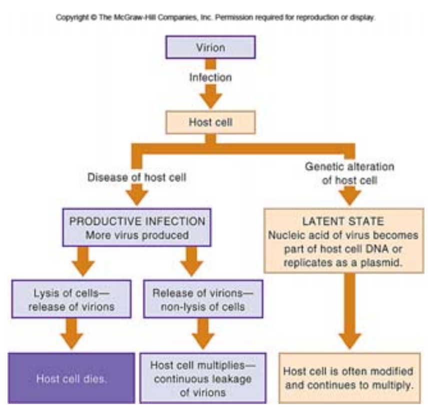


General Characteristics of Viruses

- Viral genome
  - Contains only single type of nucleic acid
    - Either DNA or RNA
      - NEVER BOTH
  - Can be linear or circular
  - Single-stranded or double-stranded
- Replication cycle overview
  - Only multiply inside metabolizing cell
    - Use host machinery to support reproduction
  - Every virus contains information to make viral proteins, assure replication and move in and out of host cells
  - Viruses live in two phases
    - Extracellular phase
      - Metabolically inert
    - Intracellular phase
      - Metabolically active

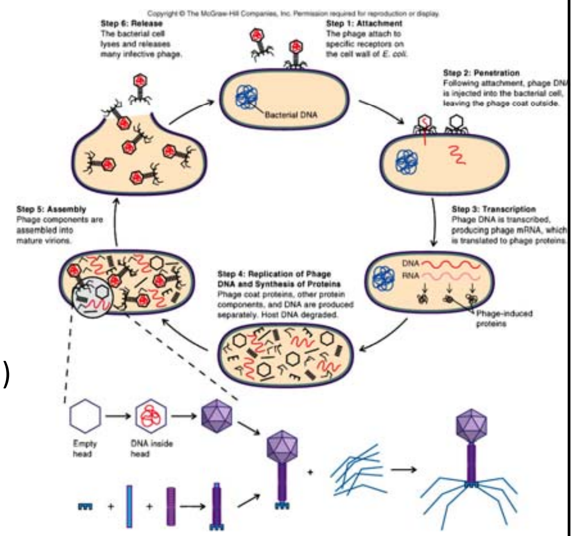
Virus Interactions with Host Cells

- Effect on cells depends on infecting phage
  - Some phage multiply inside cell, producing numerous progeny
    - Termed productive cycle
      - Lytic cycle
        - » Phage lyse infected cell
  - Some phage integrate into host genome
    - Termed latent cycle
      - Lysogenic state



Virus Interactions with Host Cells

- The six stages of the lytic cycle are:
- ✓ Adsorption/attachment
- ✓ Penetration
- ✓ Transcription/translation
- ✓ Replication
- ✓ Assembly (or maturation)
- ✓ Release



Adsorption (Attachment)

- The phage collide by chance with the bacteria
- The base plate with its tail spikes settles on the surface of the bacterium
- The phage use these structures for their own purposes

Penetration

- Penetration
  - Entrance of the virus OR its nucleic acid in the host cell
    - Plant and bacteria viruses inject the nucleic acid into the host through the cell wall
    - Animal viruses enter the cell whole
      - Animal cells have no rigid cell wall
      - Penetration of the virus is through:
        - » Phagocytosis in which the virus is engulfed by the cell
        - » Membrane fusion occurs with enveloped viruses when the viral envelope fuses with the plasma membrane of the host cell
        - » Viruses enter intact but require an uncoating step to release the nucleic acid from the protein coat

Transcription/Replication Lytic Cycle

- Transcription/Replication
  - Duplication of viral components
  - During replication:
    - Virus will inhibit activity of the host DNA
      - Virus produces enzymes to destroy host DNA
      - Viral DNA takes over and begins producing proteins
        - » Early viral proteins are synthesized and are associated with the replication of viral nucleic acid
        - » Late viral proteins are synthesized and are associated with the replication of other viral structures

Assembly

- Assembly (or maturation)
  - This stage is the assembling of the replicated viral components into an intact, mature virus
  - The protein structures of the phage such as the tail, heads, and tails (sheaths), tail spikes and tail fibers are synthesized independently of one another

