BABS1202 – APPLIED BIOMOLECULAR SCIENCES

CELL STRUCTURE

BINARY FISSION VS. MITOSIS

- Bacteria and archaea have no nucleus and no centromeres
- Binary fission cannot be divided into prophase, metaphase, anaphase and telophase

METABOLISM

- Metabolism: set of chemical reactions that happen in living organisms to maintain life
- Metabolic processes allow organisms to grow and reproduce, maintain their structures, respond to their environments
- Catabolism: breaks down organic matter (captures energy) into smaller molecules
- Anabolism: uses energy to construct components of cells
- Biological energy comes from solar energy in the form of chemical energy in bonds and ATP, or more stably in chemical bonds between carbon atoms (carbohydrates)
- Autotrophs: an organism that produces its own food using energy from light or other inorganic chemical reactions e.g. plants through photosynthesis
- Heterotrophs: animals that obtain their energy from food, requires organic substrates to get its chemical energy for growth and development

ENVIRONMENTAL CHANGES

- Positive response: causes the organism to move towards the stimulus
- Negative response: causes the organism to move away from the stimulus

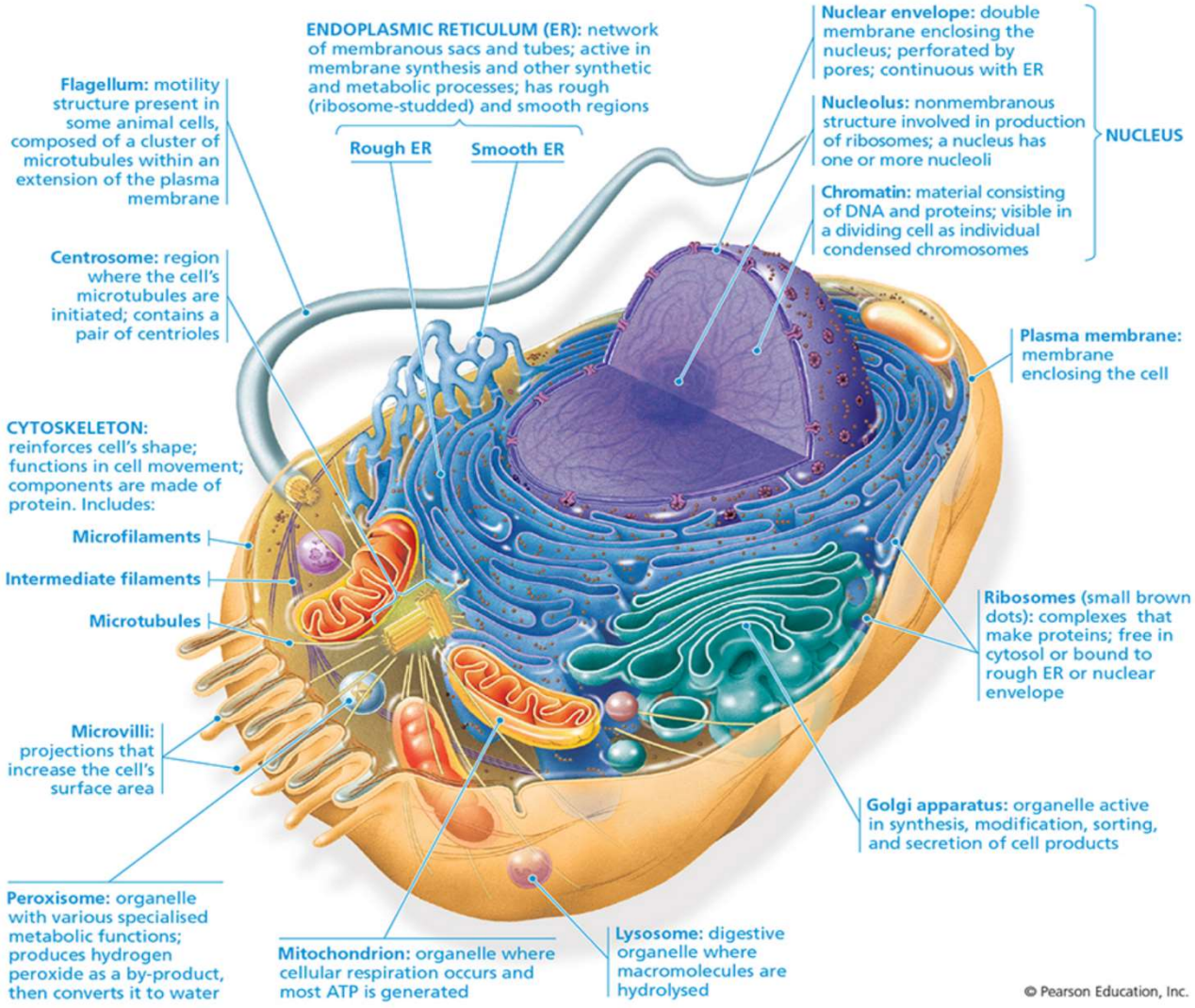
CHEMICALS OF LIFE

- Carbohydrates/Saccharides: most abundant, simple organic compounds, storage/transport of energy and structural components, monosaccharides can be linked together to form polysaccharides or oligosaccharides
