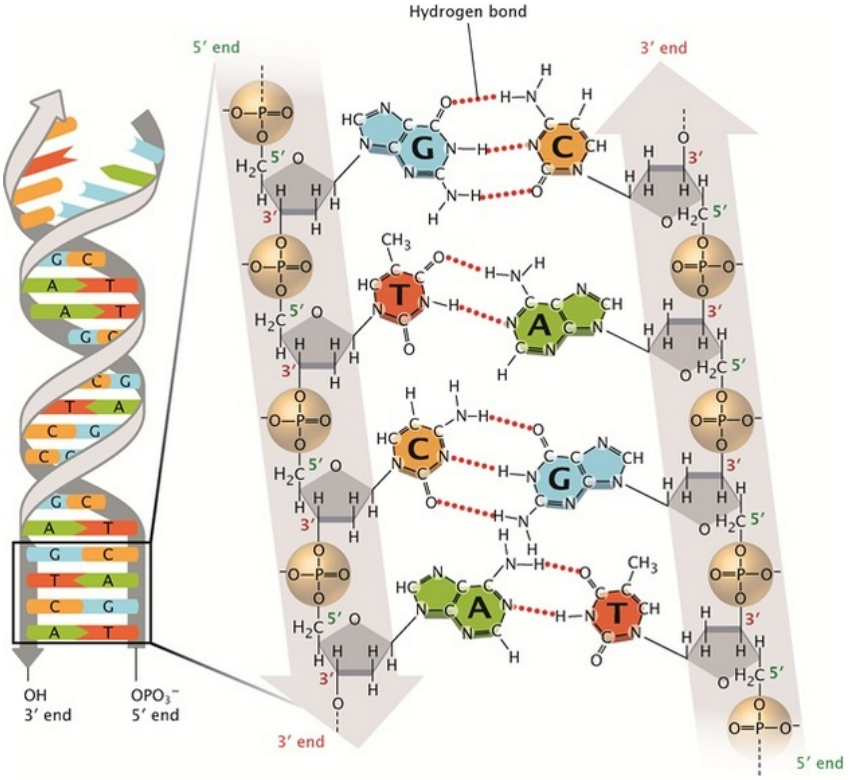
Cell Structure

Evidence DNA Codes Genetic Info

- Pauling: Genes coded by proteins
- Griffith: Transformation experiment → breakthrough
    - Mice injected with different bacteria – S strain (smooth with capsule) and R strain (rough)
    - S strain → death, but heat-killed S strain + R strain → live S strain recovered, dead mice
    - → bacteria could 'transform → what was responsible for death was DNA inside (not the capsule)
    - Removal of certain components of S + R strain → death of all unless DNA removed

Structure of DNA

- DNA – deoxyribonucleic acid
- Nucleotides – building blocks of DNA: sugar (deoxyribose) + nitrogenous base (ACTG/ACUG) + phosphate group
    - Bases: adenine, cytosine, thymine, guanine
- Structure:
    - 2 strands of nucleotides joined together in double helix (Watson + Crick)
    - **Covalent** bonds between **sugar + phosphate** groups → **backbone** of DNA
    - **Hydrogen** bonds between **nitrogenous bases** of each strand
    - Anti-parallel structure: 3' end (OH end) matched with 5' end (phosphate group)
    - **A <-> T** because they form **2 H** bonds
    - **C <-> G** because they form **3 H** bonds
    - Chargaff's Rule: **A=T, C=G, A+C = T+G**



DNA Replication

1. Enzyme **helicase unwinds** + break H bonds → opening strands (stabilised by single-strand binding proteins)
2. Enzyme **primase** puts **RNA primer** onto origin of replication site
3. Enzyme complex **DNA polymerase** places free nucleotides onto strand via complementary base pairing, joining w/ RNA primer → semi-conservative replication (one strand is from original, one is new)
4. RNA primer replaced