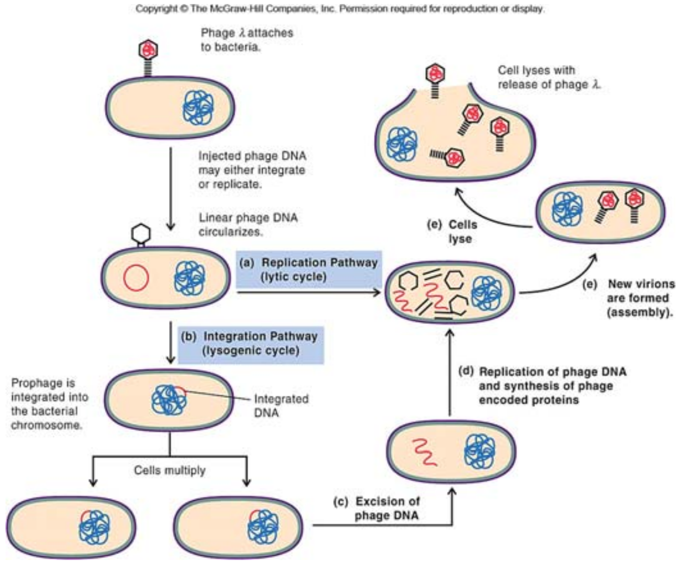
Release

- Release
  - Host cell bursts and releases viruses to the outside environment
    - Viruses are now extracellular
  - As viruses leave the host cell, the envelope is picked up
    - The envelope is made of a portion of the host cell plasma membrane which becomes the lipid envelope of the virus

Virus Interactions with Host Cells

- Lysogeny
  - Replication of a temperate virus
    - This is a non-productive cycle
  - Lysogeny begins like the lytic cycle
    - Adsorption
    - Penetration, then;
    - Incorporation

Virus Interactions with Host Cells



Virus Interactions with Host Cells

- Incorporation
  - Viral nucleic acid incorporates onto the host chromosome
    - This virus is called a prophage
  - Once incorporated, repressor genes are expressed and repressor proteins are produced
    - These hide or suppress the viral gene from host immune responses
  - The viral DNA is replicated only when the host cell replicates
    - This allows for a population of bacterial cells that carry viruses
  - Cell eventually "pops" off the host chromosome and returns to the lytic cycle

Microbial Nutrition and Metabolism

Common Requirements

- Macroelements
  - Required by microorganisms
  - C,O,H,N,S, and P: Ca^{2+}, K^{+}, Mg^{2+} ,Fe^{2+} and Fe^{3+}
  - Components of carbohydrates, lipids, nucleic acids and proteins
- Micronutrients
  - A.k.a. trace elements
  - Manganese, cobalt, zinc, molybdenum, nickel, copper

The Building Blocks

- Nitrogen, Phosphorus, Sulfur- can be obtained from same sources as carbon but also inorganic compounds
- Essential for growth
- *Nitrogen*- synthesis of amino acids, purines, pyrimidines, some carbohydrates, lipids, enzyme cofactors
- *Phosphorus*- nucleic acids, phospholipids, nucleotides (ATP), proteins and cell components
- *Sulfur*- amino acids (cysteine and methionine), some carbohydrates, biotin, thiamine

Growth Factors

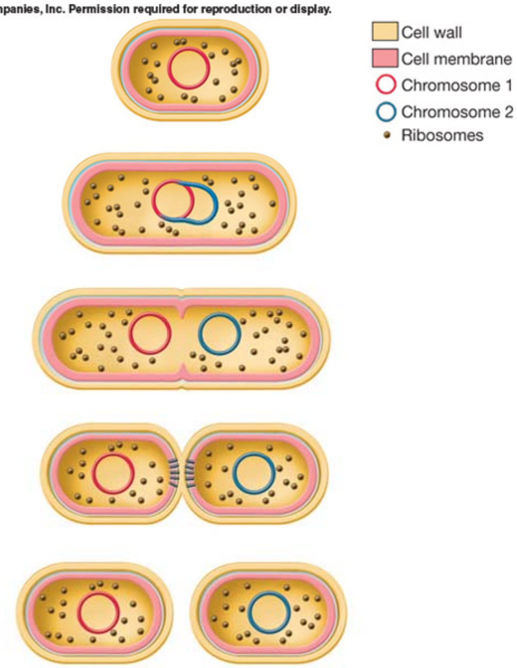
- Some microbes can make everything they need to grow….some cannot
- Essential cell components but cannot be synthesized by the microbe
- Amino acids
- Purines and pyrimidines
- Vitamins

Transport Mechanisms

- Passive
- Facilitated Diffusion
- Active Transport
  - ABC Transporters: ATP Binding Cassette
  - Symport- transport of two substances in same direction
  - Antiport- transport of two substances in different direction
- Iron Uptake
  - Siderophores- low MW organic molecules that complex with ferric iron and supply it to the cell

Prokaryotic Cell Cycle

- Reproduction by binary fission
  - Cell elongates, replicates chromosome, and separates DNA into each end of cell, divides cell in half and divides
- Cell cycle= time takes from one cell to become two, also called generation time
- Two cell pathways
  - Chromosome replication/ separation
  - Cytokinesis- formation of cross wall between two daughter cells



(a) A young cell at early phase of cycle

(b) A parent cell prepares for division by enlarging its cell wall, cell membrane, and overall volume.