- Proteins: polymers formed from linking various amino acids joined by peptide bonds, many different levels of organisation, amino acids differ by side chain (R group), 20 essential amino acids

- Lipids: any fat soluble (lipophilic) molecules, energy storage, structural components of cell membranes, examples include fats, oils, waxes, cholesterol, sterols, fat-soluble vitamins (A, D, E, K), monoglcerides, diglycerides, phospholipids
- Nucleic acids: polymers formed from linking of various nucleotides, used in storage/transfer of genetic information, examples include DNA and RNA, three components in a nucleotide (pentose sugar, phosphate group, nitrogenous base)

CELLS

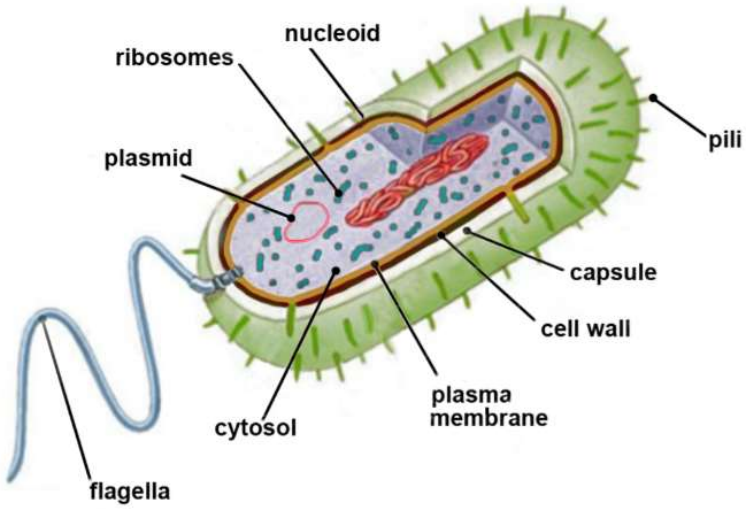
- Cells: always enclosed by a membrane, always contains cytoplasm and genetic material, mechanism for protein manufacture (ribosomes)
- All cells have genes, and replicate their DNA and produce proteins by transcribing DNA to RNA and translating RNA to proteins
- Viruses: not a cell as it is DNA/RNA surrounded by protein, dependant on host cell's functions for proteins synthesis, in the extracellular state the virus is known as a virion (metabolically inert), entering the cell allows the intracellular state to be initiated and virus replication occurs