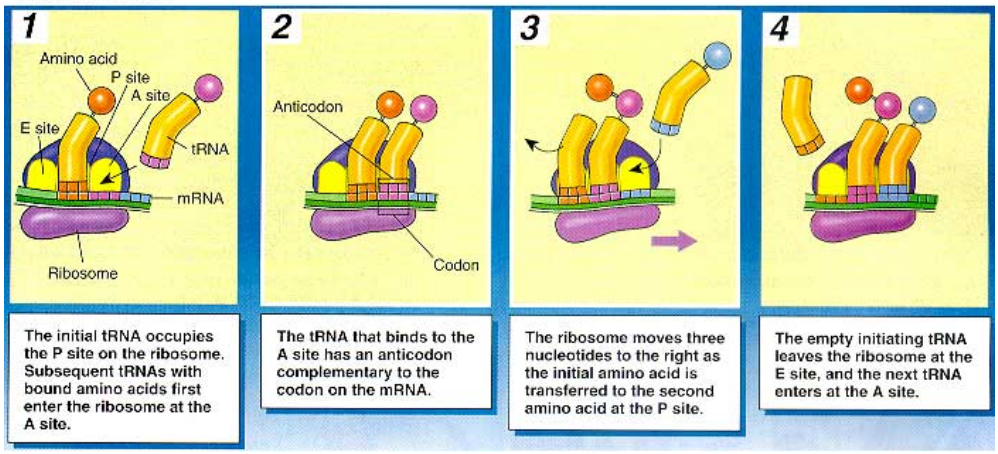
*Enzymes can only **add nucleotides to 3' end** of nucleotides → a **continuous strand** (3' end opened up) and **lagging strand** (5' end opened up)

- **Lagging** strand: RNA primer added to individual sections, DNA helicase attaches **nucleotides** in **opp. direction of unwinding**, RNA primer removed + sections (**Okazaki fragments**) joined

Protein Synthesis from DNA

1. **Transcription**: DNA → RNA
    a. Initiation:
        i. **RNA polymerase** + **sigma factor** = **holoenzyme** binds to promoter region of DNA → 'closed complex'
        ii. **Breaks H bonds → 'open complex'** + nucleotides added → sigma factor released
    b. **RNA polymerase moves along** 3' strand, unwinding and pairs nucleotides → single-stranded RNA (adding to 3' end) as DNA rewind
    c. **Rho protein** attaches to RNA; RNA forms hairpin structure, halting polymerase, and dissociates when rho protein reaches polymerase
2. mRNA made by **removing introns + splicing exons**
3. mRNA transported out of nucleus
4. **Translation**: mRNA is read → AA sequence
    a. Smaller ribosomal sub-unit + first AA tRNA @ **P (middle)** site + mRNA = complex, then larger ribosomal unit joins
        i. tRNA: Short bits of RNA with particular peptide attached
    b. tRNA recognising next **codon** (**3 nucleotides** on mRNA) joins @ **A** (right) site w/ anti-codon
    c. **AA's join at A site +** ribosome advances one codon (→ P site w/ AA chain, A site empty)
    d. tRNA released @ **E (left)** site
    e. → polypeptide chain
    f. Ribosome reaches **stop codon that doesn't code for any AA**
    g. Subunits dissociate → release of mRNA and protein

Translation



*Open reading frames: Sensible transcript w/ start codon and few hundred codons till stop codon

RNA – ribonucleic acid

- RNA:
  - Single strand
  - U bonds with T instead of A
  - 2' H instead of 2' OH group

Cell Cycle

Interphase: Non-dividing

1. **G1**: Normal cell functions
   a. Checkpoint for division
2. **Synthesis** (S): **DNA replicates** (as above) – 2 copies of each chromosome
3. **G2**: Prepares for mitosis
   a. Checkpoint to check replication