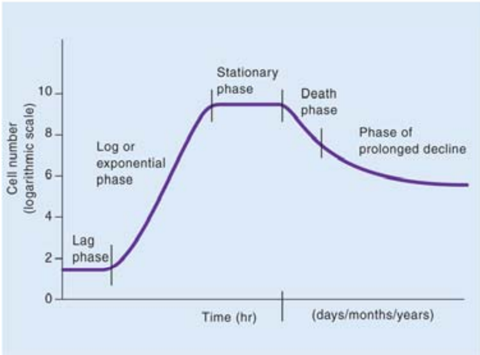
(c) The septum begins to grow inward as the chromosomes move toward opposite ends of the cell. Other cytoplasmic components are distributed to the two developing cells.

(d) The septum is synthesized completely through the cell center, and the cell membrane patches itself so that there are two separate cell chambers.

(e) At this point, the daughter cells are divided. Some species separate completely as shown here, while others remain attached, forming chains, doublets, or other cellular arrangements.

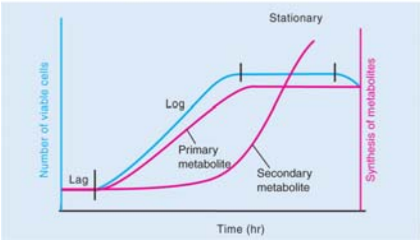
Bacterial Growth in Laboratory Conditions

- The Growth Curve
  - Characterized by five distinct stages
    - Lag stage
    - Exponential or log stage
    - Stationary stage
    - Death stage
    - Phase of prolonged decline



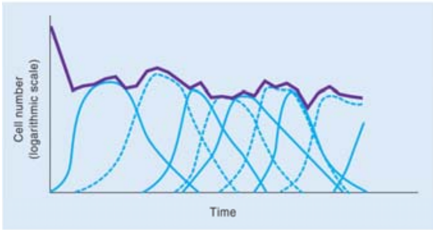
Bacterial Growth in Laboratory Conditions

- Lag phase
  - Number of cells does not increase
  - Cells prepare for growth-can vary
    - "Tooling up"
- Log phase
  - Period of exponential growth
    - Doubling of population with each generation-constant rate
  - Produce primary metabolites
    - Compounds required for growth
  - Cells enter late log phase
    - Synthesize secondary metabolites
      - Used to enhance survival
      - Antibiotics synthesized



Bacterial Growth in Laboratory Conditions

- Stationary phase
  - Overall population remains relatively stable
    - Cells exhausted nutrients
    - Cell growth = cell death
      - Dying cell supply metabolites for replicating cells
- Death phase
  - Total number of viable cells decreases
    - Decrease at constant rate
  - Death is exponential
    - Much slower rate than growth



Bacterial Growth in Laboratory Conditions

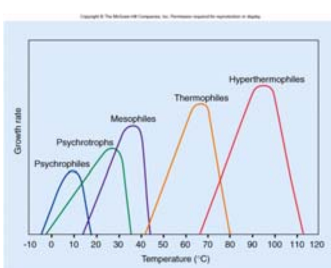
- Phase of prolonged decline
  - Once nearly 99% of all cells dead, remaining cells enter prolonged decline
  - Marked by very gradual decrease in viable population
  - Phase may last months or years
  - Most fit cells survive
    - Each new cell more fit than previous

Environmental Factors on Growth

- As group, prokaryotes inhabit nearly all environments
  - Some live in "comfortable" habitats
  - Some live in harsh environments
    - Most of these are termed extremophiles and belong to domain *Archaea*
- Major conditions that influence growth
  - Temperature
  - Oxygen
  - pH
  - Water availability

Environmental Factors on Growth

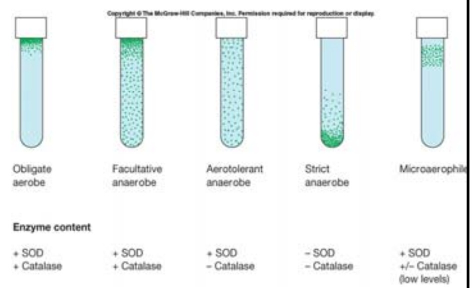
- Temperature
  - Each species has well- defined temperature range
    - Within range lies optimum growth temperature
  - Prokaryotes divided into 5 categories

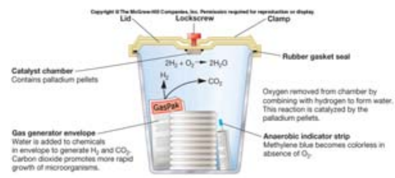


- Psychrophile
  - Optimum temperature -5°C to 15°C
    - Found in Arctic and Antarctic regions
- Psychrotroph
  20°C to 30°C
    - Important in food spoilage
- Mesophile
  25°C to 45°C
    - More common
    - Disease causing
- Thermophiles
  45°C to 70°C
    - Common in hot springs
- Hyperthermophiles
  70°C to 110°C
    - Usually members of *Archaea*
    - Found in hydrothermal vents