- Major components of eukaryotic cells

Cytoplasm	Region between the membrane and the nucleus, contains organelles of the cell
Cytosol	Gelatin-like aqueous fluid filling the cytoplasm, solution containing salts, minerals and organic compounds
Nucleolus/Nucleole	Within the nucleus, non-membrane bound, composed of protein and nucleic acids, site of ribosomal RNA transcription
Nuclear Envelope	Double lipid membrane system, encloses nucleus, selectively permeable pores to allow RNA and ribosomes out of the nucleus and nuclear proteins in
Chromosome	One DNA molecule and associated proteins
Chromatin	Complex of DNA and proteins that make up eukaryotic chromosome, when cell is not dividing it exists as a mass of long, thin fibres
Nucleoplasm	Fluid interior portion of nucleus
Nucleus	DNA directs RNA synthesis
Nuclear Envelope	Outer nuclear membrane is constant with rough ER, ribosomes attached to the surface, RNA exists nucleus through a nuclear pore
Ribosomes	Non membrane-bound, converts genetic information carried by messenger RNA into proteins, ribosomes coordinate protein synthesis by placing the mRNA, tRNA and associated protein factors in correct positions, ribosomal components of ribosomes catalyse some of the chemical reactions during translation, structurally consists of small and large subunit, biochemically consists of ribosomal RNA (rRNA) and some 50 structural proteins, catalyse the assembly of individual amino acids into polypeptide chains, uses mRNA as a template to join together the correct sequence of amino acids
Endoplasmic Reticulum	Continuous with outer membrane of the nuclear envelope, mesh of interconnected membranes
Rough ER	Rough appearance due to numerous ribosomes attached along ER, connects nuclear envelope through the mRNA to ribosomes, involved in protein synthesis and transport
Smooth ER	Lacks rough surface, manufactures lipids (fatty acids, phospholipids, sterols), involved in cholesterol metabolism and membrane synthesis, packaged in transport vesicles and sent to Golgi
Transport Vesicles	Small membrane bound sac, proteins and lipids packaged in transport vesicles to Golgi
Golgi Apparatus	Consists of 3 – 20 flattened stacks of membrane-bound sacs (cisternae), complex network of tubules and vesicles located at edge of cisternae; modifies, sorts and packages proteins and other materials from ER then stored or secreted; receives and binds to first layer (cis) then are modified as they pass through the layers (molecular tags allows sorting and packaging, indicates destination) then leaves through the trans face
Lysosomes	Small organelles that contain enzymes, enzymes break down lipids, carbohydrates and proteins, removes 'junk and clutter'
Cell Membrane	Plasma membrane separates inside from outside, controls traffic of materials into and out of the cell
Phospholipid Bilayer and Plasma Membrane	One polar hydrophilic head towards aqueous solutions, two non-polar hydrophobic tails orientated away from water; proteins, sidedness – proteins, carbohydrates and lipids distributed asymmetrically between two sides of membrane, composed of macromolecules (proteins, glycoproteins, glycolipids, cholesterol, phospholipids)
Mitochondria	Membrane-enclosed organelle, 1 – 10 micrometers, generates most of cell's ATP, involved in signalling, cell cycle, growth and death
Chloroplast	Membrane bound organelles found in plant cells, algae and bacteria, can photosynthesise, absorb light to produce sugar
Eukaryote Cytoskeleton	Network of fibrous proteins distributed throughout cytoplasm of eukaryotic cells, linked to organelles and plasma membrane

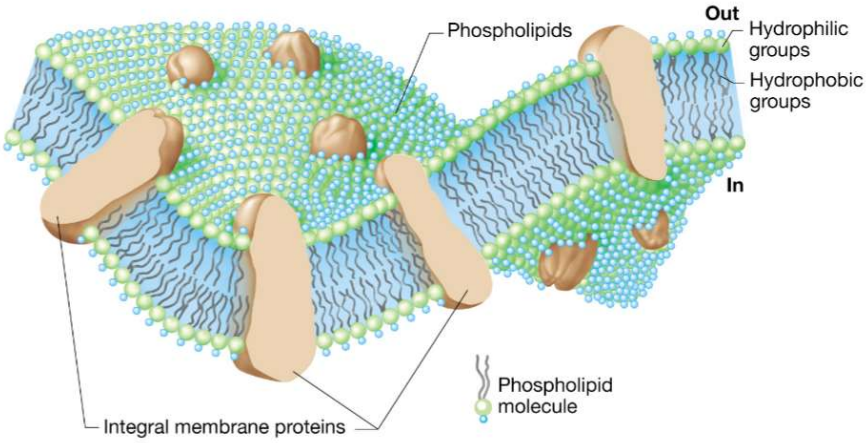
BACTERIAL CELL



- Average human body consists 10^{13} cells, at least 10^{14} number of microorganisms
- Importance of bacteria: agriculture, food, environment, health
- Bounded by a chemically complex cell wall (capsule or slime layer)
- Must be in an aqueous environment to replicate