Mitosis: Cell division

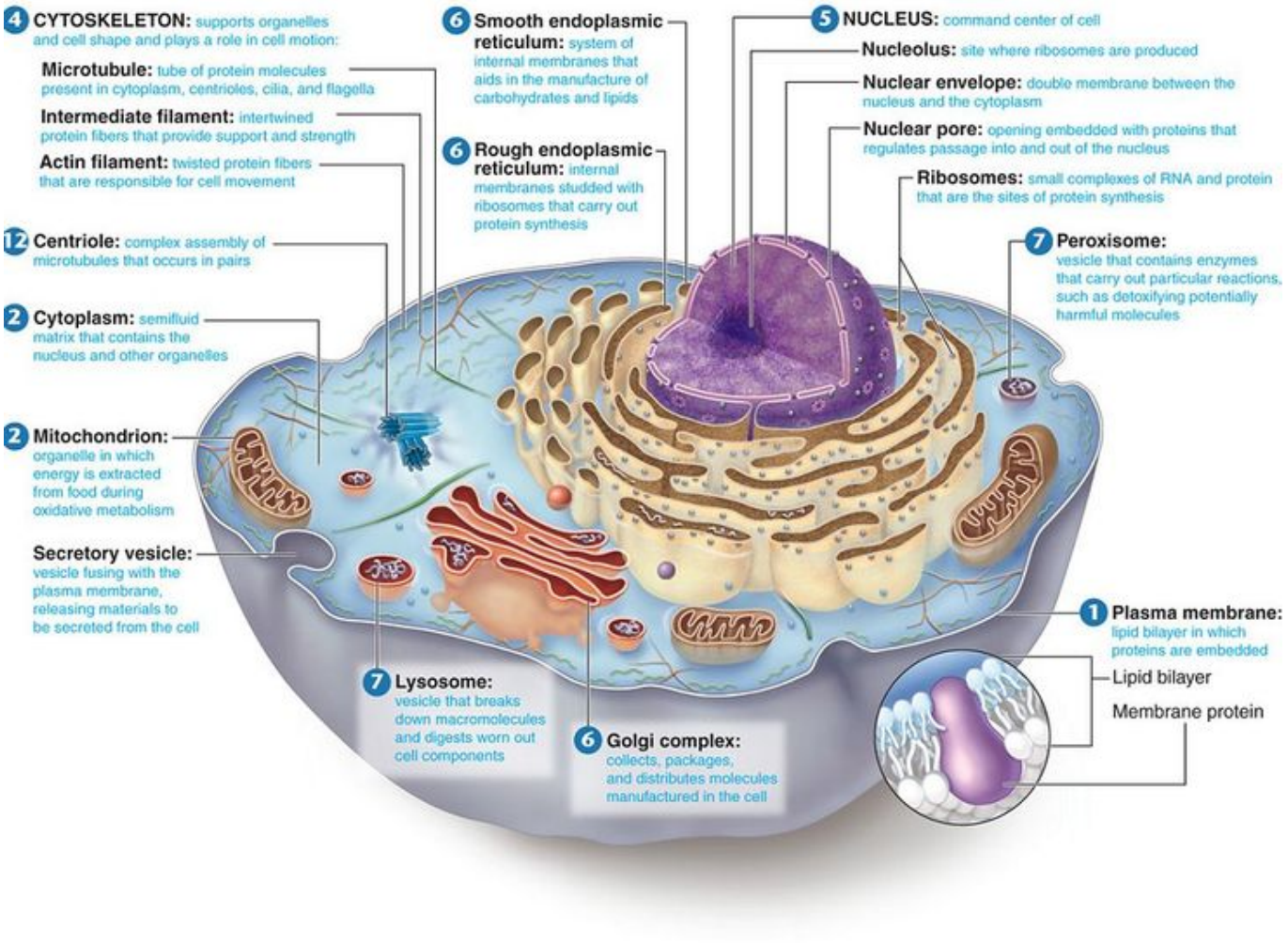
1. **Prophase**:
   a. Chromatin condenses → chromosomes w/ sister chromatids (identical) joined at centromere
   b. **Spindle fibers** (microtubules) form from **centrioles** that move to opp. ends + attach to kinetochores (proteins in centromere region)
   c. Nucleolus + nuclear membrane break down
2. **Metaphase**: Chromosomes **align** in equatorial plate
3. **Anaphase**: Spindles attached to chromosomes shorten, moving chromatids away while spindles unattached lengthen
4. **Telophase**: Chromosomes (no longer called chromatids) reach ends of cell, and spindles lengthen, pulling cells apart. **Nucleoli and nuclear membrane reform**, chromosomes unwind → chromatin

Cytokinesis: Cytoplasm divides e.g. cleavage furrow forms in animal cells – Occurs @ end of anaphase → telophase.