Environmental Factors on Growth

- Oxygen
  - Prokaryotes divided based on oxygen requirements
    - Obligate aerobes
      - Absolute requirement for oxygen
        - » Use for energy production
    - Obligate anaerobes
      - No multiplication in presence of oxygen
        - » May cause death
    - Facultative anaerobes
      - Grow better with oxygen
        - » Use fermentation in absence of oxygen
    - Microaerophiles
      - Require oxygen in lower concentrations
        - » Higher concentration inhibitory
    - Aerotolerant anaerobes
      - Indifferent to oxygen, grow with or without
        - » Do not use oxygen to produce energy



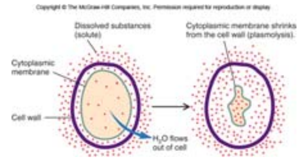


Environmental Factors on Growth

- pH
  - Bacteria survive within various pH range
  - Can help control the level in the cell and environment
    - Transport systems
    - Protein synthesis
    - Excretion of acid/ basic waste products
  - Neutrophiles
    - Multiply between pH of 5 to 8
      - Maintain optimum near neutral
  - Acidophiles
    - Thrive at pH below 5.5
      - Maintains neutral internal pH, pumping out protons (H+)
  - Alkalophiles
    - Grow at pH above 8.5
      - Maintain neutral internal pH through sodium ion exchange
        - » Exchange sodium ion for external protons
        - » Halophiles

Environmental Factors on Growth

- Water availability
  - All microorganisms require water for growth
  - Inclusion body helps with this
  - Water not available in all environments
    - In high salt environments
      - Bacteria increase internal solute concentration
        - » Synthesize small organic molecules
        - » Some have MS channels
      - Osmotolerant bacteria tolerate high salt environments
      - Bacteria that require high salt for cell growth termed halophiles



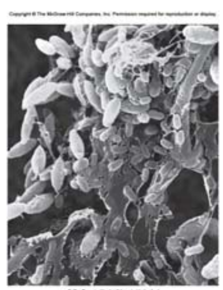
Pressure

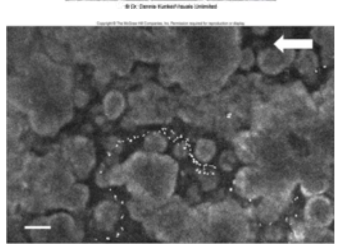
- Most bacteria live at atmospheric pressure (1atm)
- Some live in deep sea (1000m or more)- pressure reaches 600-1100 atm)
- Barotolerant
- Barophilic- grow faster at high pressure, very impt in nutrient cycling

Radiation

- UV radiation can kill many microbes
  - Deadliest wavelength 260nm- most effectively absorbed by DNA- causes thymidine dimers
  - Shorter wavelengths are absorbed by oxygen
  - Can also induce breakdown of tryptophan to toxic photoproducts. These products and the UV radiation can cause DNA breaks

Bacterial Growth in Nature



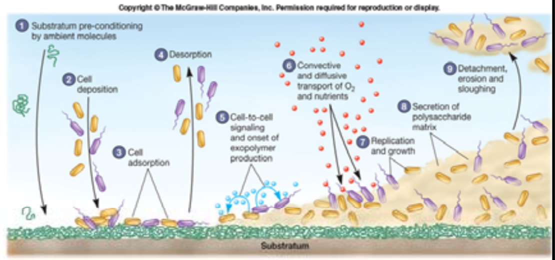


Biofilm layer

- Conditions in nature have profound effect on microbial growth
  - Cells sense changing environment
    - Synthesize compounds useful for growth
    - Cells produce multicellular associations to increase survivability
      - Example
        - » Biofilms
        - » Slime layers

Bacterial Growth in Nature

- Biofilm
  - Formation begins when planktonic bacteria attach to surfaces
    - Other bacteria attach and grow on initial layer
  - Has characteristic architecture
    - Contains open channels for movement of nutrients and waste
  - Cells within biofilms can cause disease
    - Treatment becomes difficult
      - Architecture resists immune response and antimicrobials- polysaccharide
      - Example: cystic fibrosis
  - Bioremediation is beneficial use of biofilm



Bacterial Growth in Nature

- Interactions of mixed microbial communities
  - Prokaryotes live in mixed communities
    - Many interactions are cooperative
      - Waste of one organism nutrient for another
    - Some cells compete for nutrient
      - Synthesize toxic substance to inhibit growth of competitors