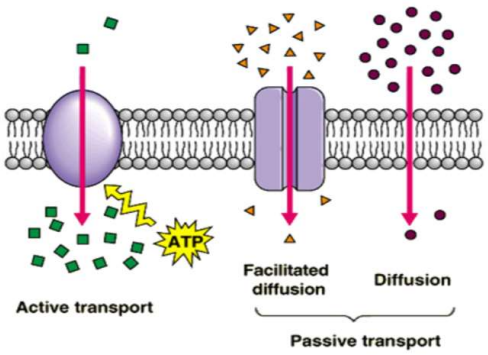
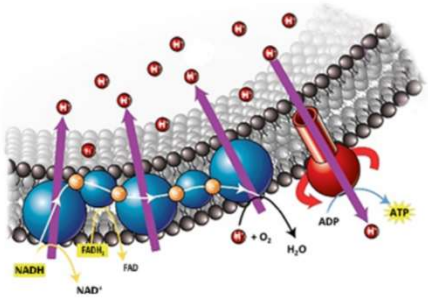
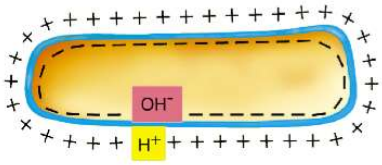
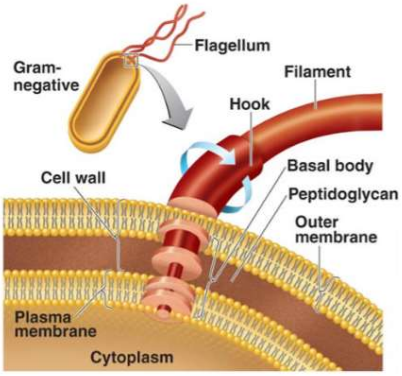
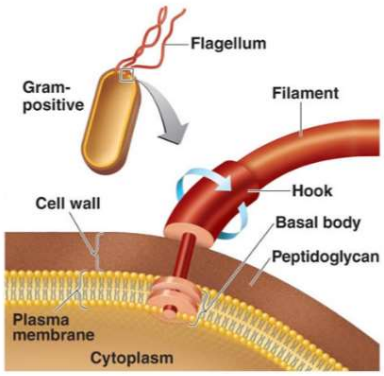
PLASMA MEMBRANE

- All living organisms have plasma membrane as its major point of contact with the environment (semi-permeable membrane)
- Encloses the cytoplasm of cells
- Integral membrane proteins allow channel and movement of substances



- Membranes contain proteins, lipids and carbohydrates
- One polar hydrophilic head oriented towards aqueous solutions, both inside and outside cell
- Two non-polar hydrophobic tails are oriented away from the water

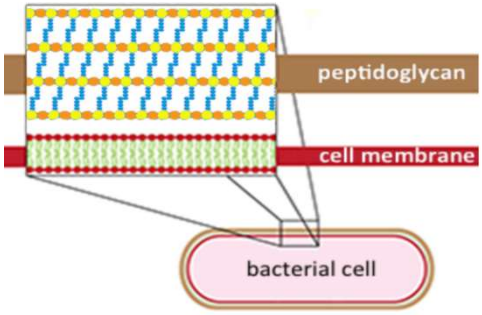
- Functions

Permeability Barrier	Prevents leakage, gateway for transport of molecules in and out of the cell 
Energy Conservation	Generation of proton motive force (chemiosmosis) Cellular respiration  
Protein Anchor	Site of many proteins involved in genetic transport and chemotaxis Fimbriae attaching to the cell  