Structures and Functions of Cells

Cell Theory

- Cell is **basic structural + functional** unit of living organisms
- Individual and collective activities of cells **determine activity of organism**
- **Principle of complementarity of structure and function**: Relative no. of specific subcellular structures dictate cell structure + function e.g. cells secreting large amounts of protein contain a lot of ribosomes



*__Eukaryotic__: Has a **nucleus**
Prokaryotic: Has **no nucleus** e.g. bacteria, archaea + **membrane-bound organelles**
*__Cytosol__: Gelatinous media which organelles are in

Nucleoli: rRNA (ribosomal RNA) is produced, and combined with proteins (transported from cytoplasm via nuclear pores) → ribosomal subunits

ER: Series of membrane-bound sacs and tubules that extend from outer nuclear membrane into cytoplasm.
Rough ER: ER with ribosomes → **protein** synthesis
Smooth ER: **Lipid** synthesis, **protein modification** e.g. folding peptides (strings of AA), detoxification, **storage of calcium** (in skeletal muscle cells)

Golgi apparatus: Closely packed stacks of curved, membrane-bound sacs – collects, modifies proteins + lipids e.g. by attaching carbs or lipids and packages and distributes them.

- Sacs mature and move outwards with the proteins inside

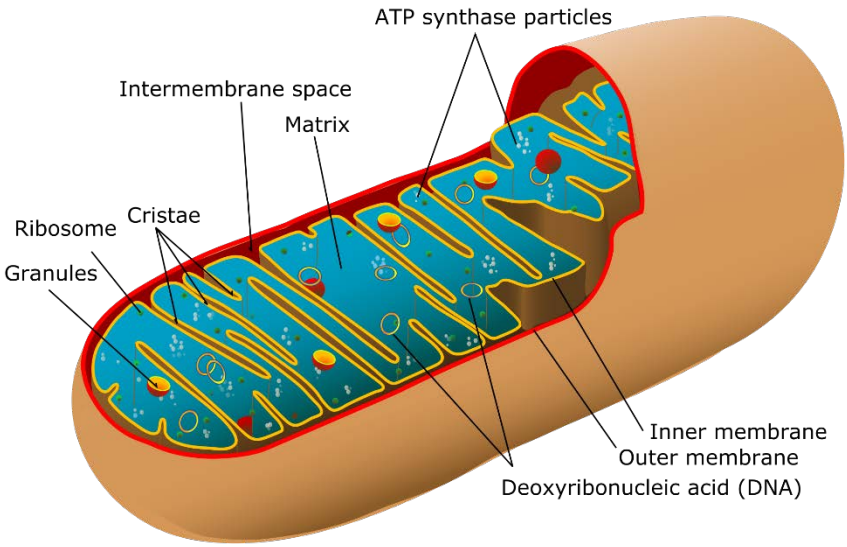
- Proteins + lipids **packaged in secretory vesicles** that pinch off from Golgi apparatus

Lysosomes: Membrane-bound vesicles (formed from Golgi apparatus) containing enzymes that digest molecules

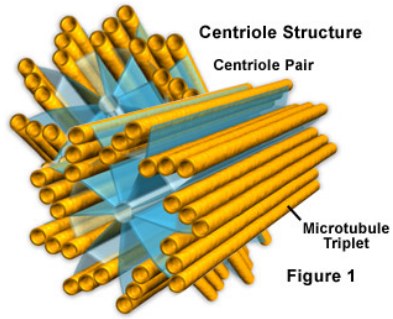
- Vesicle forms around material from outside cell using membrane
- Vesicle pinched off → separate vesicle inside cell
- Lysosome pinched off Golgi apparatus
- **Lysosome fuses w/ vesicle**
- **Enzymes** in lysosome **digest** material