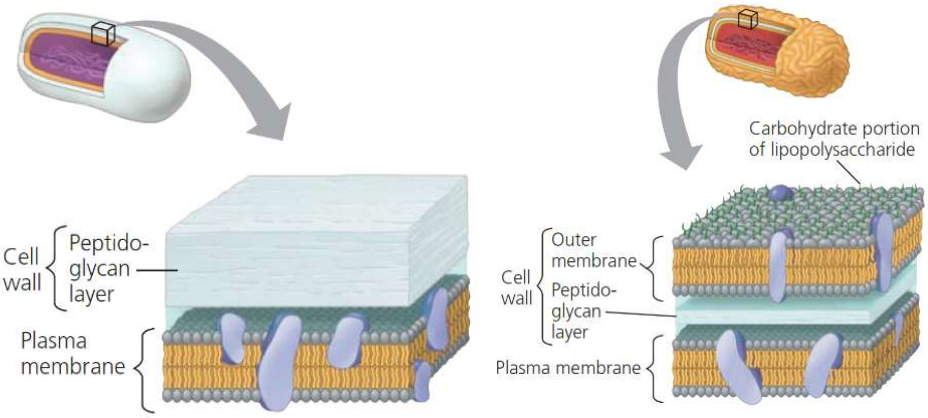
CELL WALL

- Supply structural integrity and shape
- Resists damage due to osmotic pressure – protects against lysis (pressure inside is greater than outside)
- Provides some degree of resistance to diffusion of molecules
- Single bag-like, seamless molecule
- Composed of polysaccharide chains cross linked with short chains of amino acids: peptide and glycan
- Gram negative bacteria: 30 – 100 atmospheres

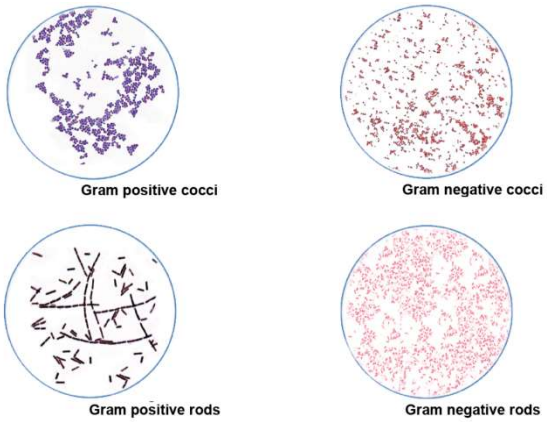
- Most bacterial cell walls contain peptidoglycan



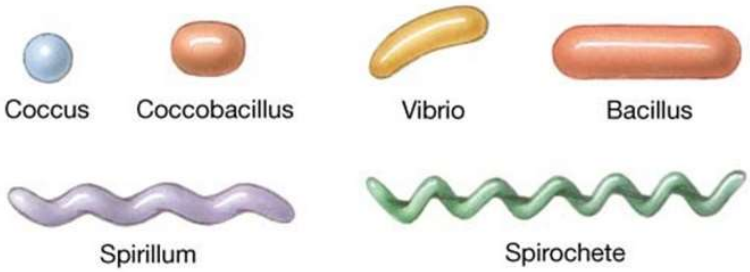
- Divided into 2 major groups: gram positive (purple) or gram negative (pink/red)



- Gram Staining

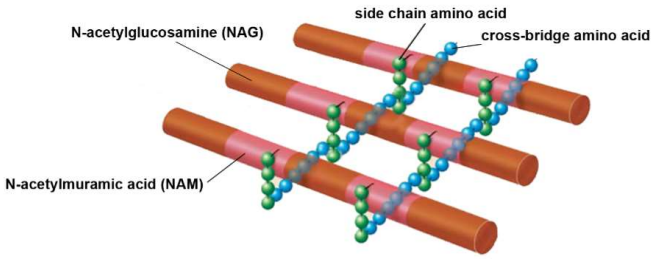


- Bacteria morphology

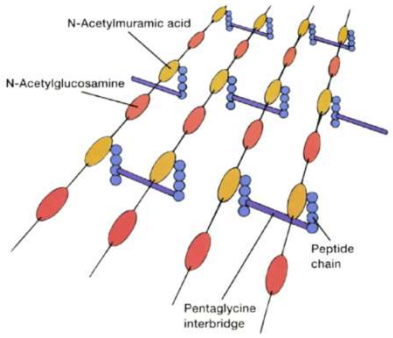


* bacillus is known as rod

- Peptidoglycan: alternating NAM and NAG molecules form a carbohydrate backbone (glycan), rows of NAG and NAM are linked by polypeptides (peptide), always attached to the NAG portion
- Polypeptide cross-bridges vary but they always have a peptide side-chain, consisting of amino acids attached to NAGs



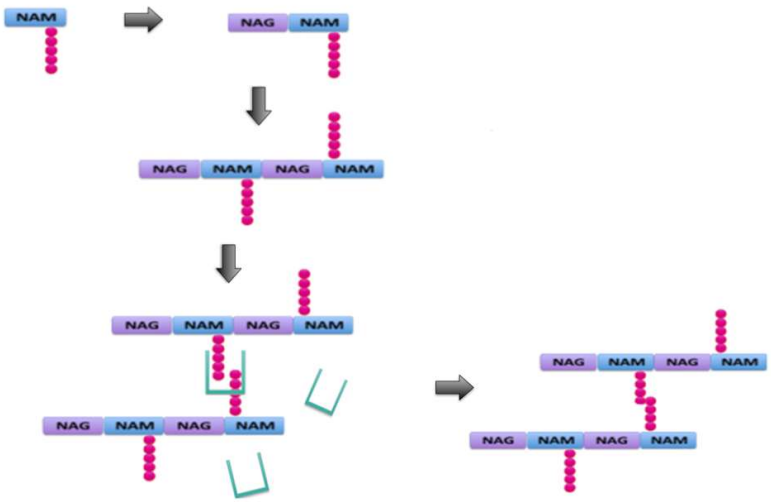
- Peptidoglycan (murein): mesh-like layer outside the plasma membrane, polymer of sugars (alternating NAG and NAM residues) and amino acids, peptide chain of three to five amino acids attached to NAM or can be cross-linked to alternate peptide chain of another strand



PEPTIDOGLYCAN ASSEMBLY

1. In the cytoplasm, amino acids attach to N-acetyl muramic acid (NAM)
2. N-acetyl glucosamine (NAG) is added to NAM to form a peptidoglycan precursor
3. The peptidoglycan precursor is transported across membrane to cell wall acceptor
4. Peptidoglycan precursors bind to cell wall acceptors and undergo cross-linking by means of transpeptidase and D-alanyl carboxy peptidase (penicillin binding proteins, PCB's)
5. A polymer of NAM & NAG cross-linked by four amino acids is formed

- Beta-lactam (penicillins and cephiasporins) antibiotics contain a beta lactam ring, binding to cross-linking enzymes transpeptidase and D-alanyl carboxy peptidase, preventing cross-linking and peptidoglycan synthesis



CAPSULE

- Most bacteria contain some sort of polysaccharide layer that lies outside the cell envelope
- Glycocalyx: type of capsule found in bacteria, thin layer of tangled polysaccharide fibres
- Capsule can protect cells from phagocytic cells such as macrophages (virulence factor)
- Capsules protect against desiccation and hydrophobic toxins

ENVELOPE

- Protects against toxic chemicals and physical trauma
- Cell wall is mechanically strong, turgor pressure, inside of the cell maintained at a higher pressure than the outside
- Slime capsule protects from noxious chemicals and from predators
- Membranes act as selective barriers
- Envelope must also sense the environment – envelope of a cell is its interface with the outside world
- Gram positive has a larger cell wall and capsule whilst gram negative has an outer membrane