Peroxisomes: Small, membrane-bound vesicles containing enzymes that **detoxify cells** by breaking down harmful molecules e.g. fatty acids, amino acids and hydrogen peroxide

Mitochondria



Centrosome: Zone of **microtubule formation**. Contains **2 centrioles** – **nine triplets** (3 parallel microtubules joined together)



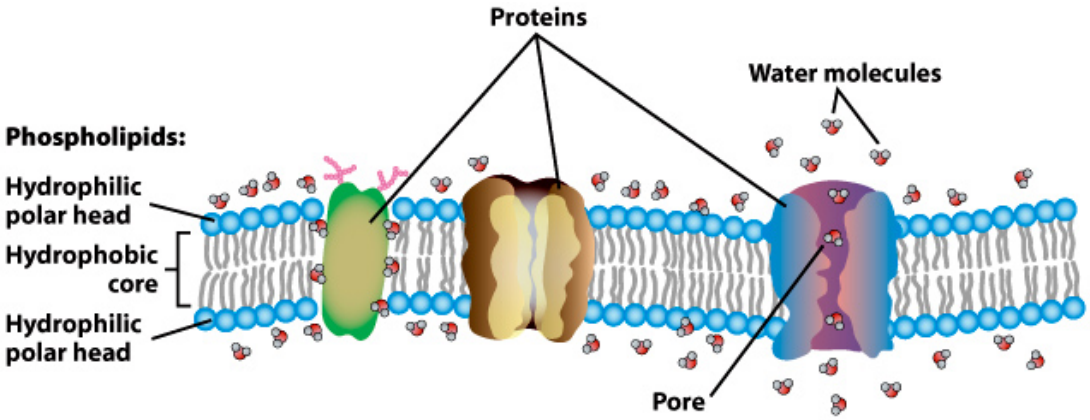
Cytoskeleton: Proteins **support cell**, **hold organelles in place** + **change cell shape**

- **Microtubules**: **Support** cytoplasm, makes up centrioles (→ spindle fibers for **mitosis**), **forms shape** of cells and helps cell **move** e.g. **cilia** (numerous microtubules moving substances on surface of cell) + **flagella** (long microtubule which propel cell)
- **Intermediate filaments**: Provide **mechanical support** to cells e.g. actin, myosin constituting myofibril in muscle fibers

- **Microfilaments**: **Support structure** of cytoplasm, maximise **surface area** of cells e.g. by forming **microvilli** (extensions of cell membrane)

Cell Membrane

- Forms **boundary** between material inside + outside cell, determining movement of substances in and out of cell
- Made up of phospholipid bilayer and proteins w/ other molecules e.g. cholesterol + carbohydrates
- Membrane has liquid quality
    - **Cholesterol** → strength + **flexibility**
    - **Proteins** float among molecules + sometimes extend throughout
    - **Carbohydrates** bind to proteins, modifying functions
- Membrane channels + carrier molecules
- Receptor molecules



Endomembrane System (Interaction of Membranes)

- **Endocytosis**: **Uptake** of material from out of cell through formation of vesicle.
    - **Phagocytosis**: Endocytosis where **solid** particles are ingested
    - **Pinocytosis**: Endocytosis where **liquid** is ingested
- **Exocytosis**: Secretory vesicles **released to outside** of cell by fusion of membranes

1. Proteins produced via transcription (DNA transcribed → mRNA) + translation (mRNA read by ribosome → polypeptide @ rough ER)
2. Polypeptide is packaged in vesicle that **buds from membrane of rough ER**
3. Vesicle **fuses with Golgi apparatus** membrane → protein transferred to Golgi
4. Membrane bound sacs mature + move outwards until it reaches outer layer
5. Protein altered + tagged e.g. w/ carbs
6. Protein + carb is packaged in secretory vesicle via **pinching off Golgi** membrane
7. Vesicle **fuses with cell membrane** → released out i.e. exocytosis

Movement through Cell Membrane

Diffusion

- Moving **along concentration gradient** (high to low conc.) - rate depends on temp, size of molecules + steepness of conc. gradient
- **Does not require energy**
- **Lipid-soluble** molecules diffuse e.g. O_2, CO_2, steroids