NUCLEOID

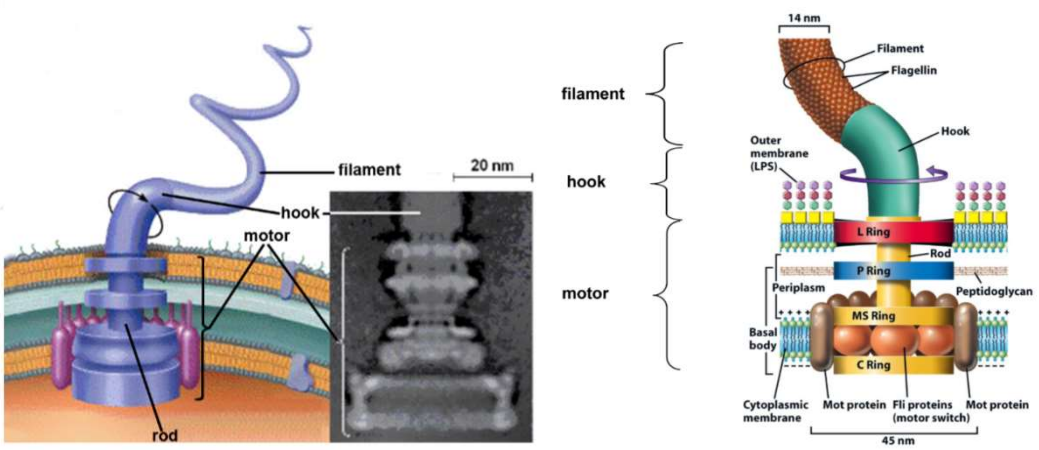
- Densely packed, irregularly shaped, single circle of DNA, several million base pairs
- Some bacteria have linear chromosomes
- Chromosome can be 1000 times longer than the bacterial cell due to DNA condensed through histone-like protein and supercoiling
- Centrally located in the cell
- During division, two copies might migrate to opposite poles

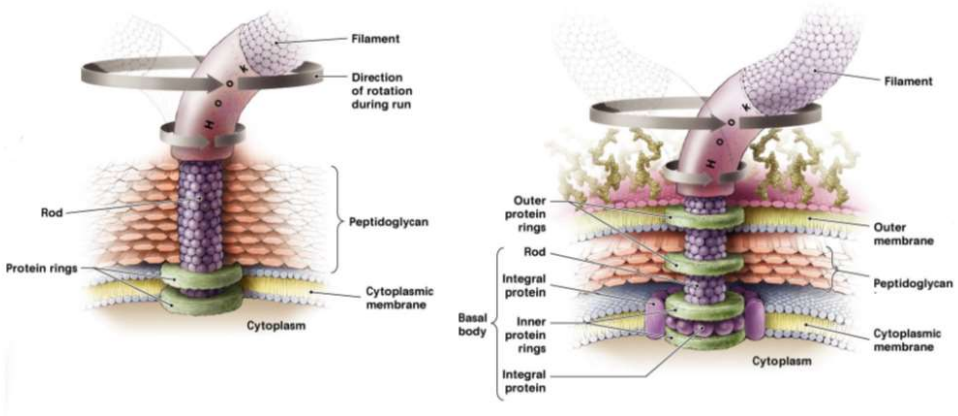
FLAGELLA

- Flagella (singular: flagellum) are long, thin, whip-like appendages
- Allows bacterial movement (motility)
- Can be several times longer than the cell, averaging 10 micrometers
- Movement driven by propeller-like rotation at 60 cell lengths/second
- Types of flagella

Monotrichous	Single flagellum 
Lophotrichous	A tuft of flagella found at one of the cell pole 
Amphitrichous	Single flagellum found at each of two opposite poles 
Peritrichous	Multiple flagella found at several locations about the cell 

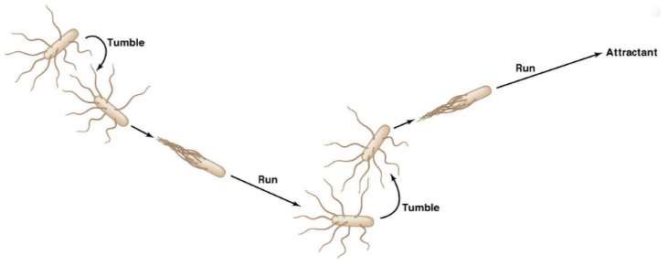
- PMF provides energy to drive flagella





Gram positive Gram negative

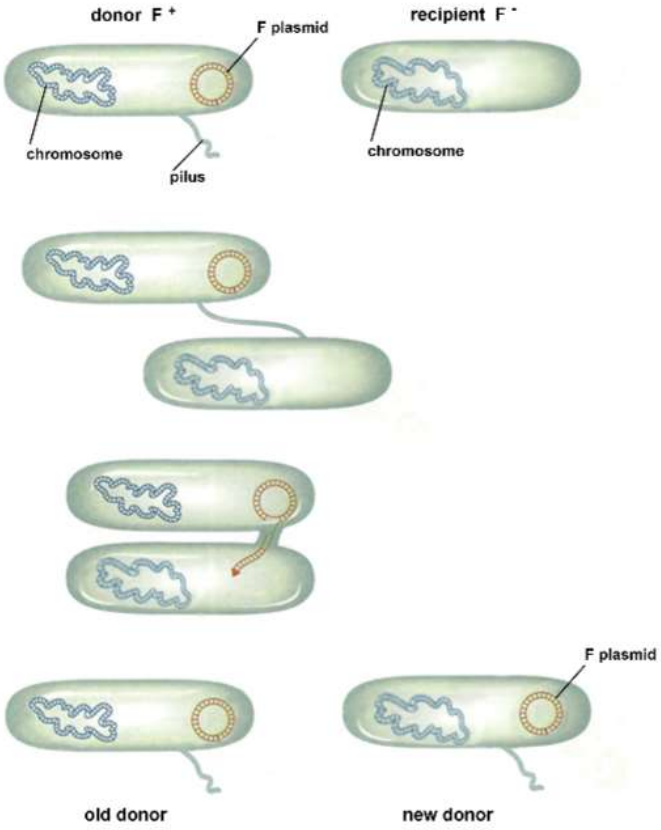
- Requires ~1000 H+ translocated per rotation
- Rotation can be clockwise or counterclockwise; reversible
- Bacteria can move in response to stimuli (taxis)
- Runs: movements of cell in single direction for some time due to counterclockwise flagella rotation; increase with favourable stimuli (positive chemotaxis, positive phototaxis)
- Tumbles: abrupt, random, changes in direction due to clockwise flagellar rotation; increase with unfavourable stimuli (negative chemotaxis, negative phototaxis)



PILI

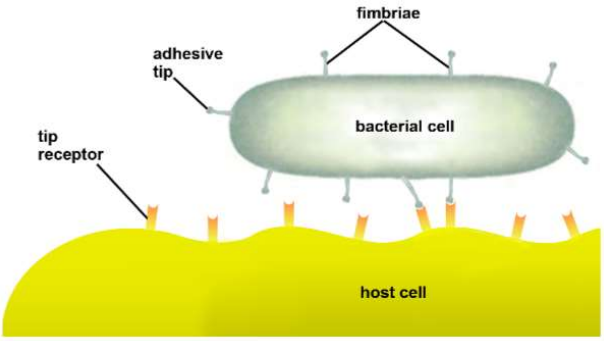
- Thin, hollow protein tubes originating from the cytoplasmic membrane
- Attachment to surfaces and motility (i.e. twitching)
- DNA transfer (conjugation) and delivery of proteins or toxins in host cells
- F: long conjugation pill or sex pilus enables conjugation

- Conjugation: transfer of DNA from one bacterium to another by cell-to-cell contact
- Typically, in Gram-negative bacteria it is the transfer of DNA (plasmid) from a donor bacterium with a sex pilus to a recipient bacterium to enable genetic recombination



FIMBRIAE

- Short attachment pili, structurally related to pili
- Shorter and straighter than flagella and more numerous
- Attachment to surfaces (virulence factor)
- Resistance to phagocytosis
- End of shaft is adhesive tip structure having a shape corresponding to that of specific glycoprotein or glycolipid receptors on a host cell



ENDOSPORES

- Produced by some bacteria (members of *Bacillus* and *Clostridium*)
- Comprises of bacterium's DNA, ribosomes and dipicolinic acid
- Dipicolinic acid forms a complex with calcium ions and binds water molecules, causing dehydration which creates heat resistance of macromolecules