- **Small non-lipid** soluble molecules/ions can diffuse
- Other non-lipid soluble molecules are repelled but can diffuse through using **membrane channels**
- Membrane channels: Large protein molecules that extend throughout membrane
    - Certain channels allow certain molecules to pass
    - **Leak** channels: Constantly allow ions to pass
    - **Gated** channels: Open and close to limit ion movement e.g. Na+ channel w/ receptor sites for ligand

Osmosis: Diffusion of water across membrane

- Moving along conc. gradient
- Water diffuses from less concentrated solution i.e. fewer solute molecules, more water molecules → more concentrated solution i.e. more solute molecules, fewer water molecules
- **Hypotonic**: **Less concentrated**; lower conc. of solutes + higher conc. of water than cytoplasm of cell
    - → water moving into cell → swelling → lysis (rupture)
- **Hypertonic**: **More concentrated**; higher conc. of solutes + lower conc. of water than cytoplasm of cell
    - → water moving out of cell → shrinkage → crenation
- **Isotonic**: Conc. of solutes and water are the same on either side of membrane

Carrier-Mediated Transport

- Carrier molecules – proteins that extend through membrane – allow large water soluble molecules/ions e.g. glucose, proteins to pass through

1. Molecule binds to specific carrier molecule
2. Carrier molecule/protein changes shape
3. Molecule moved to opp side and released
4. Carrier molecule resumes original shape

Facilitated Diffusion

- Carrier mediated transport that goes **along conc. gradient → no ATP** required
- E.g. glucose from outside → inside

Active Transport

- Carrier mediated transport that goes **against conc. gradient → ATP needed**
- E.g. amino acids from inside → outside
- E.g. Na+-K+ pump
    - **3 Na+ ions + ATP** bind to Na+-K+ pump
    - **ATP breaks down** to ADP + Energy
    - Energy → shape change to transport **Na+ to outside** of cell (**Phosphate bound** to pump)
    - **2 K+ ions** bind to pump
    - **Phosphate released** from pump
    - Pump changes back to original shape, **transporting K+ to inside** of cell

Secondary Active Transport

- **Active transport** of one substance → conc. gradient → **diffusion** through another pump which **provides energy for active transport of another** substance
- E.g. Na+ helping transport glucose into cell

Surface Area: Volume

Surface Area to Volume Ratio

- As cell increases size**, SA:V ratio decreases** as SA increases less slowly than V
- → Lower rate of diffusion as **COMPARATIVELY less membrane** for substances to diffuse through – while **demand for diffusion** increases, SA decreases (each unit of V requires specific amount of SA to function e.g. supply w raw materials)
- Prevents cell from growing too large because **SA cannot service** the **diffusion** of materials needed for cell of big size
- Max size determined by rate of diffusion of nutrients – if rate is too slow, inefficient → death

Can increase SA:V ratio → bigger max size

- Long and thin shape
- Folding surface of membrane e.g. **villi, microvilli**
    - Vacuole in plant cells pushes organelles near membrane to have ready access to materials

Can increase size

- **Intracellular transport system** e.g. membrane systems, ER and compartmentalising processes
- → nutrients readily available

Cell Metabolism

- Sum of all chemical reactions in cell
- Food broken down into ATP (stores energy)
- Aerobic respiration: O2 present and used → 36-38 ATP molecules
- Anaerobic respiration: O2 not present → lactic acid (in animals)
- Energy released when ATP → ADP in mitochondria

Adenosene Triphosphate (ATP):

- **Adenosene** (sugar **ribose** w/ **adenine** base) + **3 phosphate** groups
- ATP → ADP + ENERGY stored in covalent bond between phosphate groups

Cells are dynamic entities

- Improves technologies showing cell movement e.g. microscope
- Changes in shape and size during changes in osmotic pressure (the pressure needed to prevent osmosis)
- Cell regulates entrance and exit of substances (exocytosis + endocytosis)
- Protein synthesis on ribosomes esp. in cells that export lots of proteins